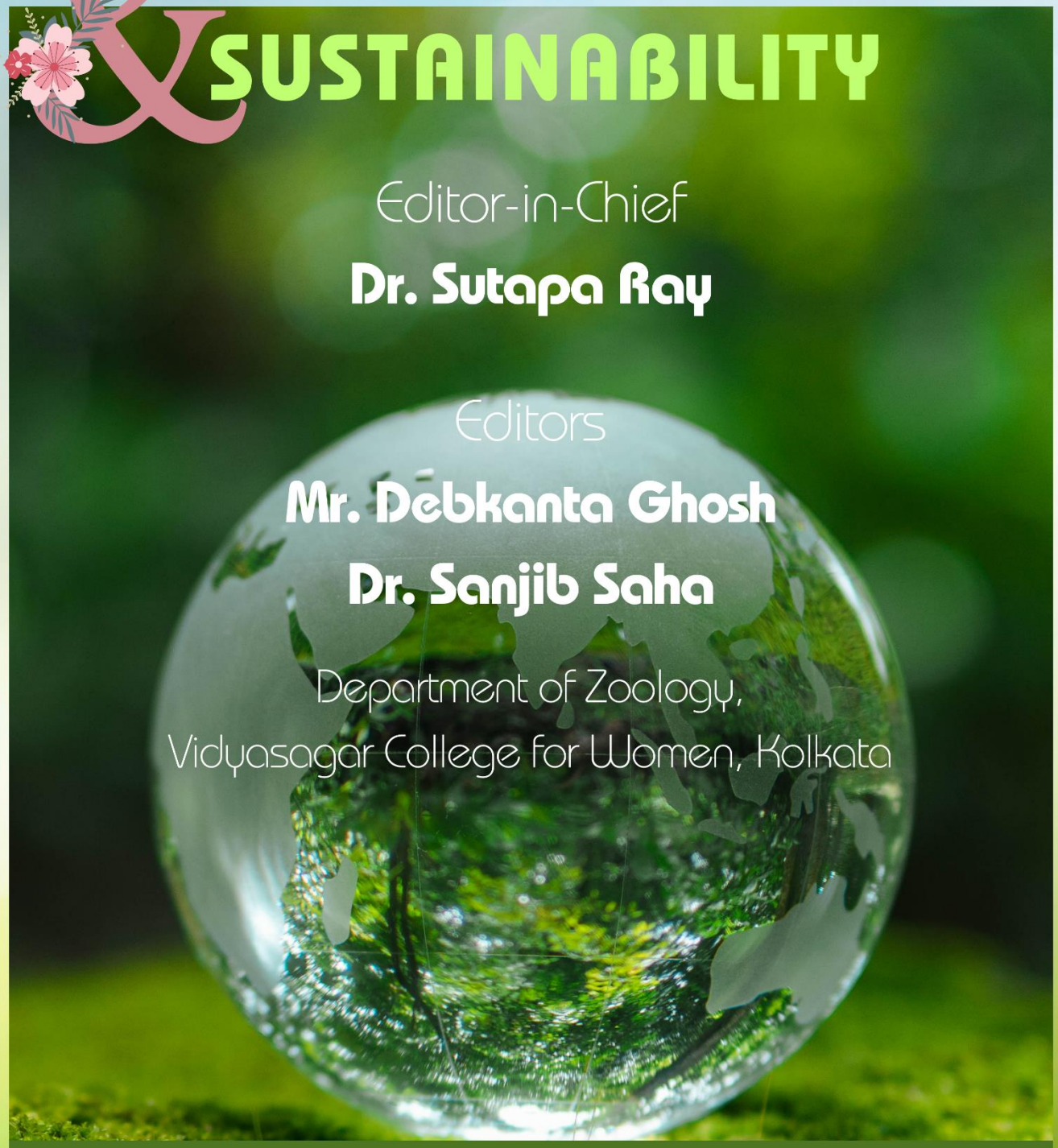
ISBN: 978-93-95847-87-2

ENVIRONMENT DEVELOPMENT & SUSTAINABILITY



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Bhumi Publishing, India
First Edition: March 2024

Environment, Development and Sustainability

(ISBN: 978-93-95847-87-2)

Published by

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BHUMI PUBLISHING

Nigave Khalasa, Tal – Karveer, Dist – Kolhapur, Maharashtra, INDIA 416 207

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PREFACE

We are delighted to publish our book entitled "Environment, Development and Sustainability". This book is a compilation of esteemed articles by acknowledged experts in the fields of environmental science, Biology & Social sciences.

"Environment, Development and Sustainability" draws on knowledge and methods from many fields of the sciences and social sciences. Many environmental specialists adopt an interdisciplinary approach to integrate these different ways of knowing to help understand and prevent environmental damage. This book also adopts an interdisciplinary approach by drawing on a variety of disciplines.

The articles in the book have been contributed by eminent scientists and academicians. Our special thanks and appreciation go to experts and research workers whose contributions have enriched this book. We thank our publisher Bhumi Publishing, India for taking pains in bringing out the book.

Finally, we will always remain a debtor to all our well-wishers for their blessings, without which this book would not have come into existence.

Editors
Dr. Sutapa Ray

Mr. Debkanta Ghosh

Dr. Sanjib Saha

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Environment, Development and Sustainability
(ISBN: 978-93-95847-87-2)

AN OVERVIEW ON THE WASTEWATER TREATMENT AT EAST KOLKATA WETLAND OF WEST BENGAL, ENHANCING THE SEWAGE FED AQUACULTURE

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Abstract:

Conservation of natural resources to attain an environmentally sustainable condition has become prime important in present days. Unutilized wastes from diverse origins should be returned to the ecosystem to perform various welfare activities. Otherwise, they may affect the biodiversity of the area and even become hazardous to biotic life. Public health engineers have provided various waste treatment technologies to minimize such effect of wastes. The only large scale formal system of wastewater fed aquaculture is located in the East Kolkata wetland (EKW) in peri-urban Kolkata, West Bengal. The 12500ha EKW was designated a Ramsar site in 2002, primarily as an example of the wise use of a wetland and greatly contributes towards purification of city. EKW was previously known as the Waste Recycling Region (WRR). Wastewater feed aquaculture was thought to have great potential for the future because it produces low-cost fish at the same time it provides a low cost method to treat waste water that is often otherwise directly discharge into surface waters. The present review intended to categorize different aspects that have contributed to its operational view with respect to the general decline in the use of waste water in aquaculture.

Keywords: Wetland, Sewage, Wastewater, Treatment Plant, Aquaculture.

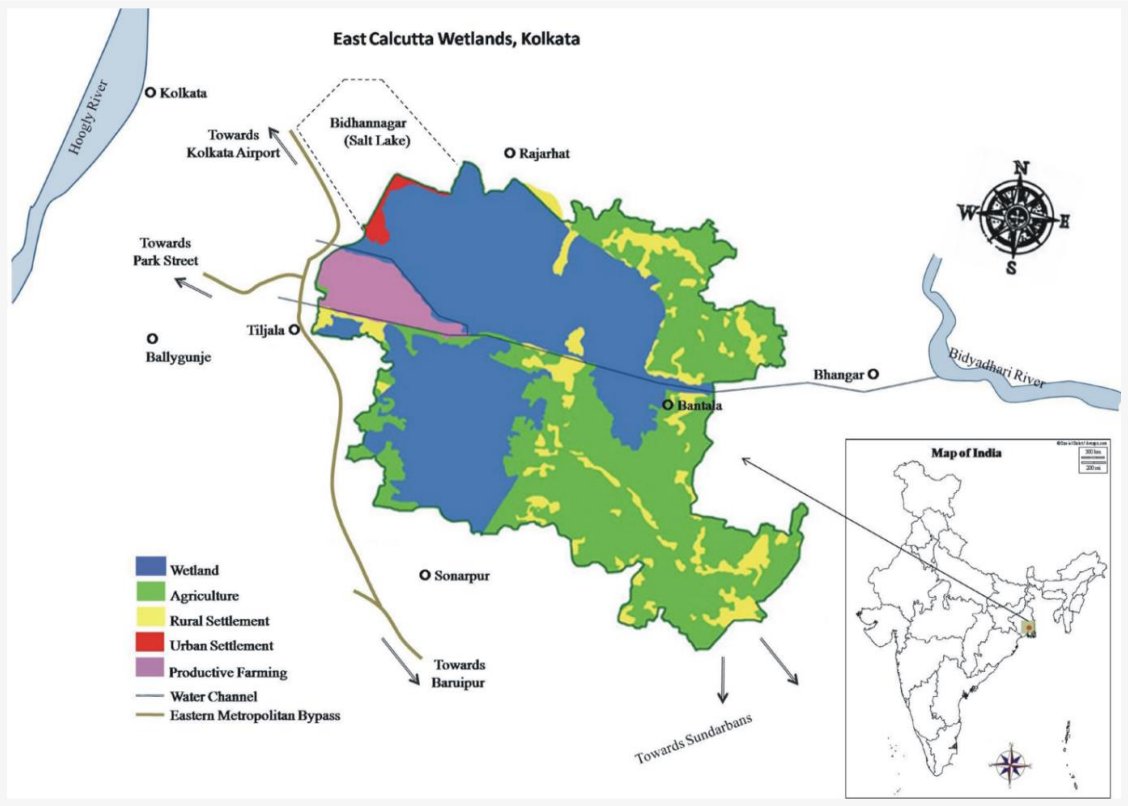
Introduction:

Wetland ecosystem is a complex ecological process where different developmental management occurs, at the same time it protects the environment and the farmers who adapt different recovery activities. It is very important for fisheries and agriculture too where the sewage from city is widely used. The East Kolkata wetland is the one of the best example of largest wetland ecosystem in the world for sewage fed fisheries [1]. In this ecosystem, the local farmers developed various resource recovery systems using waste water from the metropolitan city [2]. This was accomplished by constructing and maintaining a waste water treatment plant. The East Kolkata wetland has been recognized as a Ramsar Site in November, 2002 [3]. This wetland comprises of intertidal marshes that include salt marshes and salt meadows with significant waste water treatment areas.

The Basic Information:

The main outfall for drainage of Kolkata is the swarm water channel which falls into the Kulti River. Other than this outfall, some areas of the Kolkata city are drained by the Baghjola khal, Tolly's nullah, Belighata-circular—Kestopur canal and Hoogly. East Kolkata Wetland receives sewage only from the basin under the storm channel. The entire area is drained by four major pumping stations namely Dhapa lock pumping station, Ballygunge pumping station, Topsia pumping station and Chowbaga pumping station.

Study Site:



Map of East Calcutta Wetlands (ECW) (Google Map), Kolkata [Inset showing the location of ECW in the map of India]

Geographical Area of East Kolkata Wetlands:

Kolkata is located at 22°20´N 88°20´E in the Ganges delta at an elevation ranging between 1.5m (5ft) to 9m (30ft). It spread linearly in a north-south direction along the banks of Hooghly River. Much of the city was originally a vast wetland, reclaimed over the decades to accommodate the city's growing population. Under the Ramsar Convention the remaining part of the East Kolkata wetlands has been designated as a "wetland of international importance" [3].

The total area of East Kolkata Wetland is 12,741.30 hectare, out of this the total water body is about 5,852.14 hectare and comprising of 364 sewage fed fisheries, several other bodies, Agricultural area, Garbage disposal site, urban and rural settlements area. Before 1930 the main water source was the tidal Bidyadhari River. With the silting up of this river, the entire area

became a vast derelict swamp and for thriving the traditional fisheries in these wetland areas there was a desperate need for an alternate source of water. The role of city's sewage in this matter was quickly appreciated and utilized. The entry of the increasing volumes of sewage from Kolkata leads to considerable downfall of salinity, which was ideal for the fresh water fish culture. Presently, 3,898.70 hectare out of 5,862.14 hectare water areas are used for sewage fed fish framing. This total yield from this sewage fed fisheries is about 30,000 ton per year [4].

Climate:

Kolkata has a tropical wet-and dry climate having 26.8°C (80.2°F) annual mean temperature and monthly mean temperatures range from 19°C (66.2°F) to 30°C (86.0°F). Rainfall is due to the Bay of Bengal branch of South-West monsoon occuring between June and September and supplies the city with most of its annual rainfall of 1,582 mm (62 in). The highest rainfall occurs during August and is about 306mm (12in). The city receives 2,528 hours of sunshine per annum, with the maximum sunlight occurring in March. Pollution is a major concern in Kolkata, and the Suspended particulate Matter (SPM) level is high when compared to other major cities of India, leading to regular smog and haze. Sever air pollution in the city leads to rise in pollution-related respiratory ailments such as lung cancer.

The Role of East Kolkata Wetlands as a Waste Recycling Region

Methods of Operation of Sewage fed Fisheries in General:

These fisheries are needed to make dry in every alternate 2 to 3 years during winter months. After de-watering of the fisheries the bottom is ploughed and treated with lime. After one month the sewage is allowed into the fishery for 4 to 7 days depending on the area of the fisheries to fill upto the depth of 18-24 inches. The color of the water at this time remains deep black. After 3 to 4 days, the colour turns deep green due to algal bloom. After another 10 to 12 days the algal bloom is removed by netting. The water color of the fishery now becomes transparent. Then gradually it turns into light green. Fishery is now ready for pisciculture. Fingerlings are introduced into the fishery. The time required from de-watering of the fishery to introduction of the fingerlings is generally 25-30 days. During the culture period sewage is allowed into the fishery for 2-4 hours per day depending on the area and quality of water. Supplementary feeding or pond fertilization is not required during the culture period. Only lime is added occasionally according to the need [5].

Treatment of Sewage Fed fisheries:

The organic matter decomposed under aerobic or anaerobic condition. There is a continuons supply of free dissolved oxygen and it is very necessary to reduce the organic content of dilute liquid wastes. In case of solid waste, it must be liquefied and where the waste are highly concentrated such as solids from domestic waste water, settled organic solids and from abattor's where anaerobic digestion is very fruitful.

Aerobic Process:

In case of aerobic digestion of organic matter, carbon act as the source of energy for the organism respired as carbon dioxide. The organisms are mostly bacteria, fungi and protozoa. They react with phosphorus with the reminder carbon and nitrogen to form a new cell. In case of domestic waste waters, the weight of cell produced is equal to 40% of 60% of chemical oxygen demand (COD) and Biochemical oxygen demand (BOD) removed.

During treatment process, the quantity of oxygen required for stabilizing the organic material in the waste depends on BOD which is very satisfactory. This BOD is the oxygen that stabilizes the waste material, produced by the process of photosynthesis, in the pond. This oxygen transferred across the air-water interface and obtained from oxygen containing compound such as nitrates, phosphates and sulphates. For designing a successful treatment plant it is very important factor to know the rate at which the oxygen is used.

From the complex organic waste compounds, aerobic microorganisms synthesize new cellular material. For this reason, some of the organic material is consumed for making protoplasm and some waste material is degraded into low energy compounds. During the aerobic digestion process oxygen is required continuously. It acts as the final hydrogen acceptor during the process of oxidation of organic matter and if oxygen is not present, the reaction ceases. During this hydrogen transfer process energy liberation occurs [6].

Anaerobic Process:

The process of anaerobic fermentation is a two steps process. Firstly, the facultative heterotrophs that produces acids degrades the organic matter into fatty acids, aldehydes, alcohols etc. Secondly, methane (CH4), ammonia (NH3), carbondioxide (Co2) and hydrogen (H_2) are produced by the action of methane bacteria, converting the intermediate product [6].

The anaerobic activity mainly takes place in the bottom layer or sediments. The ponds are designed where aerobic digestion takes place but in case of deep pond there is a layer of liquid present near the bottom, where anaerobic organisms present and anaerobic digestion take place

Biological Reactions:

Biological reactions in waste stabilization ponds include the oxidation of organic material by anaerobic bacteria, nitrification of protein and nitrogenous material by aerobic bacteria, reduction of organic material by anaerobic bacteria in bottom deposits, and oxygenation of surface liquids by algae.

Oxygen Demand:

Expressing the oxygen demand of wastewater for the oxidation of its reduced matter content involves the biochemical oxygen demand (BOD) and chemical oxygen demand (COD). While these values measure different aspects, they serve as useful indicators of the total oxygen

demand on a treatment plant or waterway. Oxidizable nitrogenous material is typically measured using the BOD test, while the COD expresses the overall demand.

Physical and Chemical Parameters at East Kolkata Wetlands:

Parameters	Sewage		Fishery (Bheri) water	
	Range	**Average**	**Range**	**Average**
Total solid (ppm)	840-1150	895	330-870	440
Total dissolve solid (ppm)	470-810	675	10-680	445
Total suspended solid (ppm)	80-230	211	30-210	123
Total acidity as $CaCo_3$	37.12-321.8	127	-	18.8
Turbidity (NTU)	55-80	67.4	15-56	38.2
Total alkalinity, $CaCo_3$ (ppm)	-	437.65	-	268.25
BOD (ppm)	85-230	95	35-50	45
COD (ppm)	270-516	359	55-140	95
Total inorganic Nitrogen (ppm)	364-1092	553	154-490	320
Total organic Nitrogen (ppm)	16.24-56.0	32.14	5.6-25.2	13.14
Totalhardness (ppm)	320-624	511.81	320-624	425
Total Phosphorus (ppm)	-	15.04	-	3.61
Dissolve Phosphorus (ppm)	-	5.64	-	1.90

The Basic Hydrological Input of East Kolkata Wetland:

The main outfall for drainage of the city of Kolkata is the Storm Water Channel which falls into river Kulti. Other than this outfall, some areas of the Kolkata City are drained by the BaghjolaKhal, Tolly'sNullah, Belighata-Circular-Kestopur Canal and river Hoogly. East Kolkata Wetland Receives sewage only from the basin under the Strom Water Channel. The entire area is drained by four major pumping stations.

Kolkata City Sewage in East Kolkata Wetland:

City sewage is slightly buffered due to the presence of both organic and inorganic salts; the pH remains near to neutral. The sudden increase at the Chowbhaga collection point of the SWF channel water is basically due to mixing of well-alkaliner waste water of the tannery waste cannel. The sewage water again assumes a near neutral pH at Bantala, few kilometers away from Chowbhaga, due to the dissolved and suspended calcium hydroxide acquired from the tannery waste being removed as soluble salt precipitated as insoluble calcium compounds. In fishery water the average pH is 7.5. Total suspended solids are reduced to half of the sewage in the fishery water. Biochemical Oxygen Demand (BOD) decreases gradually in the swage canal with distance as from pumping station to Kulti River. In the fisheries the BOD remains within range from 35 to 50 ppm. Chemical Oxygen Demand (COD) values in the sewage vary from 270 to 516 ppm. COD is drastically reduced in the fishery and remains within the ranges from 55 to 140

ppm. Reduction of total acidity of sewage (as $CaCO_3$) takes place in the fishery from the average of 127 ppm to the average 18.8 ppm. The values of total inorganic nitrogen and phosphorous are also much lower in fishery water. In receiving water, the level of chromium is average 5.8 ppm. In fishery chromium is reduced to the level of 0.08 ppm. The presence of copper in the sewage is very lower. Reduction of lead and zinc in the fishery water is insignificant. Results of MPN shows the decay ranging from 99.9% to 99.99% in fishery. The same trend is also observed in the fecal coliform, coliform and salmonella count [7].

Importance of East Kolkata Wetland

Social & Cultural Values:

The East Kolkata Wetlands provide three basic securities in its fish ponds fields and garbage farms, which are critical for any third world countries. These involve food, sanitation and livelihood. The East Kolkata wetland is the vital component of the friendly water regime that provides ecological security to the mega city of Kolkata [7].

Threats:

Land use changes over a period of time have led to conversion of some of the largest fish farms from pisciculture to paddy cultivation. Large numbers of industries make unauthorized connection of their waste water effluent without treatment to the recently laid sewers emptying into the city outfall channels flowing eastwards.

Conservation Measures:

This has caused substantial amount of metal deposition in the canal sludge and rendered the waste water incapable of ensuring the edible quality of the fish and vegetable grown in the wetland.

The conservation area boundary for the East Kolkata wetlands and waste-recycling region was mapped in 1985 by the State Planning Board, Government of West Bengal. This wetland area is protected by order of the Kolkata High Court in 1992, which prohibits change in land use. High Court has directed the State Government to take recourse to statutory cover, if required to prevent any private alienation of land. Recently, the director of land Records, Govt. of West Bengal has issued a fresh order prohibiting any conversion of land use within the conservation area boundary and declaring all such conversions that have taken place since 1992, as void. Filling up of water bodies in this area is not permissible under west Bengal Town and Country (Planning and development) Act, 1979 as well as under the West Bengal Inland Fisheries Act, 1984 (with amendment in 1993).

Recycle:

(a) Wetlands absorb and treat in the most efficient, economical and natural way the huge volume of sewage and wastewater and urban solid and air wastes generated by the Kolkata city-at no cost to the city but with much gain.

(b) It fulfills substantially the requirement of fish, vegetables and food-grains in the city.

(c) It also absorbs the pollution from and purifies the air that citizens breathe.

(d) It absorbs and passes down to downstream creeks and the sea the flood waters that the monsoon downpours bring down on the city.

(e) Wetlands also provide a habitat for a variety of flora and fauna and living organism endemic to wetlands.

(f) They provide the food chain and Waste-to-wealth recycling so unique and essential to this city.

(g) They maintain the micro climatic of the region.

(h) They maintain the delicate ecological balance in a fragile environment and ecosystem [8].

Conclusion:

Wetlands maintain the micro climatic of a particular region and provide the food chain and Waste-to-wealth recycling. They are a habitat for a variety of endemic flora and fauna. Wetlands absorb and treat the huge volume of sewage in an economical and natural way. Further, wastewater feed aquaculture has great potential for the future as it produces low-cost fish at the same time it provides a low cost method to treat waste water that is often otherwise directly discharge into surface waters. Considering all this in mind it can be stated that conservation of natural resources to attain an environmentally sustainable condition can be achieved by maintaining a wetland fed by the waste water of a city.

References:

1. Banerji, Suranjana (2014). State-owned Sewage-fed Fisheries of the East Kolkata Wetlands: An Overview IOSR Journal of Humanities and Social Science (IOSR-JHSS) Volume 19, Issue 4, Ver. I (Apr. 2014), pp,11-17
2. Kundu, N., Pal, M. and Saha, S. (2008). East Kolkata wetlands: a resource recovery system through productive activities. Pro. Taal 2007: the 12th World Lake Conf.: 868-881 (ED. Sengupta, M. and Dalwani, R., 2008).
3. East Kolkata Wetlands Newsletter November 2010, Vol.1
4. Ghosh, D. (1988). In "Wastewater-Fed Aquaculture in the Wetlands of Calcutta-An Overview, (India-East Kolkata-Making the Most of It: Wastewater, Fishponds and Agriculture)
5. Ghosh, D. (2005). Ecology and Traditional Wetland Practice: Lessons from Wastewater utilization in the East Calcutta Wetlands. Kolkata: Worldview.
6. GloynaEarnes F and Eckenfelder W Wesley, (1968). Advances in water quality improvement. Austin University of Texas Press.
7. Wise use of Wetland: East Kolkata wetland, A case study – Dr. TapanSaha, IESWM.
8. Mitra, B., S.K. Das and D. Banerjee (2001). Wetland Ecosystem A Field Guide.

INTEGRATED PADDY-CUM-FISH FARMING AND SUSTAINABLE FOOD PRODUCTION IN INDIA: AN OVERVIEW

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Abstract:

Integrated paddy-cum-fish culture is a type of dual system of farming paddy with fish culture utilizing same resources in common plot, where paddy is the main enterprise and fishes are cultured for additional income. In India, it has been largely practiced in traditional way in North-eastern region. The basic principle of efficient integrated farming is based on the fact that there is efficient utilization of the synergistic effects of inter-related farm activities including the full utilization of farm wastes, and their conservation. The motive of integrated fish farming is to benefit the rural poor people and farmers of India. Indian farmers have evolved the techniques of rice-fish integrated farming, mostly in rain-fed lowlands over the years. Further, the ever-increasing population of India and its food demand has resulted in the increased use of modern technology in integrated paddy-cum-fish culture. Now days, sustainable practices are done through integrated rice-fish farming system, that optimizes wise use of resources maintaining sustainable environmental conditions, and socio-economic stability to farmers. It also contributes to household income, food security and nutrition to rural integrated farming system practiced in India.

Keywords: Paddy-Cum-Fish Culture, Food Production, Aquaculture

Introduction:

Achieving food security and adequate nutrition for all by mitigating hunger, and promoting sustainable agriculture is one of the proposed sustainable development goals to be attained by 2030. But pandemic period had seriously challenged food security and livelihoods of millions of people in India. Also there has been a significant rise in malnutrition status among women and children. In present scenario food and nutrition security for people below poverty line and eradication of hunger is a big challenge in India. Hence, a sustainable agricultural approach towards integrated paddy-cum-fish cultivation would be one of the ideal practices in rural areas. It would provide food security and livelihoods for numerous communities across India and worldwide.

In India, total inland fish production has reached to 174 lakh tonnes in 2022-23 providing livelihood opportunities to millions of people (The Economic Times, 2023). Still, the practice of fish culture in combination with agriculture or livestock by utilizing full resources is usually seen in traditional ways in various parts of India. This is integrated fish farming, which is based on the concept that 'there is no waste, and waste is only a misplaced resource which becomes a valuable material for another product' (FAO, 1977). Integrated fish farming refers to the growing of crops, preferably paddy as well as rearing of fish in coordination in the same plot of land. In India, states like West Bengal, Bihar, Odisha and Utter Pradesh, paddy-cum-fish co-culture is well practiced in rain-flooded lowland areas. Besides, integrated rice-fish farming has been traditionally practiced in many north-east states and southern India, especially parts of Kerala. To promote rice-fish technology in rice-growing belts of India, the Indian Council of Agricultural Research (ICAR)-National Rice Research Institute, Cuttack, Odisha, has developed some adoptable modern rice based integrated farming system by integrating various enterprises to provide sustainability in production, economic stability, and environmental security for farmers (Nayak *et al.,* 2020).

Selection Criteria and Preparation of Paddy Field:

The plot selected for paddy-cum-fish culture is usually prepared in the month of January-February with their raised embankment all around (40-50 cm), and should be comparatively flat.

(i) The width of bund should be 1.5 m at the bottom and 1.0 m at the top to prevent leakage and escape of cultivated fingerlings and fish during floods, and to retain water up to desired depth.

(ii) Prevention of both escape of fish and predatory fishes are avoided through provisions of weirs and screens, like bamboo slats and piece of fish net material may be used.

(iii) The paddy field may be provided with inlet and outlet. Soil of the field should be fertile and rich in organic matter with high water holding capacity. The plot must be holding water for several months and up to the depth of 30 cm.

(iv) Fishes are cultured unaffected by pesticides or chemicals used to protect paddy.

(v) Stoking of fish seed in paddy field would be done after 10-15 days paddy transplantation.

Selection Criteria for Targated Fish Species:

(i) The fish must be capable of tolerating very shallow water level with low DO level and high turbidity.

(ii) Fish should be able to withstand higher temperature and variable temperature fluctuations.

(iii) Fish species having faster growth rate to marketable size in short period.

(iv) Examples of fish highly suitable for rice-fish farming are- Common carp (*Cyprinus carpio*), Murrel (*Ophiocephalus striatus*), Spotted snakehead *Ophiocephalus punctatus*),

(Rohu (*Labeo rohita*), Catla (Catla catla), Silver carp (Ctenopharyn godonidella), Tilapia (*Oreochromis* sp.), Mrigal (*Cirrhinus mrigala*) (Saikia *et al.*, 2015; Poonam *et al.*, 2019).

Different Models of Integrated Paddy-Cum-Fish Farming:

Based upon the slope of the land three types of layouts have been proposed for construction of rice-fish-culture plot (Figures 1-4).

1. Perimeter Trench Model:

This type of plot is constructed in the zone of moderate elevation, where trenches are dug out in the periphery of the paddy field and rice cultivation area remains in the idle of the plot. In 1 ha plot, the central part selected for paddy cultivation is about 0.67 ha, and perimeter trenches occupies about 0.2 ha with perimeter dykes of another 0.12 ha.

2. Central Pond Model:

Here, fish culture occurs at the centre of the plot and paddy growing region surrounds the pond. In 1 ha plot area, part of the field for paddy cultivation is about 0.65 ha, while fish pond area would be 0.35 ha with peripheral dyke space of 0.002 ha. The dimensions of perimeter dyke are- 20 cm width and 30 cm height.

3. Lateral Trench Model:

In this case, a trench is dug at one end of a moderately sloping paddy field of dimensions top width 18 m, base 15 m and depth 1.5 m, or pond are dug at opposite ends of the paddy field. The total water area should be one-third of land area.

Types of Major Paddy-Cum-Fish Culture Systems:

1. Simultaneous Culture or Co-current Method:

In this method, paddy and fish are grown together in the same field at same time. Here, fish are raised in a trench or refuge pond lying in the periphery or in the centre of paddy field. This type of integrated farming is practiced on the rain-fed plain and medium lowlands of area 0.1 hr economically. Usually, four rice plots of 250 m^2 (25x10 m) are formed in each plot, and a canal like ditch is created in each plot which has connection with main water supply through inlet outlet system. The trench serves as capture channel when water level lowers, and also as refuge when fishes are not foraging. Fish stock density are supposed to be 1 cm Fry @ 5000/ha and 8-10 cm fingerling @ 2000/ha. Fishes are harvested about one week prior the rice harvest. After 10-20 weeks of culture, paddy fields are slowly drained off.

2. Alternate Culture or Rotational Method:

In alternate farming method rotational cultivation of paddy and fish is practiced in deeply flooded lowlands, and fish are raised in the paddy field during paddy off-season. Here, culture is done alternately when paddy field is converted into a fish pond after paddy harvest. Fish species like murrels, catfishes, and any carp species are suitable for culture. After rice harvesting the

field is prepared for fish culture. This system of culture is high yielding than simultaneous system.

Figure 1

Figure 2

Figure 3

Figure 4

Figures 1-4: Photographs showing Integrated paddy-cum-fish farming in West Bengal

Traditional Methods Practiced in India:

Integrated-paddy-cum-fish farming has been traditionally practiced in many parts of eastern India, of which most popular ones are Zabo cultivation in Nagaland, Bheri system in Sundarbans of West Bengal, Apatani farming in Arunachal Pradesh, and also in some parts of Kerala as Pokkali system. In these systems millions of hectares of seasonal rain-fed flooded plains are effectively utilized for integrated farming. Trapping fish in such rice farming fields has been a traditional practice by most small scale farmers (Sathoria and Roy, 2022).

1. Pokkali System in Kerala:

In southern India traditional farming system known as Pokkali is practised in Kerala, where the cultivation of salt-tolerant traditional varieties of rice are grown in coastal saline region and alternated with fish-prawn farming on a rotational basis. The soil is rich in organic matter ad becomes saline during summer months due to ingression of salt water. Rice is

cultivated when fields are flooded with heavy monsoon rains, washing off the salinity. Generally, manuring operations are not needed in Pokkali farming systems as paddy obtains its nutrients from the waste material excreted by prawns. Fish and prawn are cultivated immediately after the harvest of rice, where water enters the field through high tide (Nayak *et al.,* 2020).

2. Zabo Cultivation in Nagaland:

In Zabo cultivation, indigenously practiced by the Chakhesang tribe of Kikruma village in Nagaland, is a combined system of forest, horticulture, agricultural practice, fishery, and animal husbandry with well founded soil and water conservation. In this agricultural practice, hill has three tier divisions involving conservation of forests on the hill top. The middle section of hill is for residential purposes, and ponds are dug for rainwater harvesting, bringing them to lower part through channels. The collected rain water is utilized for irrigation purposes and animal drinking. The lower hill area is utilized for paddy and fish cultivation. The livestock is maintained near ponds, and animal husbandry activities are performed there, so that animal wastes are brought to the paddy fields located beneath providing nutrients for rice cultivation. The farmers gain additional earnings of rearing fish of about 50-60 kg per hectare from paddy fields (Nayak *et al.,* 2020).

3. Apatani System in Arunachal Pradesh:

The Apatani system is a form of 'water farming' practiced traditionally in the Apatani plateau located in lower Subansiri district of Arunachal Pradesh. In this system valleys are terraced into plots separated by 0.5 meters high earthen dams supported by bamboo frames. Generally, water for irrigation is trapped from small streams and channelized to the field plots with the help of traditional bamboo and pinewood pipes. Various strains of carps are simultaneously cultivated with local rice varieties. When rice seedlings are transplanted in the month of April-May, about 15-20 mm size fry are introduced in the rice fields. Fishes are reared after 3-4 months providing an additional earning in one season, besides rice monoculture. This has helped farmers in alleviating poverty in this region. Further there is no use of chemical fertilizers, since nitrogen is fixed in the soil by *Azolla* and *Lemna*. (Saikia and Das, 2008).

4. Bheri Fishery in Sundarbans:

Bheri fishery is a modified extensive method practiced since late 1960s in Sundarbans, West Bengal, where fish and prawns are cultivated along with local varieties of rice. The system involves impounding of adjacent canal having natural brackish water for fish and prawn, along with the traditional wet season rice farming. Approximately, 100-200 kg/ha fish and prawn are harvested along with 100 kg/ha of rice (Nayak *et al.,* 2020).

Significance of Integrated Farming:

(i) The integrated paddy-cum-fish culture system enhances food diversity and productivity.

(ii) The combined culture system increases the economic yield per unit area by enhancing rice production.

(iii) Fish culture in paddy fields enhances soil fertility with increased nutrient recycling.

(iv) Fish while foraging in paddy fields feed on pest and larvae, thereby reducing the attack of paddy stem borers.

(v) Controls growth of aquatic weeds and algae which usually compete with paddy plants for light and nutrients.

(vi) Efficient utilization of rainfed lowlands, serving as nutritional source for farmer's family, especially animal protein, vitamins, micronutrients and fatty acids.

Conclusion:

Integrated farming has proved to be an efficient means of both economic and environmental management. The cultivating fish in paddy field utilizing same water resource is one of the most viable solutions for sustainable production. Fish farming integrated with rice cultivation is principally dependent on sufficient availability of water for survival and growth of fish without affecting paddy crop. Through this type of combined culture, food diversity and productivity can be raised as compared to rice monoculture. Thus, the above rice-fish co-cultivation system provides opportunities for rural livelihoods, strengthen socio-economic status, and stability by efficiently utilizing water resources. The dual farming system serves as additional income for local farmers, thereby reduction in labour.

References:

1. Poonam, A., Saha, S., Nayak, P. K., Sinhababu, D. P., Sahu, P. K., Satapathy, B. S., Shahid, M., Kumar, G., Jambhulkar, N. N., Nedunchezhiyan, M., Giri, S. C., Kumar, S., Kujur, S., Nayak, A. K., & Pathak, H. (2019). Rice-Fish Integrated Farming Systems for Eastern India (NRRI Research Bulletin No. 17). ICAR-National Rice Research Institute, Cuttack, Odisha, India.
2. Saikia, A. K., Abujam, S. K., Das, D. N., & Prasad, B. S. (2015). Economics of paddy cum fish culture: A case study in Sivsagar, Assam. International Journal of Fisheries and Aquatic Studies, 2, 198-203.
3. Food and Agriculture Organization. (1977). China: Recycling of organic wastes in agriculture (FAO Soils Bulletin No. 40).
4. Nayak, P. K., Nayak, A. K., Kumar, A., Kumar, U., Panda, B. B., Satapathy, B. S., Poonam, A., Mohapatra, S. D., Tripathi, R., Shahid, M., Chatterjee, D., Panneerselvam, P., Mohanty, S., Sunil, K. D., & Pathak, H. (2020). Rice Based Integrated Farming Systems in Eastern India: A Viable Technology for Productivity and Ecological Security (NRRI Research Bulletin No. 24). ICAR-National Rice Research Institute, Cuttack, Odisha, India.

5. Sathoria, P., & Roy, B. (2022). Sustainable food production through integrated rice-fish farming in India: A brief review. Renewable Agriculture and Food Systems, 37, 527-535.
6. Saikia, S. K., & Das, D. N. (2008). Rice-fish culture and its potential in rural development: A lesson from Apatani farmers, Arunachal Pradesh, India. Journal of Agriculture & Rural Development, 6, 125-131.
7. The Economic Times. (2023). Inland fish production jumps over 2-fold in 9 years to 131 lakh tonnes: Rupala. Retrieved from https://economictimes.indiatimes.com/news/economy/agriculture/inland-fish-production-jumps-over-2-fold-in-9yrs-to-131-lakh-tonnes-rupala/articleshow/105258208.cms?from=mdr
8. Integrated Fish Farming System. (n.d.). Retrieved February 19, 2024, from https://adpcollege.ac.in/online/attendence/classnotes/files/1626934875.pdf
9. Integrated Paddy-Cum-Fish Culture. (n.d.). Retrieved February 19, 2024, from https://dof.gov.in/sites/default/files/2020-07/Integrated_Paddy.pdf

BIOFOULING: A THREAT IN MARINE FISH CULTURE AND REMEDIES

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Abstract:

Biofouling, the colonization of submerged surfaces by organisms, poses significant challenges across various industries and ecosystems. Despite considerable efforts to mitigate its impacts, biofouling remains a pervasive and costly problem with far-reaching economic and environmental consequences. Biofouling poses significant challenges to shellfish and other fish culture industries, impacting both economic productivity and environmental sustainability.

Key findings indicate that biofouling adversely affects shellfish culture by fouling nets, cages, and infrastructure, leading to reduced water flow, increased maintenance costs, and decreased shellfish growth and survival rates. In fish farming, biofouling can clog intake pipes, obstructing water flow and oxygen exchange, and promote disease transmission among farmed fish populations.

The complexity of biofouling dynamics necessitates integrated management approaches that combine physical, chemical, and biological control methods. While traditional antifouling strategies, such as toxic biocides and mechanical cleaning, have been employed, their environmental impacts raise concerns about ecosystem health and sustainability. Therefore, there is a growing need for sustainable and environmentally friendly alternatives, such as bio-based coatings, biomimetic surfaces, and biotechnological innovations.

Furthermore, regulatory frameworks and international cooperation are crucial for addressing biofouling challenges in shellfish and fish culture industries. By fostering collaboration between industry stakeholders, researchers, and policymakers, it is possible to develop effective biofouling management strategies that promote both economic prosperity and environmental stewardship in aquaculture. The main aim of this article is to review regarding biofouling, organisms involved, its type, adverse effects on shell fish and other fish culture, its remedies.

Keywords: Biofouling, Organisms Involved, Adverse Effects, Remedies, Future Aspects

Introduction:

Aquaculture is now a days is a very important industry globally as it supplies protein to low income and food deficient countries. More than half of the fish is consumed by humans exceeding 55.7 million tons and value nearly about US$ 105 billion (FAO, 2010). This

production provides either high production or high biomass. Marine shellfish are oyesters (*Crassostrea* sp, *Ostrea* sp.), mussels (*Mytilus* sp, *Perna* sp.), scallops (*Placopecten* sp, *Chlamys* sp), salmonids (*Salmo-salar*, *Oncorhyncus* sp), mullets (*Mugil* sp), tunas (*Thunnus* sp), seabreams (*Sparus* sp, *Pagrus* sp) and sea brases (*Dicentrarchus labrax*, *Lates* sp., *Lateolabrax japonicus*). All of these species are cultured by submerged components with cages, nets, floats and ropes. Surface of these equipment facing a great problem of biofouling. The presence of such large and varied surfaces provides for broad diversity of epibiotic organism to settle and grow. These marine algae and animals collectively termed biofouling and cause severe problem to culture practices and have significant economic impacts. Problems that are associated with biofouling are reduction of water flow through the net and reduced oxygen supply, reduced waste removal and fishes are prone to diseases (Chyne, 2010). Increased weight of cage due to biofouling, seriously affect cage structure and stability (Hodson *et al.,* 2000). High mortality of cultured fish is also observed (Huang, 2003, Phillipi *et al.,* 2001, Tan *et al.,* 2002, Swift *et al.,* 2006). Controlling of biofouling causes huge costs with 5-10% of production costs attributed to biofouling (Lane and Willemilen, 2004). Globally the costs are US$ 1.5 to 3 billion yr^{-1}. Aquaculture industry uses technologies to combat this problem. The main aim of this to review about biofouling, types of biofouling, organisms responsible for this, problems regarding biofouling and its remedies.

Definition of Biofouling

According to Characklis, 1990; “Biofouling refers to the undesirable accumulation of a biotic deposit on a surface”. According to Epstein, 1981, “Biofouling is the deposition of macroscopic organisms such as barnacles or mussels (“macrofouling”) and to microorganisms (“microbial biofouling”).

In biofouling, foulant, that is the microorganisms, can grow at the expense of biodegradable substances from the water phase, turning them into metabolic products and biomass. Microorganisms can multiply and produce extracellular polymeric substances (EPS), which by keeping them together glued them to the surface and cause biofouling.

Conditions Required for Biofouling

Variations of biofouling organisms are temporal and spatial. The conditions which are necessary for biofouling are seasonality of marine invertebrate populations, arrival of new species, periods of intense growth, times of dormancy and regression etc. All these are temporal changes. The spatial changes include planktonic events, larval choices during attachment and settlement and metamorphosis and mortality (Holloway and Keough 2002 a, 2002b), availability of light and water flow, depth and orientation of infrastructure (Cronin *et al.,* 1999, Howes *et al.,* 2007, Guenther *et al.,* 2010), fouling communities are less diverse in deeper waters (Cronin *et al.,* 1999, Guenther *et al.,* 2010).

Common Fouling Organisms

Some common fouling organisms in marine fish culture are summarized in Table 1 (Fitridge *et al.*, 2012).

Table 1: Common Fouling Organisms

Fouling Organism	The adverse impacts	References
Chordata: Ascidiacea • *Ascidiella aspersa* • *Botrylloides sp.* • *Botryllus schlosseri* • *Styela plicata*	Cage deformation and structural fatigue, increased desease susceptibility	Milne (1975b), Tan *et al.*, (2002), Braithwaite *et al.*, (2007)
Algae • *Antithamnion* sp • *Ectocarpus* spp • *Enteromorpha spp* • Filamentous diatoms • *Gracilaria sp.* • *Ulvia spp.*	Net occlusion Restriction of water exchange, poor water quality, Limited oxygen availability, reduced waste metabolite removal, cage deformation and structural fatigue	Milne(1975a), Milne(1975b), Morning and Morning (1975), Cronin *et al.*, (1999,
Mollusca: Bivalvia • *Crassostrea* Sp. • *Electroma georgenia* • *Modiolus sp* • *Mytilus edulis* • *Perna viridis* • *Pinctada sp.*	Net occlusion, Cage deformation and structural fatigue	Milne(1975a), Milne(1975b), Morning and Morning (1975), Lee *et al.*, (1985), Cronin *et al.*, (1999), Braithwaite *et al.*, (2007), Greene and Grizzle (2007)
Cnidaria: Hydrozoa • *Ectopleura larynx* • *Obelia dichotoma* • *Plumularia sp.* • *Tubularia sp.*	Net occlusion, Cage deformation and structural fatigue	Hodson *et al.*, (2000), Guenther *et al.*, (2009), Madin *et al.*, (2009), Guenther *et al.*, (2010), Carl *et al.*, (2011), Guenther *et al.*, (2011).

Types of Biofouling Organisms

There are different types of biofouling organisms are there. According to Cook 2001, biofouling organisms are either intertidal or sublittoral.

They may be categorized as microfouling or macrofouling organisms. Microfouling organisms include algal spores, diatoms and marine bacteria that form organic film, while macrofouling organisms include multicellular organisms (Fergusson wood, 1950). The common macrofouling organisms are tubeworms, barnacles, bryozoan, algae, hydroids, mussels, oyster etc (Madin *et al.*, 2009).

Characteristics of Biofouling Organisms

Biofouling organisms show important characteristics. They are free-swimming larva and sedentary adult form which can firmly adhere to substratum and ability to utilize dissolved nutrients and particulate material from water column. Example of such biofouling organisms are barnacles. Non-sessile organisms that are able to colonize are echinoders, isopods, amphipods, errant polychaetes, crabs, shrimps and pycnogonids (Claereboult *et al.*, 1994, Maidan *et al.*, 2009)

Effects of Biofouling in Aquaculture

Variation biofouling organisms are either spatial or temporal. Impacts of biofouling in most of the cases in aquaculture is very dangerous but in some cases is beneficial. The beneficial effects of biofouling are enhancement of shell fish growth (Dalby and Young, 1993), production of primary production of phytoplankton and cause food availability to shellfish (Lodeiros *et al.*, 2002, Le Blanc *et al.*, 2003), provide protection against predation (Wahl *et al.*, 1997, Manning and Linquist 2003), facilitate the settlement of commercial farmed shell fish (Hickman and Sause1984, Fitridge 2011), reduce disease risk (Paclibare *et al.*, 1994).

Biofouling is mainly deleterious and cost effective in finfiah and shell fish culture.

Adverse Effects on Shellfish

Biofouling cause severe adverse effects on surface of shell and equipment. Physical damage is caused on shell surface by boring into shell by endoliths or epibiotic calcareous organisms; mechanical damage is caused by colonization of shell at the hinge and lips causing feeding ability and susceptibility by predators; growth of shell fishes are affected by competition of food resources; other environmental problems are reduced water flow, decreased oxygen capacity, waste buildup, reduced food availability. Biodeposition and spreading of non-indigenous organisms have most harmful effects on nearby natural ecosystem; weight of the fishing cages and equipment by deposition of biomass of biofouling organisms increases production costs along with extra maintenance requirements and loss of stock and eqipments.

(i) Physical Damage

Physical shell damage is caused by burrowing nature of endolithic organism or epibiotic calcareous tube dwelling polychaetes which are attached to shell surface. Polychaete worm *Polydora* and *Boccardia* penetrate and excavate shell, causing cavities, burrows, blisters and tunnels deep within the nacreous layer (Lieonart *et al.*, 2003, Silina 2006, Simon *et al.*, 2006). As consequences of several bad effects are

observed which are hinge instability, disruption of shell formation, fragility, brittleness and loss of thickness (MaO Che *et al.*, 1996). As a result, shell become substantially weakened and vulnerable to predators and parasites (Kaehler and McQuaid, 1999, Stefaniak *et al.*, 2005, Buschbaum *et al.*, 2007, Thieltges and Buschbaum, 2007). Shell fish shows reduced growth and reproductive output (Kaehler and McQuid, 1999, Stefaniak *et al.*, 2005), causing a reduction in yield and quality of Shellfish which ultimately cause substantial economic losses for growers (Campbell and Kelly, 2002).

(ii) Mechanical Interference

Mechanical interference is arisen due to opening and closing of shellfish valves by hydroids *(eg Ectopleura crocea)*, macroalgae and barnacles, leading to ineffective feeding (de Sa *et al.*, 2007), abnormality in respiration (Miyauti, 1968), cause mortality (Dharmaraj *et al.*, 1983).

(iii) Biological Competition

There is a competition involved between fouling species and shellfish for food, space. As a result, growth is reduced (Adams *et al.*, 2011, Southgate and Beer, 2000, Watson *et al.*, 2009)

(iv) Environmental Modification

Environmental problem due to biofouling is associated with reduce waterflow and changing of waste products in oyster culture, reduction of water currents and exchange, leading to rapid food depletion (Yukihira *et al.*, 1998).

(v) Increased Weight and Drag

Significant increase in weight in infrastructure in shellfish and fish culture leading to management issue. As a result of which operational costs are also increased.

Adverse Effects on Fish

Biofouling Causes Serious Impacts on Fish Culture by

(1) Restriction of water exchange due to the growth of fouling organisms causing net occlusion.

(2) Disease risk due to fouling communities acting as reservoirs for pathogenic microorganisms and increasing vulnerability to disease; (3) cage deformation and structural fatigue due to the extra weight imposed by fouling.

Control of Biofouling

Biofouling causes huge economic loss in aquaculture industry. So many effeots have been adopted to combat this problem. Aquaculture industry had use antifouling agent to solve this problem. Antifouling paints has been used on the surfaces of fishing crafts and gears to reduce the problem. These antifouling paints are used to control biofouling are commonly used on surfaces in marine transport, oil and gas industries (Yebra *et al.*, 2004, deNys and Guenther

2009; Dürr and Watson 2010). In this technology, on outer surface of marine transport heavy metals and organic biocides produce a thin, toxic layer that prevent biofouling. But the drawback is that, many of the chemicals and heavy metals involved are recognized as dangerous in the environment with detrimental effects on survival and growth of Shellfish (Paul and Davies 1986; Short and Thrower 1986, Bruno and Ellis 1988). Alternative methods must be found to mitigate this problem as biofouling control remedies one of the most difficult challenges and costly in aquaculture industry. For Shellfish culture, the control of biofouling is divided into five broad categories.

Control Measures for Shellfish culture

1. **Avoidance of Natural Recruitment**

   Avoidance techniques must be adopted to prevent larval and settlement of problematic biofouling organism (Wills *et al.*, 2011, Dunham and Marshall 2012).

2. **Physical Removal**

   As chemical antifoulants cause adverse effects on Shellfish, so physical removal is the best way. Mechanical equipment is very common method. Oysters cleaned regularly thereby increase their growth (Taylor *et al.*, 1997). Washing reduces some solitary tunicates by up to 80% (Mallet and Carver 2006). But some problems are there by colonial organisms which undergo fragmentation (Hopkins *et al.*, 2011). Manual cleaning involves by knives, brushes and water pressure. Immersing fouled shellfish in freshwater is simple, cheap and environment friend technique (Denny 2008). Heat technique is another technique in many marine industries (Perepelizin and Boltovkoy, 2011). Spray and immersion technique is also popular by using acidic and alkaline chemicals.

3. **Biological Control**

   Main principle in biological control is based upon predation of pest species by other marine organisms. In Oyster culture, the introduction of periwinkles (Enright *et al.*, 1983), crab (Ross *et al.*, 2004) and sea urchin (Lodeiros and Garcia 2004, Epelbaum *et al.*, 2009) is another method.

4. **Coatings**

   Development of coatings technology to solve biofouling in shipping and on other marine infrastructure has very important. Coating involves of live pearl oysters with a biodegradable, wax – based, impervious, non – toxic materials (deNys and Ison 2004).

5. **Control and Protection for Equipment**

   Culture equipment in ropes, floats, panels, nets and trays have used heavy metals including copper due to their negative impacts on developing vertebrates and invertebrates (Oliva *et al.*, 2007) and their ability to concentrate in shellfish tissues (Changsheng *et al.*, 1990). But this technique has some problem as low surface energy coating some time releases fouling communities under physical cleaning.

Control Measures for Fish Culture

Commercially marine fish farm operations usually employ a multifacted approach to control net fouling. This includes:

(i) Net changing and cleaning to remove fouling organisms and maintain water exchange.

(ii) Chemical antifoulants such as copper.

(iii) Biological control using herbivorous fish or invertebrates to graze biofouling from the net surface.

New Strategies to Control and Mitigate Biofouling in Aquaculture

Introduction of new antifouling solutions for aquaculture in marine transport industry plays important role to mitigate problem of biofouling. The new antifouling technologies should have implemented in aquaculture industry. They should be

(i) Effective against a broad range of fouling taxa.

(ii) Be environment friendly

(iii) Have no residual effect on cultured species.

(iv) Have no negative effects on cultured species

(v) Be able to withstand on shore handling and cleaning

(vi) Be commercially viable.

Prediction of occurrence of biofouling episodes is one of the most effective measures. As a result of such prediction infrastructure can be moved away from fouling settlement peaks. Farmers can place their collecting ropes outside normal collecting times which cause low fouling settlement. More research is required for controlling of such problems. Application of food grade oil to farm buoys, ropes and floats reduce fouling by algae and tunicates by more than 90% (Bakker *et al.,* 2011). Management of husbandry and cleaning strategies prevent removal of fouling agents. Hard fouling such as barnacles, tubeworms and bivalves are particularly difficult and costly to remove. For controlling of foulant in fishing nets and other fish farm is largely restricted to a limited range of products which release copper or zinc. New products should have low surface energy coatings, texturing and surface bound compounds, fouling release technologies rely on hydrodynamics forces to remove fouling organisms with poor adhesion. New approaches should focus on pharmaceuticals (Pinori *et al.*, 2011), bioactive (Dahlstorm and El wing 2006) and commercially available enzymes (Pettitt *et al.,* 2004) as antifoulants. Biocide – free, low surface energy siloxane elastomass and fluropolymers may provide a non-toxic alternative to control biofouling (Lewis 2009, Magin *et al.,* 2010).

Conclusion:

Biofouling, the colonization of submerged surfaces by organisms, continues to pose formidable challenges across diverse industries and ecosystems. While significant strides have been made in understanding and mitigating its impacts, the future of biofouling management

demands a multifaceted approach that integrates scientific innovation, regulatory action, and global cooperation.

Emerging Technologies in Biofouling Management:

The future of biofouling management lies in the realm of emerging technologies that offer novel approaches to prevention and control. Nanostructured surfaces, engineered to mimic natural antifouling properties, hold immense promise for inhibiting microbial attachment and biofilm formation. These advanced materials can significantly reduce the need for toxic biocides while enhancing the efficiency and longevity of antifouling coatings. Additionally, biotechnological innovations, such as enzyme-based treatments and bio-inspired peptides, offer environmentally friendly alternatives for disrupting biofilm formation and deterring fouling organisms.

Furthermore, the convergence of artificial intelligence and robotics presents exciting opportunities for autonomous monitoring and maintenance of fouling-prone surfaces. Autonomous underwater vehicles equipped with sensors and imaging systems can detect biofouling at its earliest stages, enabling timely intervention and optimization of antifouling strategies. Similarly, robotic systems capable of on-site cleaning and inspection can minimize the reliance on labor-intensive manual processes, reducing operational costs and environmental impact.

Challenges and Considerations:

Despite the promise of emerging technologies, several challenges must be addressed to realize their full potential in biofouling management. One significant obstacle is the development of environmentally sustainable and economically viable antifouling solutions. While traditional biocidal coatings have proven effective, their ecological impacts raise concerns about marine toxicity and ecosystem disruption. Thus, there is a pressing need for research into bio-based alternatives that offer robust fouling prevention without compromising environmental integrity.

Furthermore, the complexity of biofouling dynamics requires a holistic understanding of the underlying mechanisms and interactions between fouling organisms and substrates. This necessitates interdisciplinary collaboration between scientists, engineers, and policymakers to integrate biological, chemical, and physical approaches into effective antifouling strategies. Additionally, the global nature of maritime trade and shipping underscores the importance of international cooperation in establishing standardized regulations and best practices for biofouling management.

Regulatory Frameworks and International Collaboration:

Regulatory frameworks play a crucial role in shaping the future of biofouling management by setting standards for antifouling coatings, monitoring protocols, and environmental protection measures. International agreements, such as the International Maritime

Organization's (IMO) International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS Convention), provide a framework for regulating the use of biocidal coatings and promoting the adoption of environmentally friendly alternatives.

Moreover, regional initiatives and partnerships facilitate knowledge exchange and capacity building among stakeholders, fostering innovation and best practices in biofouling management. Collaborative research consortia, industry alliances, and academic networks serve as platforms for sharing expertise, resources, and data to address common challenges and accelerate the development of sustainable solutions.

Future Prospects and Conclusion:

In envisioning the future of biofouling management, a proactive and collaborative approach is essential to harnessing the potential of emerging technologies and addressing persistent challenges. By investing in research and innovation, fostering interdisciplinary collaboration, and strengthening regulatory frameworks, we can pave the way for sustainable and effective biofouling solutions.

Moreover, public awareness and engagement are critical in driving demand for environmentally friendly antifouling products and practices. Educating stakeholders about the ecological and economic benefits of biofouling prevention can incentivize industry-wide adoption of sustainable technologies and promote responsible stewardship of marine resources.

In conclusion, the future of biofouling management holds immense promise for innovation, sustainability, and global cooperation. By embracing emerging technologies, overcoming persistent challenges, and forging partnerships across sectors and borders, we can navigate towards a cleaner, more resilient, and biodiverse marine environment for future generations.

References:

1. Adams, C. M., Shumway, S. E., Whitlach, R. B., & Getchis, T. (2011). Biofouling in marine molluscan shellfish aquaculture: A survey assessing the business and economic implications of mitigation. Journal of the World Aquaculture Society, 42, 242-252.
2. Bakker, J. A., Paetzold, C., Quijon, P. A., & Davidson, J. (2011). The use of food grade oil in the prevention of vase tunicate fouling on mussel aquaculture gear. Management of Biological Invasions, 2, 15-25.
3. Braithwaite, R. A., Carrascosa, M. C. C., & McEvoy, L. A. (2007). Biofouling of salmon cage netting and the efficacy of a typical copper-based antifoulant. Aquaculture, 262, 219-226.
4. Bruno, D. W., & Ellis, A. E. (1988). Histopathological effects in Atlantic salmon, *Salmo salar* L., attributed to the use of tributyltin antifoulant. Aquaculture, 72, 15-20.

5. Buschbaum, C., Buschbaum, G., Scherey, T., & Thieltges, D. W. (2007). Shell-boring polychaetes affect gastropod shell strength and crab predation. Marine Ecology Progress Series, 329, 123-130.
6. Campbell, D. A., & Kelly, M. S. (2002). Settlement of *Pomatoceros triqueter* (L.) in two Scottish lochs, and factors determining its abundance on mussels grown in suspended culture. Journal of Shellfish Research, 21, 519-527.
7. Carl, C., Guenther, J., & Sunde, L. M. (2011). Larval release and attachment modes of the hydroid *Ectopleura larynx* on aquaculture nets in Norway. Aquaculture Research, 42, 1056–1060.
8. Changsheng, Z., Bingyin, S., Yunbi, H., & Xianggui, X. (1990). Effects of JS-876, a copper-tin compounded anti-fouling agent, on growth of the scallop *Pecten maximus*. Journal of Oceanography of Huanghai & Bohai Seas, 8, 40-46. (Chinese with English abstract).
9. Characklis, W. G. (1990). Microbial biofouling. In Characklis, W. R., & Marshall, K. C. (Eds.), Biofilms (pp. 523–584). Wiley.
10. Cheyne, I. (2010). Regulation of marine antifouling in international and EC law. In S. Durr & J. C. Thomason (Eds.), Biofouling (pp. 306–318). Wiley-Blackwell.
11. Claereboudt, M. R., Bureau, D., Cote, J., & Himmelman, J. H. (1994). Fouling development and its effect on the growth of juvenile giant scallops (*Placopecten magellanicus*) in suspended culture. Aquaculture, 121, 327–342.
12. Cook, E. (2001). A review of biofouling on artificial substrates. In A review of the environmental impacts of marine cage aquaculture, processes of biofiltration relevant to impact mitigation, the biological properties of marine invertebrates relevant to biofiltration and biofouling on artificial structures. BIOFAQs, Q5RS– 2000-30305, Technical Annex Annual Report, (December 2001), 87–96.
13. Cronin, E. R., Cheshire, A. C., Clarke, S. M., & Melville, A. J. (1999). An investigation into the composition, biomass and oxygen budget of the fouling community on tuna aquaculture farm. Biofouling, 13, 279-299.
14. Dahlstrom, M., & Elwing, H. (2006). Adrenoceptor and pharmacocoactive compounds as putative antifoulants. In N. Fusetani & A. S. Clare (Eds.), Antifouling Compounds (Vol. 42, pp. 171-202). Progress in Molecular and Subcellular Biology.
15. Dharmaraj, S., & Chellam, A. (1983). Settlement and growth of barnacle and associated fouling organisms in pearl culture farm in the Gulf of Mannar. In Proc Symp on Coastal Aquaculture, Cochin, India, 1980. Part 2: Molluscan Culture (pp. 608-613). Marine Biological Association of India. Available from http://eprints.cmfri.org.in/2306/.

16. Dalby, J. E., & Young, C. M. (1993). Variable effects of ascidian competitors on oysters in a Florida epifaunal community. Journal of Experimental Marine Biology and Ecology, 167, 47-57.
17. Denny, C. M. (2008). Development of a method to reduce the spread of the ascidian *Didemnum vexillum* with aquaculture transfers. ICES Journal of Marine Science, 65, 805-810.
18. de Nys, R., & Ison, O. (2004). Evaluation of antifouling products developed for the Australian pearl industry (Project No 2000/254). Final Report to the Fisheries Research and Development Corporation. James Cook University.
19. de Nys, R., & Guenther, J. (2009). The impact and control of biofouling in marine finfish aquaculture. In C. Hellio & D. Yebra (Eds.), Advances in marine antifouling coatings and technologies (pp. 177-221). Woodhead Publishing Ltd.
20. de Sa, F. S., Nalesso, R. C., & Paresque, K. (2007). Fouling organisms on *Perna perna* mussels: Is it worth removing them? Brazilian Journal of Oceanography, 55, 155-161.
21. Dunham, A., & Marshall, R. D. (2012). Using stocking density modifications and novel growth medium to control shell deformities and biofouling in suspended culture of bivalves. Aquaculture, 324, 234-241.
22. Dürr, S., & Watson, D. I. (2010). Biofouling and antifouling in aquaculture. In S. Dürr & J. C. Thomason (Eds.), Biofouling (pp. 267-287). Wiley-Blackwell.
23. Enright, C., Krailo, D., Staples, L., Smith, M., Vaughan, C., Ward, D., Borgese, E. (1983). Biological control of fouling algae in oyster aquaculture. Journal of Shellfish Research, 3, 41-44.
24. Epelbaum, A., Pearce, C. M., Barker, D. J., Paulson, A., & Therriault, T. W. (2009). Susceptibility of non-indigenous ascidian species in British Columbia (Canada) to invertebrate predation. Marine Biology, 156, 1311-1320.
25. Epstein, N. (1981). Fouling: Technical aspects. In E. F. C. Somerscales & J. G. Knudsen (Eds.), Fouling of heat transfer equipment (pp. 31–53). Hemisphere.
26. Food and Agriculture Organization. (2010). The State of World Fisheries and Aquaculture. Accessed February 2012.
27. Ferguson Wood, E. J. (1950). The role of bacteria in the early stages of fouling. Australian Journal of Marine and Freshwater Research, 1, 81-91.
28. Fitridge, I. (2011). The ecology of hydroids (Hydrozoa: Cnidaria) in Port Phillip Bay, Australia, and their impacts as fouling species in longline mussel culture (PhD thesis). Department of Zoology, The University of Melbourne, Australia.
29. Fitridge, I., Dempster, T., Guenther, J., & de Nys, R. (2012). The impact and control of biofouling in marine aquaculture: A review. Biofouling, 28(7), 649-669.

30. Greene, J. K., & Grizzle, R. E. (2007). Successional development of fouling communities on ocean aquaculture fish cages in the western Gulf of Marine, USA. Aquaculture, 262, 289-301.
31. Guenther, J., Carl, C., & Sunde, L. M. (2009). The effects of colour and copper on the settlement of the hydroid *Ectopleura larynx* on aquaculture nets in Norway. Aquaculture, 292, 252-255.
32. Guenther, J., Misimi, E., & Sunde, L. M. (2010). The development of biofouling, particularly the hydroid *Ectopleura larynx*, on commercial salmon cage nets in Mid-Norway. Aquaculture, 300, 120-127.
33. Guenther, J., Fitridge, I., & Misimi, E. (2011). Potential antifouling strategies for marine finfish aquaculture: The effects of physical and chemical treatments on the settlement and survival of the hydroid *Ectopleura larynx*. Biofouling, 27, 1033-1042.
34. Hickman, N. J., & Sause, B. L. (1984). Culture of the blue mussel (*Mytilus edulis planulatus*) in Port Phillip Bay, Victoria Australia. III: Larval settlement. Report No. 75. Victoria (Australia): Marine Science Laboratories (Fisheries Victoria). 25 pp.
35. Hodson, S. L., Burke, C. M., & Bissett, A. P. (2000). Biofouling of fish-cage netting: The efficacy of a silicone coating and the effect of netting colour. Aquaculture, 184(34), 277-290.
36. Holloway, M. G., & Keough, M. J. (2002a). An introduced polychaete affects recruitment and larval abundance of sessile invertebrate. Ecological Applications, 12, 1803-1823.
37. Holloway, M. G., & Keough, M. J. (2002b). Effects of an introduced polychaete, *Sabella spallanzanii*, on the development of epifaunal assemblages. Marine Progress Series, 236, 137-154.
38. Hopkins, G. A., Forrest, B. M., Piola, R. F., & Gardner, J. P. A. (2011). Factors affecting survivorship of defouled communities and the effect of fragmentation on establishment success. Journal of Experimental Marine Biology and Ecology, 396, 233-243.
39. Howes, S., Herbinger, C. M., Darnell, P., & Vercaemer, B. (2007). Spatial and temporal patterns of recruitment of the tunicate *Ciona intestinalis* on a mussel farm in Nova Scotia Canada. Journal of Experimental Marine Biology and Ecology, 342, 85-92.
40. Huang, Z. G. (2003). Marine biofouling in Hong Kong: A review. Acta Oceanologica Sinica - English Edition, 22(3), 467-482.
41. Kaehler, S., & McQuaid, C. D. (1999). Lethal and sub-lethal effects of phototrophic endoliths attacking the shell of intertidal mussel *Perna perna*. Marine Biology, 135, 497-503.
42. Lane, A., & Willemsen, P. R. (2004). Collaborative effort looks into biofouling. Fish Farming International, September 2004, 34-35.

43. Le Blanc, A. R., Landry, T., & Miron, G. (2003). Fouling organisms of the mussel *Mytilus edulis*: Their effect on nutrient uptake and release. Journal of Shellfish Research, 22, 633-638.
44. Lee, H. B., Lim, L. C., & Cheong, L. (1985). Observations on the use of antifouling paint in netcage fish farming in Singapore. Singapore Journal of Primary Industries, 13, 1-12.
45. Lewis, J. A. (2009). Non-silicone biocide-free antifouling solutions. In C. Hellio & D. Yebra (Eds.), Advances in marine antifouling coatings and technologies (pp. 709-724). Woodhead Publishing Ltd.
46. Lodeiros, C., Prieto, A., Narvaez, N., & Guerra, A. (2002). Growth and survival of the pearl oyster *Pinctada imbricata* (Rodling 1758) in suspended and bottom culture in the Golfo de Cariaco, Venezuela. Aquaculture International, 10, 327-338.
47. Lodeiros, C., & Garcia, N. (2004). The use of sea urchins to control fouling during suspended culture of bivalves. Aquaculture, 231, 293-298.
48. Lieonart, M., Handlinger, J., & Powell, M. (2003). Spionid mud-worm infestation of farmed abalone (Haliotis spp). Aquaculture, 221, 85-96.
49. Madin, J., Chong, V. C., & Barsi, B. (2009). Development and short-term dynamics of microfouling assemblages on fish-cage nettings in a tropical estuary. Estuarine, Coastal and Shelf Science, 83, 19-29.
50. Magin, C. M., Cooper, S. P., & Brennan, A. B. (2010). Non-toxic antifouling strategies. Materials Today, 13, 36-44.
51. Mallet, A. L., & Carver, C. E. (2006). Incorporating the New Zealand Tunicate Treatment Technology into a tunicate management strategy for Indian Point Marine Farms. Report prepared for Aquaculture Association of Nova Scotia. Dartmouth (Nova Scotia): Mallet Research Services. 21 pp.
52. Manning, L. M., & Lindquist, N. (2003). Helpful habitat or pernicious passenger: Interactions between an infaunal bivalve, an epifaunal hydroid and three potential predators. Oecologia, 134, 415-422.
53. Mao Che, L., Le Campion-Alsumard, T., Boury-Esnault, N., Payri, C., Golubic, S., & Bezac, C. (1996). Biodegradation of shells of the black pearl oyster, *Pinctada margaritifera* var. cumingii, by microbes and sponges of French Polynesia. Marine Biology, 126, 509-519.
54. Milne, P. H. (1975a). Fouling of marine cages-Part one. Fish Farming International, 2, 15-19.
55. Milne, P. H. (1975b). Fouling of marine cages-Part Two. Fish Farming International, 2, 18-21.

56. Miyauti, T. (1968). Studies on the effect of shell cleaning in pearl culture - III. The influence of fouling organisms upon the oxygen consumption in the Japanese pearl oysters. Nihon Seitai Gakkai Shi (Jap J Ecol.), 18, 40 (in Japanese with English abstract).
57. Moring, J. R., & Moring, K. A. (1975). Succession of net biofouling material and its role in the diet of pen-cultured Chinook salmon. Progress in Fish-Culture, 37, 27-30.
58. Oliva, M., Carmen Garrido, M. D., Perez, E., & Gonzalez De Canales, M. L. (2007). Evaluation of acute copper toxicity during early life stages of gilthead, *Sparus aurata*. Journal of Environmental Science and Health, Part A, 42, 525-533.
59. Paclibare, J. O., Evelyn, T. P. T., Albright, L. J., & Prosperi-Porta, L. (1994). Clearing of the kidney disease bacterium *Renibacterium salmoninarum* from seawater by the blue mussel *Mytilus edulis*, and the status of the mussel as a reservoir of the bacterium. Diseases of Aquatic Organisms, 18, 129-133.
60. Paul, J. D., & Davies, I. M. (1986). Effects of copper and tin-based antifoulant on the growth of cultivated scallops (*Pecten maximus*) and oyster (*Crassostrea gigas*). Aquaculture, 54, 191-203.
61. Perepelizin, P. V., & Boltovskoy, D. (2011). Thermal tolerance of *Limnoperna fortunei* to gradual temperature increase and its applications for biofouling control in industrial and power plants. Biofouling, 27, 667-674.
62. Pettitt, M. E., Henry, S. L., Callow, M. E., Callow, J. A., & Clare, A. S. (2004). Activity of commercial enzymes on settlement and adhesion of cypris larvae of the barnacle *Balanus amphitrite*, spores of the green alga *Ulva linza*, and the diatom *Navicula perimuta*. Biofouling, 20, 299-311.
63. Phillipi, A. L., Connar, N. J. O., Lewis, A. F., & Kim, Y. K. (2001). Surface flocking as a possible anti-biofoulant. Aquaculture, 395(3-4), 225-238.
64. Pinori, E., Berglin, M., Brive, L. M., Hulander, M., Dahlstrom, M., & Elwing, H. (2011). Multi-seasonal barnacle (*Balanus improvisus*) protection achieved by trace amounts of a macrocyclic lactone (ivermectin) included in rosin-based coatings. Biofouling, 27, 941-953.
65. Ross, K. A., Thorpe, J. P., & Brand, A. R. (2004). Biological control of fouling in suspended scallop cultivation. Aquaculture, 229, 99-116.
66. Short, J. W., & Thrower, F. P. (1986). Accumulation of butyltin in mussels of Chinook salmon reared in sea pens treated with tri-n-butyltin. Marine Pollution Bulletin, 17, 542-545.
67. Silina, A. V. (2006). Tumor-like formations on the shells of Japanese scallops *Patinopecten yessoensis*. Marine Biology, 148, 833-840.
68. Simon, C. A., Ludford, A., & Wynne, S. (2006). Spionid polychaetes infesting cultured abalone *Haliotis midae* in South Africa. African Journal of Marine Science, 28, 167-171.

69. Southgate, P. C., & Beer, A. C. (2000). Growth of black lip pearl oyster (*Pinctada margaritifera*) juveniles using different nursery culture techniques. Aquaculture International, 87: 97-104.
70. Stefaniak, L. M., McAtee, J., & Shulman, M. J. (2005). The cost of being bored: Effects of a clionid sponge on the gastropod *Littorina littorea*. Journal of Experimental Marine Ecology, 327, 103-114.
71. Swift, M. R., Fredriksson, D. W., Unrein, A., Fullerton, B., Patursson, O., & Baldwin, K. (2006). Drag force acting on biofouled net panels. Aquacultural Engineering, 35, 292-299.
72. Tan, K. F., Nowak, B. F., & Hodson, S. L. (2002). Biofouling as a reservoir of *Neoparamoeba pemaquidensis* (Page, 1970), the causative agent of amoebic gill disease in Atlantic salmon. Aquaculture, 1-4, 49-58.
73. Taylor, J. J., Southgate, P. C., & Rose, R. A. (1997). Fouling animals and their effect on the growth of silverlip pearl oysters, *Pinctada maxima* (Jameson) in suspended culture. Aquaculture, 153, 31-40.
74. Thieltges, D. W., & Buschbaum, C. (2007). Vicious circle in the intertidal: Facilitation between barnacles epibionts, a shell boring polychaete and trematode parasites in the perwinkle *Littorina littorea*. Journal of Experimental Marine Biology and Ecology, 340, 90-95.
75. Wahl, M., Hay, M. E., & Enderlein, P. (1997). Effects of epibiosis on consumer – prey interactions. Hydrobiologia, 355, 49-59.
76. Watson, D. I., Shumway, S. E., & Whitlach, R. B. (2009). Biofouling and the shellfish industry. In S. E. Shumway & G. E. Rodrick (Eds.), Shellfish safety and quality (pp. 317-336). Cambridge, UK: Woodhead Publishing.
77. Willis, J. E., Stewart-Clark, S., Greenwood, S. J., Davidson, J., & Quijon, P. A. (2011). A PCR-based assay to facilitate early detection of *Diplosoma listerianum* in Atlantic Canada. Aquatic Invasions, 6, 7-16.
78. Yebra, D. M., Kiil, S., & Dam-Johansen, K. (2004). Antifouling technology - past, present and future steps towards efficient and environmentally friendly antifouling coatings. Progress in Organic Coatings, 50, 75-104.
79. Yukihira, H., Klumpp, D. W., & Lucas, J. S. (1998). Effects of body size on suspension feeding and energy budgets of the pearl oysters *Pinctada margaritifera* and *P. maxima*. Marine Ecology Progress Series, 170, 119-130.

AGEING IN WEST BENGAL AND CHALLENGES

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Abstract:

The elderly population in West Bengal is growing fast and at an alarming rate in comparison with the all India average. Proper safety, security and social protection of ageing population majority of whom being woman is of utmost criteria of consideration in West Bengal gerontological research. The state faces the urgent need to study her ageing processes so that its influence and impact on elderly population as well as society could be judged.

Introduction: The concept of Ageing

Ageing is a continuous, irreversible, universal process, which starts from conception till the death of an individual. However, the age at which one's productive contribution declines and one tends to be economically dependent can probably be treated as the onset of the aged stage of life. Old age is the last phase of human life cycle, which is again universally true. As such it is difficult to provide a clear definition. Different writers have viewed ageing in different contexts as the outcome of biological, demographic, sociological, psychological or other processes.

Objective of the Study: To find out the fast growing ageing population in the state, problems faced by them, way out and ultimate implication on the society.

Methodology: The methodology followed in this article relates to the data collection from sources like research journals, magazines, books and internet.

Discussions and Findings:

Categorization and Dimensions of Ageing

The WHO defines those aged 60 -74 years as elderly. In 1980 the UN recommended 60 years as the age of transition for the elderly segment of the population, and has been categorized as follows:

1. Young Old- between the ages of 60-75 years.
2. Old-Old- between the ages of 75-85 years.
3. Very Old- 85 years and above

Gerontologists say that age and ageing have at least **four dimensions**. The dimension most of us think of is chronological age, defined as the number of years since someone was born. A second dimension is biological ageing, which refers to the physical changes that "slow us down" as we get into our middle and older years. For example, our arteries might clog up, or problems with our lungs might make it more difficult for us to breathe. A third dimension,

psychological ageing, refers to the psychological changes, including those involving mental functioning and personality, that occur as we age. The fourth dimension of ageing is social. Social ageing refers to changes in a person's roles and relationships, both within their networks of relatives and friends and in formal organizations such as the workplace and houses of worship. World Population Data Sheet- 2002 considers aged population as population in the age group of 65+ as old.

Indian Population on Age Perspective

In the Indian context, the age of 60 years has been adopted by the census of India for the purpose of classifying a person as old, which coincides with the age of retirement in government sector. The terms Young-Old for 60 to 69, Old-Old for 70 to 79 and Oldest Old for 80 to 89 have been used.

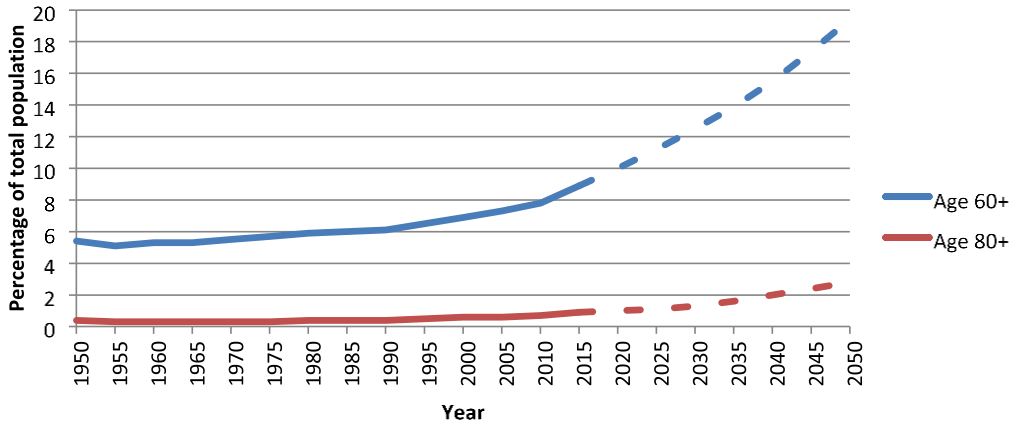

Figure 1: The number of older Indians is growing rapidly as a proportion of the country's population Source: (United Nations 2015); dashed lines represent projections under a medium-fertility scenario

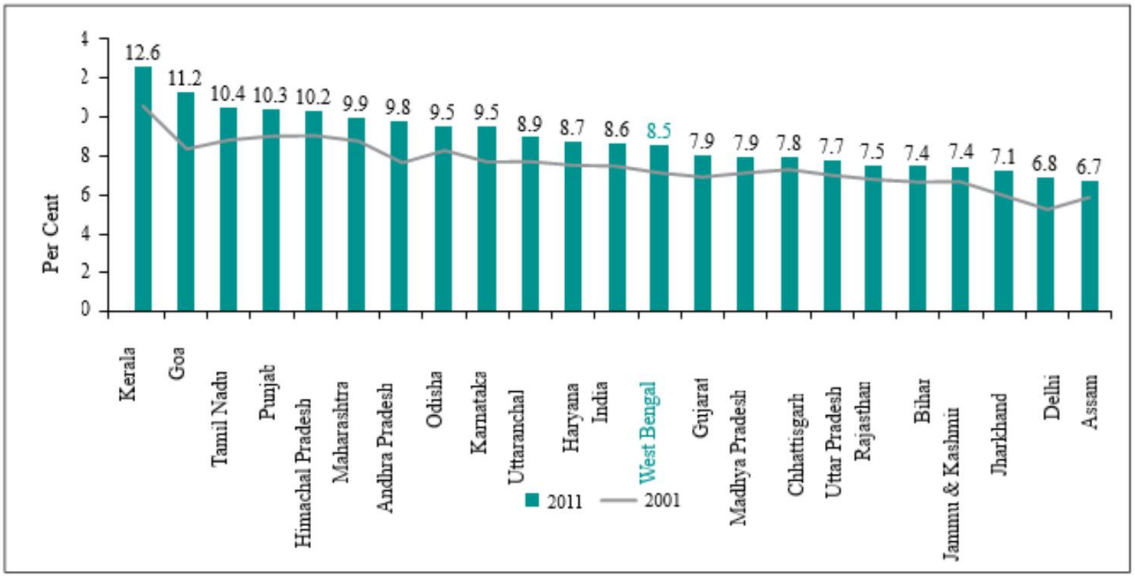

Figure 2: State wise Population Aged 60 years and above according to Census 2001 and 2011

West Bengal Population on Age Perspective:

The ageing population in West Bengal has got relatively less priority in gerontological research in India despite the fact that she acquires fourth position among all states and Union Territories (UT) in India in respect of absolute numbers of aged people (Census, 2001). However, the elderly population in the state of West Bengal is growing in a faster rate than all India average. It could be projected that, in near future, West Bengal would emerge as an important state in India in respect of population ageing.

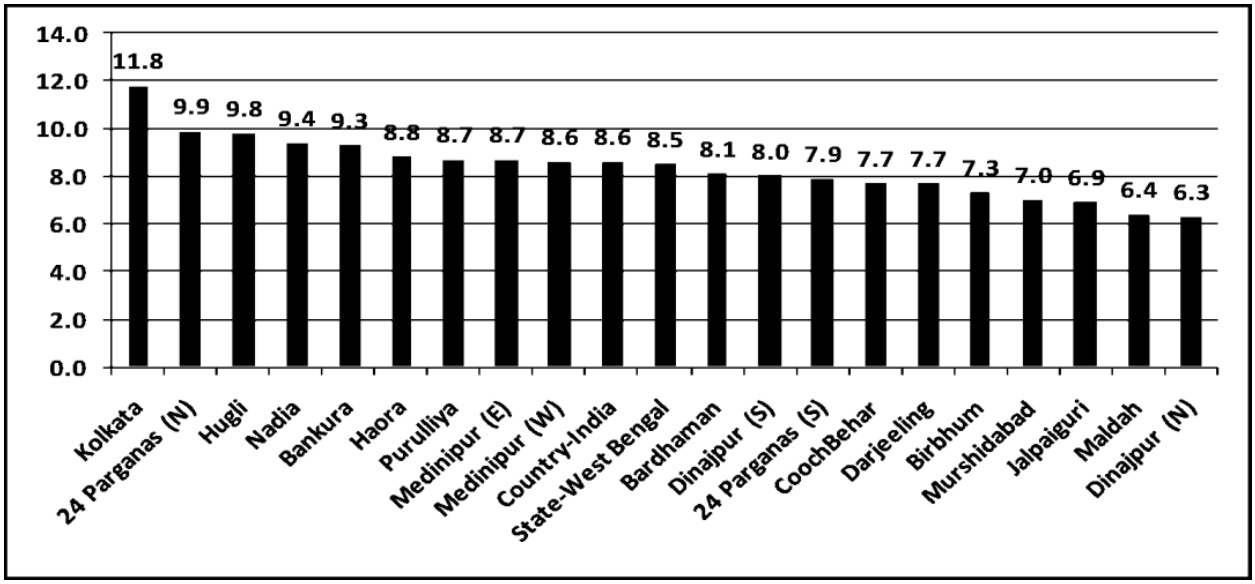

Figure 3: Percent of Elderly for Districts of West Bengal Along with West Bengal and India in 2011 (Source: Census of India)

Table 1: Percent Distribution of Population by Age Groups in West Bengal

Source	Age groups (years)			
	0 – 14	**15 – 59**	**60 -**	**Total**
Census 2001	33.3	59.6	7.1	100
Census 2011	27.2	64.3	8.5	100

Age and Sex in West Bengal

The sex ratio across the elderly age groups, as shown in above Figure: 4 , clearly indicates a steadily increasing female dominance with age – the sex ratio increases from 1,053 (60-69 years) to 1,376 in the 80+ age group.

Rising feminization of ageing was prominent in West Bengal, similar to the seven state report, with the sex ratio being 1135 females per 1000 males in the 60+ age group. Nearly two-thirds of the elderly (63%) are in the 60-69 age group confirming ageing as a recent phenomenon requiring immediate attention. Almost three-quarters of the elderly females are widows and the lifetime migration among the elderly women is very high (82%) as against men (36%).

Surprisingly, remarriage rate is marginally higher in rural locales (4%) than the urban locales (1%). Nearly half the elderly population (48%) surveyed in the state has no formal education.

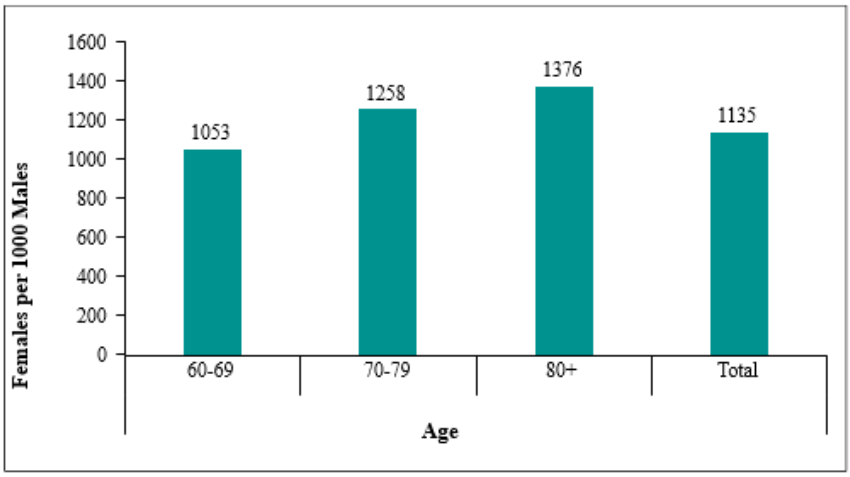

Figure 4: Sex ratio (females per 1,000 males), West Bengal 2011
(Source: Census of India, 2011)

Amenities Presently Available:

Health Care for the Elderly (HCE) Public health expenditure in West Bengal is reasonably low. The elderly here largely suffer from communicable diseases and impairment of special sensory functions like vision and hearing. Track records of the estimates of health burden of the BPL elderly are not in order. Geriatrics is not yet a popular specialty. As a result, there was no dedicated infrastructure for elderly health care particularly for the groups under the BPL category till the National Programme for the Health Care for the Elderly (NPHCE) commenced in 2013. This section discusses the currently operational government-initiated health care schemes and community response initiatives for the elderly.

Programmes

i) National Programme for Health Care of the Elderly (NPHCE) The NPHCE scheme is financed in the ratio 80:20 by the central and state governments respectively. The purpose of this scheme is to provide acceptable, affordable and quality long-term comprehensive dedicated health care services to the ageing population of the country. For West Bengal 2013 is the maiden year. NPHCE is open to all the elderly, irrespective of economic class. In order to address human resource issues under the NPHCE, it has been proposed to develop 12 additional regional geriatric centres in select medical colleges of the country in addition to 8 regional geriatric centres being developed during the 11th Plan. One of the regional centres and medical colleges proposed is Kolkata Medical College (KMC).

ii) Briddhashree Yojana (BY) of Government of West Bengal The Government of West Bengal has announced Briddhashree Yojana for the health care of 17 lakh (approximately) BPL elderly beneficiaries on record receiving old age pension. This scheme would be operational during the fiscal year 2013. (Ananda Bazar Patrika, 19 October 2013).

iii) Varistha Yojana for Senior Citizens (VYSC) This programme has been launched by National Insurance and other major insurance companies and caters to multiple health needs of senior citizens in the age group 60–80 years. The policy covers hospitalization and domiciliary hospitalization expenses as well as expenses for treatment of critical illnesses. However, beneficiaries of this scheme in West Bengal constitute only 2 per cent in APL category (The Economic Times, 10 July 2004).

iv) Mobile Medicare Unit (MMU) The scheme framed by the Ministry of Social Justice and Empowerment (MOSJE) limits grants-in-aid for projects for older people living in slums, rural and inaccessible areas where proper health facilities are not available. Currently there are seven MMUs in the state. The total number of beneficiaries is 2,800 (Annual Report, GoWB, 2011). Contemporary West Bengal is focused more on ageing and elderly care than child care.

The Kolkata Police and an NGO "Bengal" started a program called **'Pronam'**. It is a unique attempt to provide physiological and physical support to the elderly through a helpline number. Pronam also provides emergency ambulance facilities and financial support in a restricted way. The same programme has been replicated in the Salt Lake City under the name of **'Saanjhbaati'** to provide assistance to NRIs living alone in that part of the city (Hindustan Times, 10 September, 2012).

Another notable initiative in West Bengal is of the Indian Medical Association (IMA), Behala. This is a doctors association that provides various medical services to the elderly population residing in Behala. Services provided include- hospitalization at subsidized rates; home visits by professional doctors; ambulance facilities and medical insurance for some of the fatal diseases (UNFPA, 2014).

Challenges Before the Elderly People: We have come across some facilities are available or some attempts have been taken to ease the life of the elderly people, but in reality those programmes need a considerable time and sincere effort to overcome the following challenges faced by the elderly people.

(i) Challenges in Urban Area

(ii) Challenges in Rural Area

The challenges faced by the aged people both in urban and rural area can be identified under the following major heads.

Urban Area:

i. Monetary – The urban population has a wide range of income groups and thus the average expenditure reflects the actual capacity of consumption.
ii. Social Association – Nuclear family and isolated existence.
iii. Medication – High cost of life saving drugs.
iv. Transportation – Facilities are available but not up to the mark.
v. Lack of oldage care amenities and infrastructure

Table 2: Average Monthly Per Capita Expenditure on Broad Groups of Items in West Bengal (N.S.S 68th Round, July 2011 to June 2012)

Average monthly per capita expenditure (in Rs.) Urban

State	Food total	Fuel and light	Clothing and footwear	Education	**Total Medical**	Durable goods	Others	Total consumer expenditure
West Bengal	989.16	201.39	170.98	193.59	**211.35**	151.16	572.26	2489.89

Rural Area:

i. Monetary - The rural population has a narrow range of income groups and its average expenditure reflects the actual capacity of consumption.
ii. Medication – High cost of life saving drugs.
iii. Transportation – Negligible facilities are available.
iv. Lack of oldage care amenities and infrastructure

Table 3: Average Monthly Per Capita Expenditure on Broad Groups of Items in West Bengal (N.S.S 68th Round, July 2011 to June 2012)

Average monthly per capita expenditure (in Rs.) Rural

State	Food total	Fuel and light	Clothing and footwear	Education	**Total Medical**	Durable goods	Others	Total consumer expenditure
West Bengal	639.92	117.67	84.40	48.57	**93.49**	33.49	152.57	1170.11

Comparative analysis of the challenges faced by the elderly people in rural and urban sectors of West Bengal

The foregoing assessment portrays that the population of two sectors (rural and urban) of West Bengal have some common problems faced by the elderly people. Basically the elderly people of urban sector though having the similar problems with the rural population but they stand in different footing. As we see, socio-economic status of urban population is far better than the rural population though it may not be sufficient and thus monetary problem is generally faced by the elderly people of middle class, lower middle class and of the slum area. On the contrary this monetary problem is mainly faced by the majority of the rural elderly people except some exceptions.

To provide emergency service to the elderly people there is no special provision even in the urban area and it is obvious no need to opine about the rural area. Since the elderly people is passing through a vulnerable stage, they need some special amenities and infrastructure such as equipments for their easy movment, safe corridor for their public interaction and artificial life saving aid to lessening their pain and trouble including health and sanitary facilities. At present only the rich population of the urban area and some exceptional rural people can manage to avail those facilities, which needs institutional or governmental interventions for mass utility. It is now revealed from various studies that the life expectancy of any population rises by using life saving drugs and it is also applicable to the elderly people who uses regularly life support drugs. Due to monetary problem and high cost of these life saving and life support drugs a part of the urban elderly population and a major portion of the rural elderly population cannot avail those drugs.

It is one of the major socio-psycho problem caused mainly by socio-economic independence reaching to the nuclear family from joint family. This rampant problem is mainly faced by the urban elderly population due to social and family structure. It is a natural phenomenon as the age goes up the elderly people loses their peers which reduces their communication to exchange their views. On the other hand, the younger generation is on the age of rat race and lacking in to spend valuable times with their elderly people which resulted the elderly people to face extreme isolation and indirectly forced them to dip into depression. On the contrary though the rural family structure is mostly nuclear still the rural elderly people have some social association which prevents them to face the problems as faced by the urban elderly people.

Some Innovative Approaches which may help in better way the elderly people if implemented in the state:

i) Dance movement therapy: It is now-a-days used as a successful media to increase the health status of any age group by eliciting positive changes in certain aspects of physical fitness and healthy wellbeing (Chatterjee, 2013a). It has a great potential to improve antioxidant status and

prevent free radical injury (Chatterjee, 2013b). Western ballroom dance forms had been used in gerontology research to enhance balance and functional autonomy (Borges *et al.*, 2012). Salsa dance had also been used to increase balance and strength among older adults (Granacher *et al.*, 2012). But such attempts with Indian dance forms are in a very nascent stage. Though the Indian classical, folk and innovative dance forms has a great treasure in therapeutic aspects (Chatterjee 2013c), but the subject still necessitates in-depth practical application. Further the folk and tribal dance forms of West Bengal have a great influence on physical health, mental health and social health (Chatterjee 2013d).

ii) Age-friendly cities and communities: An age-friendly city or community is a good place to grow old. Age-friendly cities and communities foster healthy and active ageing and, thus, enable well-being throughout life. They help people to remain independent for as long as possible, and provide care and protection when they are needed, respecting older people's autonomy and dignity.

The WHO Global Network of Age-friendly Cities and Communities was established in 2010 to support municipalities that wished to transform these ambitions into reality, involving older people in the process and maximizing their opportunities at the local level. The network seeks to do this by:

Inspiring change and showing what can be done and how it can be done;

Connecting cities and communities worldwide to facilitate the exchange of information and experience;

Supporting cities and communities to find solutions by providing innovative and evidence-based technical guidance. The network builds on previous work by WHO, and by 2015 included more than 250 cities and communities in 28 countries.

iii) Safe Streets for seniors programme has developed measures to improve the safety of older pedestrians in particular areas of the city where older people had been involved in accidents that resulted in severe injuries or fatality. Initiatives in other cities, have focused on enhancing mobility by making transportation affordable for and accessible to older people, including in rural areas. For example, in Winnipeg, Canada, **Handi-transit** provides transportation for older people who are not well served by public transport or who can no longer drive. To address the challenges of social isolation and loneliness, many communities have developed telephone hotlines as well as befriending schemes in which volunteers visit older people. Another way of tackling social isolation and loneliness is through schemes that offer activities of interest to older people. An example is the **Men's Sheds** in Australia and Ireland that target men at risk of social isolation, offering activities of interest to them, such as wood turning, repairing vintage vehicles, compiling heritage memorabilia and classes on information technology.

Conclusion:

Statistics embodies the trend of increasing elderly people in the state of West Bengal. Some discrete approaches have been taken to ease the life of the elderly people within the state under the existing infrastructure. But no common programme has yet been taken for all the people who have crossed the age limit of sixty years. It may rise a viable question to the existing and future young generation how would they treat their yesterday's nation builders who are now elderly people and what will happen when their turn will come.

References:

1. Bureau of Applied Economics & Statistics Department of Statistics & Programme Implementation Government of West Bengal. (2015). State Statistical Handbook 2015 (Appendix-VI, p. 237, 238).
2. Hooyman, N. R., & Kiyak, H. A. (2011). Social gerontology: A multidisciplinary perspective (9th ed.). Upper Saddle River, NJ: Pearson.
3. http://mospi.nic.in/sites/default/files/publication_reports/ElderlyinIndia_2016.pdf
4. http://shodhganga.inflibnet.ac.in/bitstream/10603/57408/9/09_chapter%203.pdf
5. https://www.hsph.harvard.edu/pgda/wp-content/uploads/sites/1288/2012/11/Population-Aging-in-India_PGDA-Working-Papers.pdf
6. Mishra, N. (2014, August). Ageing in India: Concerns and Challenges. Bold, 24(4), 5-11.
7. Nayak, A., & Bagchi, K. K. (2017). Trends and Pattern of Population Ageing in India and West Bengal: A Comparative Study. PRAGATI: Journal of Indian Economy, 4(2), 96-119. doi: 10.17492/pragati.v4i02.11466
8. Roy, S. (2013). The Emerging Scenario of Population Ageing in West Bengal: Past Trends and Future Direction. Indian Journal of Gerontology, 27(4), 588-597.
9. Shettar, S. C. (2013). Problems of Aged in Changing Indian Scenario. Web Exclubsives, Social issues Yojna Archives. http://yojana.gov.in/problems-of-aged.asp
10. UNFPA. (2014). The Status of elderly in W.B, 2011 (p. 4-6, p. 50-53).
11. WHO. (2015). World Report on Ageing and Health (Chpt. 6, p. 161).
12. WHO. (2019). Ageing in India (p. 1-17).

BREATHLESS-ASSESSING THE AIR QUALITY - A CASE STUDY OF KOLKATA

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Abstract:

India has been on the road to massive urbanization for the last two decades. Urbanization has led to several problems the city is facing at present. Urbanization has always posed sustainability threats to the surrounding and Kolkata is no exception. There are several AQI stations in Kolkata for monitoring the air quality on a regular basis. However, the study encompasses three major stations- Fort William, Victoria, and Jadavpur. An increasing trend is observed from 2022 onwards with a significant dip between 2020-2021. The average monthly AQI of Kolkata for the year 2023 has been depicted which shows an unhealthy air quality for the winter months of January, November and December, a poor air quality for the months of February, March, April, October, moderate air quality in June and August and a good air quality only for the months of July and September. All the stations have shown a clear predominance of particulate matter emissions which are most detrimental for the society and ecology. A Z Score index has also been prepared. This standardized measure allows for a clear comparison across different times of the year, highlighting months with potential air quality issues or improvements. The natural and anthropogenic causes of air pollution are manifold. The paper highlights the issues of air polluting materials and also the detrimental effects of the menace. The city is breathing the air that exceeds the WHO's guideline of permissibility of maximum limit of pollutants. Funding projects that promote clean air can have enormous benefits for human health, economic development, climate change and mitigation.

Keywords: Pollution, Urbanization, Air Quality, Particulate Matter, Mitigation, Sustainability.

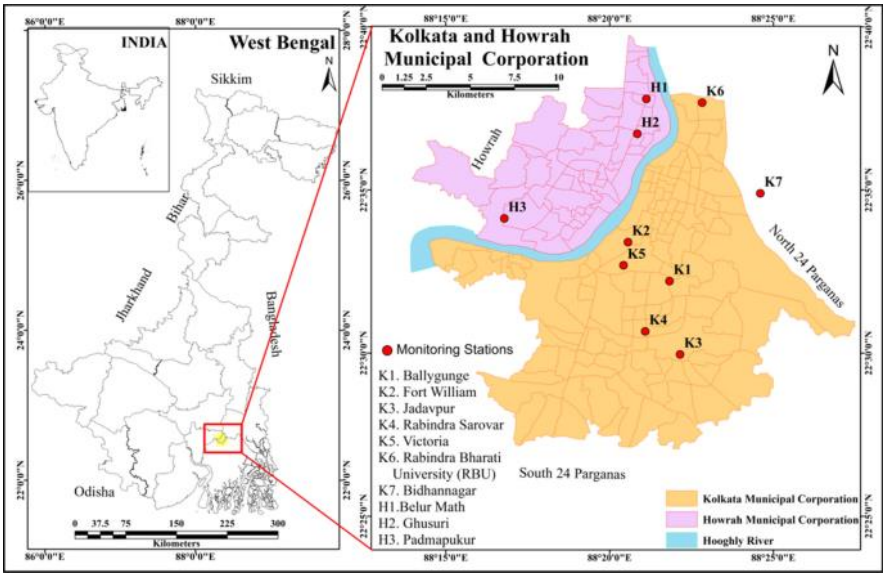
Introduction:

India has been on the road to massive urbanization for the last two decades. The metropolitan and cosmopolitan population are increasing on an alarming rate. Urbanization has led to several problems the city is facing at present [1]. Urbanization has always posed sustainability threats to the surrounding and Kolkata is no exception. The National Air Quality Index Standard (NAQI) in India was launched by The Minister for Environment, Forests & Climate Change, Shri Prakash Javadekar, on 17 September 2014. The issue of urban air pollution poses a serious threst to the environment and the lives of citizens and thus the Government has initiated this mission to introduce the culture of cleanliness in the country. Governmental organizations measure and notify the public about air pollution levels using an Air Quality Index (AQI). A significant portion of the populace will suffer from serious adverse health effects when

the AQI rises. An air monitor and the air pollutant concentration during a predetermined averaging period are needed for the AQI measurement [2]. The results are grouped into ranges, and each range is assigned a descriptor, a colour code and a standardized public health advisory. The major determinants of AQI levels are PM 2.5, PM 10, CO, CO_2, Ozone and several others. Though the year of worldwide lockdown has brought about some remarkable changes in the AQI for 2020-2021, yet India holds twenty- two most polluted cities of the world. For the world to sustain the focus of the scientists, researchers should be on this major issue which threatens the very existence of mankind as a whole.

Study Area:

The area of study taken for the purpose of this study is Kolkata which is a prominent metropolitan city of India. With an area of 206.1 sq km, it consists of nearly 1.53 crores of people (2023). It is the third most populous city of India and the cultural capital of the country as well. There are several AQI stations in Kolkata for monitoring the air quality on a regular basis. However, the study encompasses three major stations- Fort William, Victoria, and Jadavpur. The study area for this project comprises three AQI stations located in three different locations. These stations are spread across different areas of the city and are subject to various sources of air pollution, including vehicular emissions, industrial pollution, and construction activities. The AQI levels in these areas can vary depending on a range of factors such as weather conditions, traffic volume, and industrial activities. Studying the AQI levels in these areas can help provide a better understanding of the air pollution situation in Kolkata and may inform policy decisions aimed at reducing pollution levels and improving public health.



Source: Internet

Literature Review:

S. Praveen and J Josephraj presented the condition and quality of the air by measuring Air Quality Index (AQI) for the development of environmental impact assessment for building

construction projects in Coimbatore city in their research work 'Air Quality Index (AQI) for Development of Environmental Impact Assessment (EIA) Reports of Urban Infrastructural Projects in Coimbatore City' published in Nature Environment and Pollution Technology: An International Quarterly Scientific Journal on March, 2018.He showed that the emissions from foundry clusters and automobiles are the major sources of pollution which determine the ambient air pollution condition of the zone. It is observed that the AQI is lower during the monsoon, followed by winter and higher in summer. The results also revealed that the pollution level is low for residential zones and moderate for commercial zone and is high for industrial zone. In addition to critically analysing the 2009–2017 air pollution data analysis, Nidhi Sharma *et al.*, (2018) suggested a critical observation of the 2016–1017 Delhi, India, air pollution trend that was released by Elsevier Ltd. They have forecasted future trends for a number of contaminants, including carbon monoxide (CO), suspended particulate matter (PM), nitrogen dioxide (NO2), sulphur dioxide (SO2), and benzene. Utilizing time series regression forecasting in data analytics, they have projected the future values of the pollutants previously indicated based on historical records. The Delhi monitoring stations in Anand Vihar and Shadipur are being examined, per the study's findings. The results clearly demonstrate the rising pollution in Delhi, with a sharp rise in PM10 concentration levels and noticeable increases in NO2 and PM 2.5. The Air Quality Monitoring Committee (AQMC) in Kolkata prepared a comprehensive Air Quality Action Plan in response to an order passed by the Hon'ble National Green Tribunal on 08.10.2018. The plan aims to address the issue of air pollution in Kolkata by proposing measures such as reducing emissions from vehicles, promoting public transportation, promoting clean energy sources, and reducing industrial emissions. The plan also includes measures to increase public awareness and encourage public participation in efforts to improve air quality. Overall, the plan is a comprehensive and proactive approach to improving air quality in Kolkata.

Objectives of the Study:

The objectives of the study are:

- To analyse the overall quality of air
- To analyse the quality of air at selected stations
- The comparative seasonal and spatial analysis
- Determining the major pollutants
- Measures to combat the detrimental air quality index

Materials and Methods:

The study relates to mixed method being both qualitative and quantitative. This consisted of collection of real time secondary data on air quality of the three stations of Kolkata- Jadavpur, Fort William, Victoria for the year 2023. Secondary data was collected from West Bengal Pollution Control Board, books, websites and journals relating to the area under study. The data

gathered, has been analysed with the help of representative maps and various cartographic techniques. The collected data is processed and analysed with the help of multiple methods such as tabulation and preparation of various types of charts as well.

Air Quality Trends in Kolkata:

The fundamental right of the citizens should be clean air which is mutilated in the metropolitan cities like Kolkata, mostly for anthropogenic reasons. The overall air quality has been deteriorating in Kolkata for the last few years with only an exception of 2020-2021 during the overall lockdown of the country [3]. But an increasing trend is again observed from 2022 onwards. The central government together with the state pollution control agencies implemented the National Air Monitoring Program (NAMP) covering 240 cities of the country with more than 342 monitoring stations. Accordingly, an AQI scheme has been prepared to quantify the effects of air pollution. AQI of 0-50 indicates good air quality, 51-100 indicates moderate air quality, 101-200 indicates poor air quality, 201-300 indicates unhealthy air quality, 301-400 indicates severe air quality and 401-500 indicates hazardous air quality. Kolkata is suffering from poor to severe air quality throughout 2022-2023 which causes respiratory diseases and problems in healthy masses also. The major pollutants are found to be PM2.5, PM10, Carbon Monoxide, Carbon di oxide, Ozone, Sulphur di oxide [4].

Table 1: The Average Monthly AQI of Kolkata, 2023

Months	Average AQI
January	229.86
February	129.63
March	115.67
April	112.42
May	71.21
June	59.77
July	37.28
August	69.80
September	42.53
October	111.16
November	230.55
December	223.37

Source: West Bengal Pollution Control Board

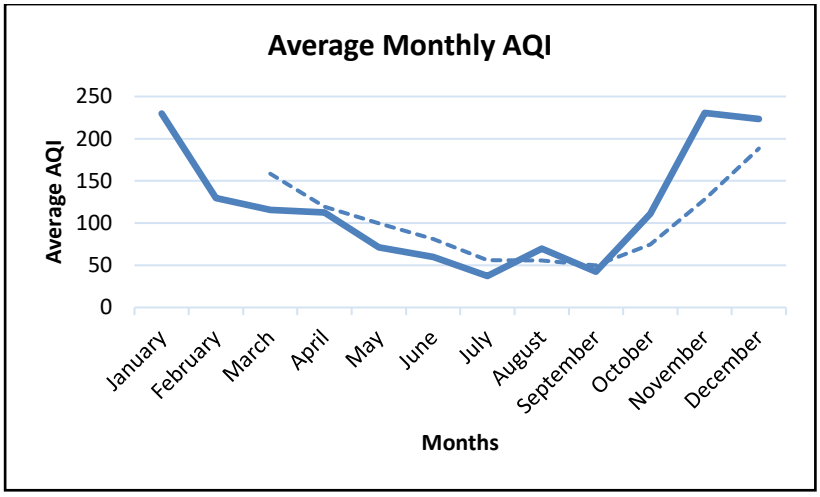


Figure 1: The Average Monthly AQI of Kolkata-2023

Source: West Bengal Pollution Control Board

The average monthly AQI of Kolkata for the year 2023 has been depicted by the line graph which shows an unhealthy air quality for the winter months of January, November and December, a poor air quality for the months of February, March, April, October, moderate air quality in June and August and a good air quality only for the months of July and September. The trend line also denotes the same indicating an increasing trend on two sides of the curve and a downward trend for the mid part only. The raw data also depicts that, three days in January scored more than 300 AQI level- 8th January being the highest (308), six days in November scored more than 300 AQI level- 11th and 13th November being the highest (346), two days in December has scored more than 300 AQI level- 15th December being the highest (318). Thus, severe air quality has been a major threat faced by the residents of this metropolis during the winter months.

Table 2: Pollutant Emissions of Jadavpur Monitoring Station,2023

Pollutants	**PM 2.5**	**PM 10**	**Ozone**	**NO_2**
Emissions	125.41	104.67	81.58	50.58

Source: West Bengal Pollution Control Board

PM stands for particulate matters which are otherwise known as particle pollution. They are an admixture of solid and liquid particles quite detrimental to human health. PM 2.5 and PM 10 are inhalable fine particles with diameters less than 2.5 and 10 micrometers respectively [5].They include dirt, soot, ashes etc. these particles are emitted from industries and automobiles and consisted of hundreds of various chemicals and are the result of complex reactions of Sulphur di oxide and Nitrogen di oxides. There has been a detrimental emission of PM2.5 and PM10 in Jadavpur monitoring station as the national standard of emission is specified to be 40 mg/m^3.

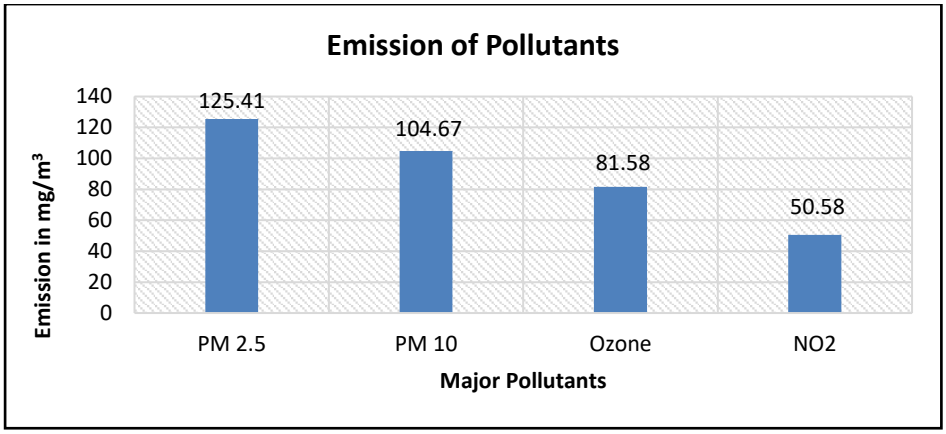


Figure 2: Pollutant Emissions of Jadavpur Monitoring Station, 2023

Source: West Bengal Pollution Control Board

Table 3: Pollutant Emissions of Fort William Monitoring Station, 2023

Pollutants	**PM 2.5**	**PM 10**	**Ozone**	**NO_2**
Emissions	106.67	87.67	64.5	57.25

Source: West Bengal Pollution Control Board

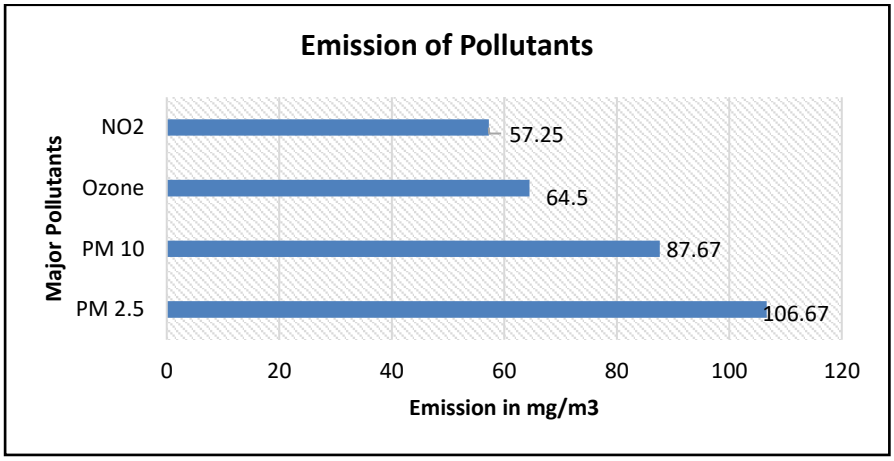


Figure 3: Pollutant Emissions of Fort William Monitoring Station, 2023

Source: West Bengal Pollution Control Board

The emission levels of Fort William Monitoring station are lower in range than that of the previous station yet the emission rates of PM 2.5 and PM10 is on the higher side.

Table 4: Pollutant Emissions of Victoria Monitoring Station, 2023

Pollutants	**PM 2.5**	**PM 10**	**Ozone**	**NO_2**
Emissions	114.67	109.08	93.00	59.42

Source: West Bengal Pollution Control Board

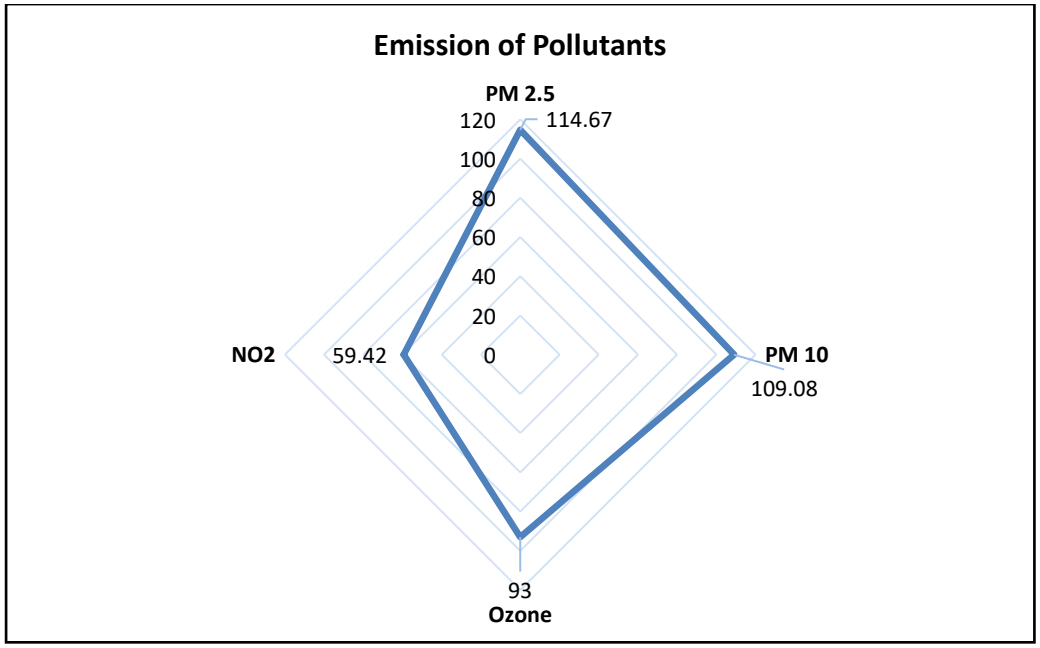


Figure 4: Pollutant Emissions of Victoria Monitoring Station, 2023

Source: West Bengal Pollution Control Board

The condition of air pollutant emission is moderate in Victoria station, though here also an excessive emission of particulate matters is noted. While the toxic soup over Kolkata consists of several pollutants like Sulphur di oxide, carbon monoxide, nitrogen di oxide, the most predominant ones are PM 2.5, PM10 and Ozone which are the most disastrous as well. The main pollutant has been PM 2.5 over all the three major stations of Kolkata.

Table 5: The Comparative Analysis of AQI of Kolkata- 2022 and 2023

Months	Average AQI, 2023	Average AQI, 2022
January	229.86	241.3
February	129.63	153.88
March	115.67	131.83
April	112.42	54.37
May	71.21	63.58
June	59.77	51.8
July	37.28	35.08
August	69.80	36.2
September	42.53	53.48
October	111.16	63.97
November	230.55	208.17
December	223.37	264.58

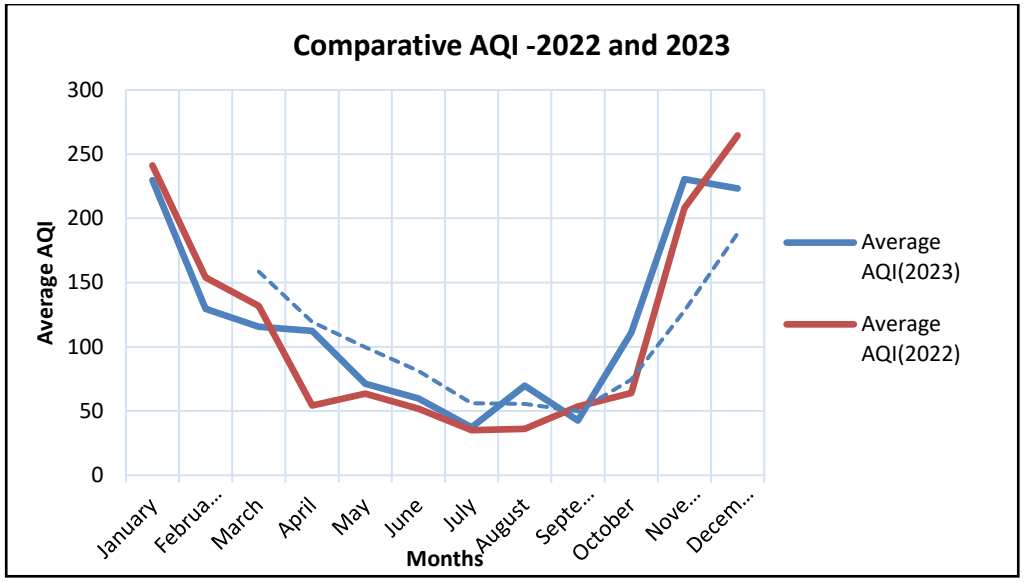


Figure 5: Comparative Analysis of AQI of Kolkata-2022 and 2023

Source: West Bengal Pollution Control Board

Table 6: Calculation of Z Score on AQI of Kolkata, 2023

Months	AQI, 2023	Z Score
January	229.86	1.539495
February	129.63	0.142102
March	115.67	-0.05253
April	112.42	-0.09784
May	71.21	-0.67238
June	59.77	-0.83188
July	37.28	-1.14543
August	69.80	-0.69204
September	42.53	-1.07223
October	111.16	-0.1154
November	230.55	1.549115
December	223.37	1.449012

Source: Calculated by the Author

The Z-score calculation provided here shows how each month's Air Quality Index (AQI) in 2023 compares to the mean AQI over the year, standardized against the variability in AQI across all months. January and November have significantly higher AQI values compared to the annual mean, indicating worse air quality. Their Z-scores are more than 1.5, which suggests that the AQI is more than one and a half standard deviations above the mean. Similarly, December also shows a higher AQI, with a Z-score close to 1.5, indicating poor air quality that's

significantly above the mean. February's AQI is slightly above the annual mean, but the Z-score is close to 0, indicating that its AQI is near the average AQI for the year. March, April and October have AQI values slightly below the annual mean. Their Z-scores are near zero but negative, indicating air quality slightly better than average. May and August months show better air quality with their AQI values being lower than the mean. The negative Z-scores suggest these values are less than one standard deviation below the mean. June, July, September, have significantly better air quality, with Z-scores indicating that the AQI is more than one standard deviation below the mean. July, in particular, has the lowest AQI, with a Z-score indicating it's significantly below the mean, suggesting much cleaner air compared to the rest of the year. In summary, Z-scores help in understanding how each month's air quality compares to the yearly average. Positive Z-scores indicate worse air quality than the yearly average, while negative Z-scores indicate better air quality. The farther a Z-score is from zero, the more significant the deviation from the average AQI [6]. This standardized measure allows for a clear comparison across different times of the year, highlighting months with potential air quality issues or improvements.

Discussion:

The overall AQI figures of Kolkata also denotes a very unhealthy situation from October to April which sometimes turn to severe as well. In summer, the air in the lower atmosphere is lighter and warmer and rises up more easily. It carries pollutants away from the ground and rainfall helps the pollutants to settle in the ground below [7,8]. Thus, the overall AQI decreases during summer and monsoon months. During winter, the planetary boundary air is cooler and denser. The cooler air is trapped inside the warmer layer which forms a kind of atmospheric lid. This phenomenon is called winter inversion [9]. Since the vertical mixing of the air occurs only in this layer, the emitted pollutants do not have enough space to spread into the atmosphere. In these three major stations of Kolkata, vehicular and industrial emissions coupled with biomass burning in the surrounding areas causes more pollution. The amount of particulate matter shoots up. Thus, the overall AQI sparks up during the post monsoon and winter months. The seasonal variation of air quality is more prominent than the spatial variation. Overall, the three stations have shown a tendency of increasing particulate matter emissions, though the quantities may vary. Most of the particulate matter concentration in the air is attributed to the roadside eateries and combustion of fuels by the households [10].

The natural and anthropogenic causes of air pollution are manifold. A cosmopolitan city like Kolkata which is still growing must wrap under its arm a huge influx of population including the migratory ones. The industrial effluents, increasing vehicular emissions, individual houses and massive cutting down of trees for expansion of roads have all contributed much to the problem. But the problems the citizens are facing is becoming a matter of concern especially for

the children and the elder ones [11]. Irritation of eyes, skin, bronchitis are the short-term effects. But long exposure to air pollution can lead to chronic respiratory and cardiovascular problems like lung cancer, heart problems and emphysema. Long exposure to severe AQI can lead to ill development of respiratory organs in children. Exposure to pollutants like particulate matter, nitrogen di oxide and volatile organic compounds can lead to increased respiratory infections. Acid rain, smog in winter are the other negative effects which muffles the daily intake of oxygen by the citizens. The combined effects of indoor and outdoor pollution is the cause of huge premature deaths and birth defects in new born all over the world [12]. In Kolkata, air pollution significantly impacts human health, with a long-term study revealing that 70% of residents suffer from respiratory diseases such as lung cancer, dyspnea, and asthma due to air pollution. Kolkata has been identified as having one of the highest numbers of lung cancer cases among Indian cities, contributing to its nickname as the "lung cancer capital of India."(Times of India, December, 2023). Despite low rates of car ownership compared to other large cities, air pollution remains high, suggesting the need for measures to reduce emissions and improve vehicle efficiency standards. Air pollution significantly impacts mortality rates by contributing to respiratory and cardiovascular diseases. Long-term exposure to polluted air can lead to chronic conditions such as asthma, lung cancer, and heart disease, which increase the risk of premature death. Fine particulate matter (PM2.5) and toxic pollutants in the air can penetrate deep into the lungs and bloodstream, causing inflammation and exacerbating existing health conditions [13]. Studies have shown that reducing air pollution levels can lead to a decrease in mortality rates by improving overall air quality and public health. According to ENT Specialist, Dr Dwaipayan Mukherjee, the National President of Otolaryngologists of India, patients suffering from bronchial and hearing issues had gone up manifold in recent times due to the rise in particulate matter and dust particles in the air and winters are really bad as the city is enveloped in smog (Times of India, February, 18, 2024).

To combat air pollution in Kolkata, several measures have been implemented, including promoting carpooling to reduce vehicle traffic, enforcing pollution checks on all vehicles, organizing cleaning drives, and controlling construction activities. These efforts aim to mitigate the harmful effects of air pollution on the city's residents and environment [14]. A fleet of twenty electric buses have already started plying in Kolkata to make it environmentally sustainable. The Pollution Control Board plays a crucial role in combating air pollution through regulatory and advisory functions. It enforces environmental laws and regulations, monitors air quality and pollution sources, and sets emission standards for industries and vehicles. Additionally, it promotes cleaner technologies and practices, conducts environmental impact assessments, and raises public awareness about air pollution and its health impacts **(15)**. Through these activities,

the board aims to reduce pollution levels, protect public health, and ensure sustainable development.

Conclusion:

The city is breathing the air that exceeds the WHO's guideline of permissibility of maximum limit of pollutants. The presence of particulate matters like PM 2.5 and PM 10 exceeds 22.5 times the WHO's guidelines. The results are being already faced by the citizens and will be far more detrimental in recent future. Our transition to cleaner fuels and industrial processes is the best way towards reducing air pollution [(16)]. The electronic vehicles can go a long way in helping the situation. Rational choices on fuels, living styles and renewable energy resources will help us conserve the resources and make a sustainable living. Air pollution and childbirth are global public health issues. Clean air acts as a catalyst to achieve the sustainable development goals set by the United Nations for 2030. Funding projects that promote clean air can have enormous benefits for human health, economic development, climate change and mitigation which in turn would contribute to sustain the natural ecosystem and the society.

References:

1. Jacobson, M. Z. (2012). Air Pollution and Global Warming: History, Science and Solutions. Cambridge University Press, pp. 21-53.
2. Lal, S. (2017). Air Pollution. Educreation Publishing, pp. 147-169.
3. Rao, H. V. N., & Rao, M. (2017). Air Pollution. Mc Graw Hill Education, pp. 39-45.
4. Smedley, T. (2019). Clearing the Air: The Beginning and End of Air Pollution. Bloomsbury Sigma, pp. 68-76.
5. Yerramilli, A. (2020). Air Pollution- Prevention and Control Technologies. BS Publications, pp. 32-66.
6. Roger, G. D. (2006). Principles of Air Quality Management. Routledge Press, pp. 124-136.
7. Vibhaw, N. (2020). Environment, Energy and Climate Change. Lexis Nexis Publications, pp. 54-98.
8. Doabia, T. S. (2023). Environmental and Pollution Laws in India. Lexis Nexis Publications, pp. 155-198.
9. Kumar, A. (2012). Air Pollution and Environment. DPS Publishing House, pp. 118-156.
10. Aghaei, M. (2021). Long Term Exposure to Air Pollution and Risk of Preterm Birth and Low Birth Weight in Tehran, Iran. Journal of Air Pollution and Health, eISSN No-2476-3071, 6(4), pp. 233-242.
11. Gupta, D., & Duan, X. (2023). Role of Meteorological Parameters in Covid 19 Pandemic Waves in Delhi, India. Open Journal of Air Pollution, 12(2).

12. Sethi, R. (2013). Air Pollution- Sources, Prevention, Health Effects. Nova Science Publisher, pp. 147-169.
13. Budakoti, S. (2023). Assessment of Causal Relationship between Air Quality of Delhi and Neighbouring Cities using Granger Causality Network. Journal of Air Pollution and Health, eISSN No-2476-3071, 8(4), pp. 453-470.
14. Ramesh, M. (2019). The Climate Solution- India's Climate Change Crisis and What We Can Do About It. Hachette India, pp. 258-280.
15. Manisalidis, I., Starvopoulou, E., & Starvopoulou, A. (2020). Environmental Health and Impacts of Air Pollution- A Review. Frontiers, 8.
16. Gurjar, B. R., Molina, L. T., & Ojha, C. S. P. (2010). Air Pollution, Health and Environmental Impacts. CRC Press, pp. 158-202.
17. https://app.cpcbccr.com/AQI_India_Iframe
18. https://www.epa.gov/pm-pollution/particulate-matter
19. https://india.mongabay.com/2019/12/can-kolkata-clean-its-air-by-2030
20. https://scied.ucar.edu/learning-zone/air-quality/effects-air-pollution
21. https://www.weforum.org/agenda/2019/11/kolkata-india-air-pollution-electric-buses
22. https://www.iqair.com/in-en/newsroom/cost-of-air-pollution

A COMPREHENSIVE REVIEW ON IMPORTANCE OF *BELLAMYA BENGALENSIS* IN THE CONTEXT OF ECOTOXICOLOGICAL STUDY

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Abstract:

Bellamya bengalensis (Lamarck, 1822) in one of the most important fresh water, edible, widely distributed snails found in India. This species is present throughout Asia and Africa, and of great medicinal as well as socioeconomic values. Moreover, it is a cheap source of protein which is even higher than some common fish and red meat groups. Besides human, it is also a beneficial food source of many aquatic fishes and birds; hence, *Bellamya bengalensis* is one the significant part of aquatic ecosystem. Studies revealed that it has been used in the treatment of different human diseases like chronic gastric disorder, arthritis, joint pain, rheumatism, cardiovascular disease, night blindness, asthma, rickets, diarrhea etc. Although it possesses high protein content, it is being neglected than other proteinaceous resources in terms of food choice. Various bacteria present in the gut and flesh of *Bellamya bengalensis* act positively in the growth and survival of the snails. As snails are mostly found in the polluted water bodies, toxic elements present in polluted water affects the host-bacteria equilibrium, and hence changes in the metabolism and physiology of snails may have been observed. Acute and chronic toxicity studies with different toxic elements like formic acid, copper sulphate, fluoride, mercury etc. from industrial effluent showed behavioral and respiratory alterations along with decreased oxygen consumption rate in *Bellamya bengalensis*. This review provides an overview of ecological importance and its application on *Bellamya bengalensis*. Further studies will be done on physiological alterations upon application of toxic elements.

Keywords: Freshwater Snails, Ecological Importance, Host-Bacteria Equilibrium.

Introduction:

Bellamya bengalensis is a freshwater edible snail which is abundant and widely distributed in temporary as well as permanent water bodies throughout India. It is mainly used as food and medicine within the ethnic races of the North-Eastern parts of India (Bar, 2020). Along with other snails, this snail plays an important role in maintaining the economy as well as the tradition of West Bengal by serving as food (Khalua *et al.*, 2014). It is a cheap source of protein which is even higher than some common fish and red meat groups. Village people and ethnic

people use this as a good source of protein because of its lower market value, availability, monetary point of interest, and ethno-medicinal value. Studies revealed that it has been used in the treatment of different human diseases like chronic gastric disorder, arthritis, joint pain, rheumatism, cardiovascular disease, night blindness, asthma, rickets, diarrhea, etc. It breeds throughout the year (Srivastava *et al.,* 2010) reaching its peak during April to July and lays the eggs on the lower surface of the aquatic plants. Recent studies have focused on the ethnomedical importance of *Bellamya bengalensis* in terms of its protein and amino acid composition (Chakraborty *et al.,* 2015). It has been reported that various bacteria are present in flesh, gut, and mucus of *Bellamya bengalensis*. Nowadays, many aquatic ecosystems are being polluted due to extensive increase in industrialization, uncontrolled use of pesticides which increases the discharge of chemicals from farms as well as factories and runoff into adjacent surface water (Gobi *et al.,* 2018). Toxicity studies with different toxic elements like formic acid, copper sulphate, fluoride, mercury etc. from industrial effluents showed physiological and behavioral changes in *Bellamya bengalensis* which are exemplified in different studies mentioned in journals. This review is based on socio-economic and ecological impact of *Bellamya bengalensis* and changes related to its behavior and physiology in context of toxicity of different toxicants.

Ecological Importance of *Bellamya bengalensis*

B. bengalensis is one of the important components of freshwater ecosystems. This feeds on microorganisms and plankton by using biofiltration mechanism (Bar, 2020). This snail plays as a good bioindicator for a large number of aquatic species. Their population density has a positive correlation with the temperature, TDS, electric conductivity, salinity, whereas negative correlation with pH, hardness, etc. Thermal stress impacts on physiological parameters and growth patterns of *B. bengalensis* (Baag *et al.,* 2020). Hence, it plays an important role for freshwater ecosystems. This specimen can be used for laboratory studies for the standardization of freshwater sediment toxicity test protocol.

1. Nutritional values of *Bellamya bengalensis*

It is a cheap source of protein which is even higher than some common fish and red meat groups (Table 1). It has high demand to less economic background people because of its lower market value. Not only protein it contains a considerable amount of carbohydrate and fat also (Khalua *et al.,* 2014). This snail contains a large number of amino acids (Table 2). These amino acids play a vital role in controlling human physiological stress (Baby *et al.,* 2010; Chakraborty *et al.,* 2015). There is a great seasonal variation in the nutrient content of the snail. The carbohydrate, protein, and fat contents are maximum during pre-monsoon (March-June) and minimum during post-monsoon season.

2. Medicinal values of *Bellamya bengalensis*

From the immemorial time beings, ethnic people are very conscious about the ethno-medicinal values of *B. bengalensis*. They strongly believe about the functions *B. bengalensis*, which can cure several diseases such as controlling conjunctivitis, night blindness, diarrhea, stomach upset, and chronic gastric disorders, arthritis, joint pain, rheumatism, cardiac diseases, controlling blood pressure, asthma, rickets, calcium metabolism, nervousness, giddiness etc. Depending on the intended use, various parts of the animal body, its derivatives, or the entire animal itself may be utilized. Particularly noteworthy is the reliance of individuals living below the poverty line in the northeastern regions of our country (Chhattisgarh, Jharkhand, Bihar, West Bengal, Sikkim, Tripura, Manipur, Mizoram, etc.) on *B. bengalensis* as their primary source of income and sustenance. Both in vivo and in vitro studies have lent support to traditional beliefs regarding the snail's immune-boosting, anti-carcinogenic, anti-inflammatory, and cardio-tonic properties. Anti-inflammatory, analgesic, and antipyretic activity: - It is used for the treatment of arthritis, joint pain. Rheumatism etc. Studies revealed that Swiss mice show significant anti-inflammatory, analgesic, and antipyretic activity of the lymph secretion of *B. bengalensis* (Ray *et al.,* 2017) in a dose-dependent manner. Peripheral and central analgesic activity are found within its body fluid. The analgesic activity is due to inhibitory actions on protease or prostaglandin biosynthetic activity (Adhikari *et al.,* 2017; Ray *et al.,* 2017). Hence, prostaglandin synthesis inhibitors or non-steroidal anti-inflammatory drugs (NSAIDs) are commonly used in the treatment of inflammations, arthritis, and pain but serious adverse events have alerted against repeated use of NSAIDs. Hence, it can be a better alternative to develop safer anti-inflammatory drugs.

Apoptotic and Anti-Cancer Property: The first line defense against cancer cell cycle regulation and apoptosis. The in-vitro studies revealed that the secretion extract of *Bellamya bengalensis* plays an important role in cell cycle regulation and apoptosis (Besra *et al.,* 2013; Besra *et al.,* 2015). Its anti-hepatocellular carcinoma activity on human hepatic cell line is reported (Besra *et al.,* 2015). Cell cycle analysis reported that treatment with the extraction of *Bellamya bengalensis* arrested the human hepatic carcinoma cell and leukemic cell populations in early phase of cell cycle (Besra *et al.,* 2013). This apoptotic property has a great significance to develop anti-cancer drug development. The extract of *Bellamya bengalensis* shows hepatoprotective activity in rat against carbon tetrachloride-induced hepatotoxicity.

Anti-Oxidative Property: In vitro study suggests a significant free radical scavenging activity of BBE (*Bellamya bengalensis* Extract) on arsenic exposed human liver cells, lung epithelial cells, and brain tissues (Ali *et al.,* 2017). According to Ali (Ali & Maiti, 2017), BBE demonstrated dose-dependent antioxidant effects in rat models of arsenic-induced intestine injury. Supplementation with BBE significantly mitigated arsenic-induced oxidative, necrotic, and apoptotic damage to liver tissue. This protective effect is crucial for averting the harmful

consequences of arsenic-induced oxidative stress, which poses a significant risk of cancer development in humans. Studies have provided compelling evidence of BBE's medicinal efficacy in counteracting oxidative stress induced by arsenic.

Anti-Microbial Property: A novel antimicrobial peptide of 1676 Da was purified from *Bellamya bengalensis*. The effect of this peptide on Staphylococcus epidermidis resistant to ampicillin and chloramphenicol reveals that it increases the staphylococcal membrane permeability in a dose-dependent manner (Gauri *et al.*, 2011). Hence, the peptide can be a promising candidate for anti-Staphylococcal drug development.

Table 1: Protein content analysis of *Bellamya bengalensis* by Kjeldahl procedure (AOAC, 1991) (Baby *et al.*, 2010; Chakraborty *et al.*, 2015)

Type	**Protein Content (% dry weight)**
Molluscs	
Bellamya bengalensis	48.65±0.85%
Pila globosa	8.27%
Melania tuberculata	12.36%
Lamellidens marginalis	6.46%
Anisus convexiusculus	12.92%
Helix sp.	8.64%
Fish	
Carp	42-43%
Pomfret	19%
Salmon	30%
Mackerel	30%
Meats	
Chicken	30%
Mutton	21%
Pork	22%
Beef	28%

Table 2: Isolation of Protein and Amino acid content in *B. bengalensis* and a parallel comparison (accordingto WHO, 2007) onthedaily requirement of protein and amino acid for child and adult human (Length - 3.84±0.26cm; Weight - 3.76±0.15gm)

Name of Amino Acid	Quantity (gm/100 gm of Protein)
Aspartic acid	6.59±0.72
Glutamic acid	7.93±0.61
Serine	7.62±0.45
Histidine	6.19±0.50
Glycine	1.85±0.36
Threonine	18.89±0.88
Arginine	5.61±0.59
Alanine	8.64±0.23
Tyrosine	1.90±0.60
Valine	3.66±0.12
Methionine	0.61±0.39
Cysteine	0.84±0.82
Isoleucine	2.70±0.33
Leucine	7.51±0.26
Phenylalanine	2.10±0.36
Lysine	16.13±0.51

Toxicity Studies in *B. bengalensis*

1. Toxicity of Copper Sulphate to *Bellamya bengalensis*

According to Kamble *et al.* (2014) four groups of studies *viz*., control group and exposure of toxicants after 24 hours, 48 hours,72 hours and 96 hours are monitored. The control group of snails is fully immersed in water. Initially, they retract their bodies into their shells, with closed opercula. Within 6 to 8 hours of the experiment, they exhibit protective behaviours, quickly protruding their bodies outside the shell, engaging in regular movements including radular movements for feeding, and displaying swift tentacular movements. The snails freely move their foot, securely attaching to the trough, secreting ample mucus. They congregate on the floor and walls of the trough, exhibiting normal courtship behaviour, with whitish or colourless embryos visible.

After 24 hours of exposure to copper sulphate, snails' body parts expand, releasing excreta into the trough. Tentacular movements change to a side-to-side motion, and foot stretching occurs. Mucus secretion increases under stressful conditions, with snails remaining

grouped or paired. As mucus secretion intensifies, they become static and gradually decrease their response to external stimuli.

No grouping or pairing of snails is observed during 48h period. Excessive excretory product secretion occurs, accompanied by slowed tentacular movements and reduced response to stimuli. The foot size decreases, with increased mucus secretion from the foot. Snails show minimal response to pin touch or vibrations, retracting their bodies under the shell to counteract toxic effects.

After 72 hours of exposure, snails lose their protective behaviour, closing their shell openings with opercula and remaining stationary. Tentacular movements cease, foot movements stop, yet extensive mucus secretion persists. They exhibit diminished response to mechanical stimuli.

After 96 hours of copper sulphate exposure, snails remain motionless under chemical stress, tightly closing their shell openings with opercula. Tentacular and foot movements cease entirely, while mucus secretion increases significantly. Thick, gelatinous white mucus is observed in the trough, and courtship behaviour ceases, with snails remaining solitary.

According to Kamble (2014) these behavioural changes were observed at a predetermined mean LC_{50} of 0.56 ppm of pod extract of *A. sinuata* at 24, 48, 72, and 96 hours of exposure.

2. Effect of *Acacia sinuate* on *Bellamya bengalensis*

Within 24 hours of exposure to *Acacia sinuata* pod extract, the movement of the snails gradually decreases. Tentacular movements occur irregularly within the trough, and snails begin secreting mucus from their feet to mitigate toxicity. Initially, quick responses to stimuli such as pin touches are observed. After 48 hours of intoxication, snails retract their body parts inside the shell, with excess excreta present in the trough. Tentacular movements become irregular, and while a few snails may be paired, courtship behavior is absent.

At both 72 and 96 hours of exposure, tentacular and foot movements diminish, and snails show no response to external stimuli. Mucus secretion increases significantly, resulting in the presence of thick, white, gelatinous mucus in the trough. Courtship behavior ceases, and snails remain solitary. They become immobile, losing their normal movement within the trough.According to Kamble (Kamble & Kamble, 2014), these behavioral changes were observed at a predetermined mean LC_{50} of 2.32 ppm of pod extract of *A. sinuata* at 24, 48, 72, and 96 hours of exposure.

3. Fluoride Toxicity on *Bellamya bengalensis*

Different studies are performed on the basis of predetermined LC50 values of fluoride at 24, 48, 72, and 96 hours of exposure. Behavioral changes in the test organisms exposed to various concentrations of the toxicant, like crawling movement, tentacle movement, clumping

tendency, touch reflex, and mucous secretion, can be studied by naked eye observation during the bioassay following the methods of (Rand & Petrocelli, 1985). By scoring in the range of –3 to +3, indicating normal, none, strongly decreased, mildly decreased, mildly increased, moderately increased, and strongly increased respectively (Dhara & Guhathakurta, 2021) can be studied. The snails in the control group are active throughout the test period and show their normal tentacle movements, crawling movements, response to touching, and remain attached over each other's shell surface as their normal clumping tendency. They show normal crawling movement initially but it gradually decreases with increasing concentration of fluoride and time of exposure than the control study. Similarly, tentacle movements of the snails inversely vary with increasing concentrations of the toxicant and exposure time and finally cease at higher doses (450 mg/L) at 96 h. The clumping tendency of the treated *B. bengalensis* is found to increase with increasing concentration of fluoride and exposure times but reduces at 96 h and they are gradually separated from each other and remain individual during this period. With the passage of time, touch reflex as well as reflex from any mechanical stimulus is also reduced in the treated snails and no response is recorded at higher doses at 72 and 96 h. The snails exposed to the toxicant are found to withdraw their body into the shell. Excessive mucous secretion is observed in the treated snails at higher concentrations of fluoride at 72 and 96 h of exposure. It gradually increases with time and concentration of toxicants. Oxygen consumption rate is more or less similar at 24 hours of exposure. After increasing the period of time, it decreases. At the end of 48 hours, oxygen consumption rate drastically decreases. Oxygen consumption rate is mostly low at the 96 hours of exposure. The oxygen consumption rate in the control group of test organism is almost similar throughout the experiment. But the rate in the snails is found to be increased gradually during 24 and 48 hours of exposure. For the chronic toxicity studies, the sublethal concentrations of a toxicant are determined on the basis of its 10% (Treatment 1) and 20% (Treatment 2) of 96 h LC50 value to *B. bengalensis* (i.e., Control-0.00 mg/L; T1–27.324 mg/L; T2–54.648 mg/L) (Dhara & Guhathakurta, 2021). These studies can be done for a longer duration than acute toxicity (30 days).

4. Toxicity of Mercury on *Bellamya bengalensis*

Analytical grade Mercuric Chloride, HgCl2 (purity 98%; procured from E. Merck (India) Ltd., Mumbai) may be utilized as a toxicant. Various vital parameters, including behavioral changes, alterations in hemocyte count, rate of oxygen consumption, and analysis of protein content in different organs, are studied at various times and concentrations of toxicant exposure. The exposure duration follows the same procedure as before, but the rate of exposure needs to be predetermined. Several studies have observed behavioral changes based on foot movement, tentacle movement, mucus secretion, courtship behavior, response to touch, distress syndrome, and withdrawal into the shell.

Discussion:

Literature surveys indicate that the behavioral patterns of molluscan animals change due to exposure to toxic compounds, including pesticides, metals, phenolic compounds, and oils in the surrounding medium. Control groups of snails show normal behavior with standard mucus secretion. However, intoxication by metals and molluscicides leads to an increased quantity of mucus. The exposure and duration of toxicants impact changes in clumping tendency, crawling movement, tentacle movement, touch response, and mucus secretion in fluoride-treated *Bellamya bengalensis*. These behavioral changes are likely a reflection of early stages of physiological stress due to the effects of toxicant exposures such as copper sulphate, *Acacia sinuata*, fluoride, and mercury. Mucus secretion occurs as a result of the underlying deployment of mucoprotein. It is one of the primary physiological reactions of gastropods aimed at preventing tissue damage, fluid loss, and the incidence of pathogen and parasite infections (Triebskorn *et al.,* 1996). Mucus secretion is found to be higher due to mercury intoxication compared to cadmium and zinc (Devi *et al.,* 1996). Mucus dilutes toxins and helps epithelial cells protect themselves from toxins (El-Gendy *et al.,* 2019). Severe toxicity may damage tissue even though mucus secretion is highly increased. Studies have revealed that behavioral changes due to the toxicity of copper sulphate and *A. sinuata* within 24hrs, 48hrs, 72hrs, and 96hrs are more or less similar. However, behavioral alterations due to copper sulphate intoxication are more acute and occur earlier than intoxication with *A. sinuata,* demonstrating that copper sulphate has more toxicity than the pod extract of *A. sinuata*in the freshwater snail *Bellamya bengalensis*. Locomotion is crucial for ecological behavior, particularly migration, food search, reproduction, and predator avoidance; therefore, altered locomotion capacity may affect organism fitness and lead to ecological disadvantages (Baatrup & Bayley, 1993). Snails sense their environment by withdrawing their tentacles when encountering an obstacle; reduced tentacle movement is observed with increased toxic concentration, leading to degenerative changes in snails. Oxygen consumption rate increases as the toxicity rate rises, possibly as a compensation mechanism for snails to overcome toxic shock. As more energy is needed, oxygen demand also increases. A significant reduction in haemocyte count has been observed due to exposure to mercury and fluoride. Haemocytes serve various functions such as blood haemostasis, wound healing (Ottaviani*et al.,* 2000), shell formation and repair mechanisms (Mount *et al.,* 2004), metal transportation, metabolism, and even the stress response through the release of vertebrate-like endocrine molecules (Ottaviani*et al.,* 2000). Toxic heavy metals are known to affect haematological parameters in aquatic organisms, especially in molluscs, interrupting normal bodily functions (Ray *et al.,* 2013; Leomanni *et al.,* 2016). They can decrease cell viability and cause cell death by accumulating in granular haemocytes. Since haemocytes of molluscs are involved in various physiological functions and innate immunity (Serpentini *et al.,* 2000; Ray *et al.,* 2013), the adverse effects of

mercury on haemocytes may increase the susceptibility of organisms and reduce their survival capability. A lower number of haemocytes in the haemolymph occurs due to the toxic effects of fluoride, mercury, etc., which can be considered potential biomarkers.

Conclusion:

Bellamya bengalensis has a significant and proven role in monitoring all the ecological and environmental factors of freshwater. Among all the freshwater edible mollusks, *Bellamya bengalensis* has the highest protein content (% dry weight) and it also has a significant medicinal value. Different studies provide support for its use as an anti-inflammatory, anti-cancer, anti-oxidative, and anti-microbial agent. In the present era of global warming and industrial pollution, it can play an important role as a bioindicator species of water quality and in water biofiltration. Therefore, it can be concluded that *Bellamya bengalensis* is a freshwater snail with easy availability, cheap market price, and immense potential for new drug development.

References:

1. Adhikari, A., Bhattacharya, S., Chanda, A., & Sur, T. K. (2017). Assessment on antinociceptive actions of soluble fractions derived from edible mollusc (*Bellamya bengalensis* Lam.). *International Journal of Basic & Clinical Pharmacology. 6*(12), 2916.
2. Ali, S. S., & Maiti, S. (2017). Therapeutic Potentials of Edible Freshwater-Snail *Bellamya bengalensis* Extract against Arsenic-induced Rat Tissue Damage are Conferred by Antioxidative Mechanism and Attenuation of Pro-Inflammatory Response. *Journal of Pharmacology and Experimental Therapeutics*, 362(3), 487-496.
3. Baag, S., Mahapatra, S., & Mandal, S. (2020). Unravelling the effects of elevated temperature on the physiological energetics of *Bellamya bengalensis*. *Journal of Thermal Biology. 88*, 102494.
4. Baatrup, E., & Bayley, M. (1993). Effects of the pyrethroid insecticide cypermethrin on the locomotor activity of the wolf spider *Pardosa amentata*: quantitative analysis employing computer-automated video tracking. *Ecotoxicology and environmental safety. 26*(2), 138-152.
5. Baby, R., Hasan, I., Kabir, K., & Naser, M. J. J. o. S. R. (2010). Nutrient analysis of some commercially important molluscs of Bangladesh. *Journal of Scientific* Research, 2(2), 390-396.
6. Bar, A. (2020). *Bellamya bengalensis*: A review on its Ecological importance, Nutritional values & Ethnomedicinal importance. *European Journal of Pharmaceutical and Medical Research. 7*(10), 315-319.
7. Besra, A. R., Pal, K., Basu, S., & Besra, S. E. (2015). Anti tumor activities of secretion extract of *Bellamya bengalensis* in human hepatocellular carcinoma cell lines is mediated by caspase-dependent apoptosis and cell cycle arrest. *World Journal of Pharmaceutical*

Research. 4(10), 2326-2344.

8. Besra, S. E., Ray, M., Dey, S., Roy, S., & Deb, N. (2013). Apoptogenic activity of secretion extract of *Bellamya bengalensis* f. annandalei via mitochondrial mediated caspase cascade on human leukemic cell lines. *International Journal of Pharmaceutical Science Review and Research. 20*, 146-152.
9. Boyd, W. A., Brewer, S. K., & Williams, P. L. (2002). Invertebrates living in polluted environments. *Behavioural ecotoxicology. 293*.
10. Chakraborty, D., Mukherjee, M., & Maity, J. (2015a). Estimation of proximate fatty acid composition in Ethno-medicinally important Viviparous gastropod, *Bellamya bengalensis* (Lamarck, 1822). *International Journal of Advanced Scientific and Technical Research, 5*(1), 84-92.
11. Chakraborty, D., Mukherjee, M., & Maity, J. (2015b). Ethno-medicinal importance of viviparous gastropod, *Bellamya bengalensis* (Lamarck, 1822) in terms of estimation of its proximate protein and amino acid composition. *measurement, 3*, 0.26.
12. Devi, M., Thomas, D. A., Barber, J. T., & Fingerman, M. (1996). Accumulation and physiological and biochemical effects of cadmium in a simple aquatic food chain. *Ecotoxicology and environmental safety. 33*(1), 38-43.
13. Dhara, K., & Guhathakurta, H. (2021). Toicity of neem (Azadirachta Indica a, juss) Leaf extracts on fresh water snail, *Bellamya bengalensis* (Lamarck, 1882). *BIOINFOLET-A Quarterly Journal of Life Sciences. 18*(1a), 35-39.
14. El-Gendy, K. S., Radwan, M. A., Gad, A. F., Khamis, A. E., & Eshra, E.-S. H. (2019). Physiological traits of land snails Theba pisana as simple endpoints to assess the exposure to some pollutants. *Environmental Science and Pollution Research. 26*, 6922-6930.
15. Gauri, S. S., Mandal, S. M., Pati, B. R., & Dey, S. (2011). Purification and structural characterization of a novel antibacterial peptide from *Bellamya bengalensis*: activity against ampicillin and chloramphenicol resistant *Staphylococcus epidermidis*. *Peptides. 32*(4), 691-696.
16. Gobi, N., Vaseeharan, B., Rekha, R., Vijayakumar, S., & Faggio, C. (2018). Bioaccumulation, cytotoxicity and oxidative stress of the acute exposure selenium in *Oreochromis mossambicus*. *Ecotoxicology and environmental safety. 162*, 147-159.
17. Kamble, S., & Kamble, N. (2014). Behavioural changes in freshwater snail *Bellamya bengalensis* due to acute toxicity of copper sulphate and *Acacia sinuata*. *Int J Sci Environ Technol, 3*, 1090-1104.
18. Khalua, R. K., Tripathy, S., Paul, B., & Bairy, D. (2014). Seasonal variation of carbohydrate, protein and lipid of common freshwater edible gastropod (*Bellamya bengalensis*) of Medinipur district, West Bengal. *Research Journal of Biology. 2*, 49-52.

19. Leomanni, A., Schettino, T., Calisi, A., & Lionetto, M. G. (2016). Mercury induced haemocyte alterations in the terrestrial snail *Cantareus apertus* as novel biomarker. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology. 183*, 20-27.
20. McIntyre, A. D., & Mills, C. F. (2012). *Ecological Toxicology Research: Effects of Heavy Metal and Organohalogen Compounds*: Springer Science & Business Media.
21. Ottaviani, E., Franchini, A., Malagoli, D., & Genedani, S. (2000). Immunomodulation by recombinant human interleukin-8 and its signal transduction pathways in invertebrate hemocytes. *Cellular and Molecular Life Sciences CMLS. 57*, 506-513.
22. Rand, G. M., & Petrocelli, S. R. (1985). *Fundamentals of aquatic toxicology: methods and applications*. Retrieved from
23. Ray, M., Bhunia, A. S., Bhunia, N. S., & Ray, S. (2013). Density shift, morphological damage, lysosomal fragility and apoptosis of hemocytes of Indian molluscs exposed to pyrethroid pesticides. *Fish & shellfish immunolog. 35*(2), 499-512.
24. Ray, M., Deb, N., Datta, R. and Besra, S.E., 2017. Analgesic, anti-pyretic and anti-inflammatory activity of the lymph extracted from *Bellamya bengalensis* f. Annandalei in rodent models. World Journal of Pharmaceutical Research. 6: 772-783.
25. Serpentini, A., Ghayor, C., Poncet, J., Hebert, V., Galéra, P., Pujol, J. P., Lebel, J. M. (2000). Collagen study and regulation of the de novo synthesis by IGF-I in hemocytes from the gastropod mollusc, *Haliotis tuberculata*. *Journal of Experimental Zoology. 287*(4), 275-284.
26. Srivastava, P., Kumar, P., Singh, V., & Singh, D. (2010). Effect of Piper nigrum and *Cinnamomum tamala* on biochemical changes in the nervous tissue of fresh water snail *Lymnaea acuminata*. *Bioscan*, 247-256.
27. Triebskorn, R., Henderson, I., Martin, A., & Köhler, H.-R. (1996). Slugs as target or non-target organisms for environmental contamination: a study on metal accumulation in slug tissues. Environmental Pollution, 91(3), 331-339.

DNA VACCINE: TRIALS AND POSSIBLE THERAPEUTIC APPROACHES

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Abstract:

Two decades ago, successful DNA vaccination was attempted by transfection of antigen to antigen-presenting cells (APC) and producing adaptive immune responses in different animals. Transferring the target gene into the target animal by plasmid is the main strategy of this process. After thousands of trials, it's demonstrated that though it's well effective to the small animals the output in larger animals is not so fruitful. So making it more useful to the larger animals as well as to the human population the techniques are getting more modified by following electroporation, using live virus vectors to make it more efficient, or molecular adjuvants to get better results. Scientists are summing up the DNA vaccination trials to get the fruitfulness against Cancer, HIV, HPV, and many other autoimmune disorders. In this review, the total journey of DNA vaccination is summarised with the current research information about the development and usefulness of DNA vaccines.

Keywords: DNA Vaccine, Antigen-Presenting Cell, Adaptive Immune Response, Electroporation, Autoimmune Disorder

Introduction:

Vaccination is a process of triggering and stimulating the host's immune response by introducing the infectious agent which doesn't cause any disease but makes sure that the immune system can neutralize the pathogen before causing disease. Different types of vaccines are used like live-attenuated, killed pathogens, virus-like particles, viral subunit, viral-vector, mRNA and DNA vaccines for infectious disease and cancer (Jain *et al.,* 2020, Baba *et al.*,1999). In the early era of vaccination, the killed virus-induced vaccines were used to be applied which didn't have any specific killer T cell responses. Thus, non lived vaccines generally do not confer long term protection. The killed virus-induced vaccines were useful only for some particular diseases. In contrast, the living but weakened organisms (live attenuated) can induce a better TH (cellular) and antibody (humoral) responses and imparts a prolonged immunity (Bernadette *et al.*, 2011). Nucleic acid-based vaccine platforms are more promising that the older protein-based vaccine platforms. They are thermostable, simple, stored easily, reproducible, versatile, purified easily, cost effective, and low risk in application (Gary and Weiner 2020, Leitner *et al.*, 1999, Tang *et al.,* 1992). DNA Vaccine is produced by using several DNA sequences (vehicles) such as plasmids, minicircle DNA or linear DNA (Stenler *et al.,* 2014) which induce both cellular and

humoral immune responses by producing appropriate DNA copies after reaching the target. Polynucleotide vaccine, genetic vaccine, nucleic acid vaccine are the type of DNA vaccine. Among those the nucleic acid vaccine has been chosen by WHO which later divided into DNA and RNA vaccine (Wolff *et al.,* 1990). In early 1990, it's reported that plasmid DNA can respond to both viral and nonviral antigen after delivering it to an animal's body which is able to produce both a humoral and cellular immune response (Baba *et al.,*1999, Bernadette *et al.,* 2011, Gary and Weiner 2020). Two decades ago, in the first trial of DNA vaccine the role of recombinant plasmid DNA was demonstrated by showing the expression of foreign proteins encoded by plasmid (Tang *et al.,* 1992). After the first trial, in 1992 in the second trial the immune response against the expressed foreign proteins has been reported by introducing a plasmid to a mice skin directly through a gene gun. Later on, in 1993, during clinical trials on lethal influenza immune response was noticed in mice (Ulmer *et al.,* 1993, Fynan *et al.,* 1993). Though the response of the DNA vaccine wasn't well established, it created a great excitement in the vaccine and immunology community that is induced for cancer treatment, allergies and several clinical trials of autoimmune disease, infectious diseases, have started. In the USA, 500 clinical trials were registered at a time based on viral infection (Wang *et al.,* 1998).

Different Era of DNA Vaccine:

In early 1990, the DNA vaccine trials were done by using mice. The trails became successful for the smaller animal and created an excitement for further trails. In the starting generation of the DNA vaccine both immune and humoral responses were relatively low and the CD8+ activation was neither very frequent. So, the application of this vaccine to the larger animals was quite challenging due to its low immune responses. In the case of the human body at least 5-20 mg of DNA should be injected into the body because the major target for DNA is crossing the nuclear membrane of the target cell and getting transcribed. But plasmids degradation is relatively common that become a barrier for successful transfection of DNA (Bender *et al.,* 1998, Fioretti *et al.,* 2014). To enhance the successful transfection of it, a few steps are taken in the second generation which includes increasing gene expression by optimising the encoded antigen transfecting through plasmids, designing better vectors, and introducing molecular adjuvants (Bender *et al.,* 1998).

Structure and Composition of DNA Vaccine:

DNA vaccines generally made of plasmid that get inserted into the host cell and express the encoded antigen through transcription and induce immune responses. The plasmid is made of two parts- plasmid backbone and transcriptional unit (Mariana Ingolotti, 2010). In plasmid designing, the backbone consisting of the origin of replication helps the bacteria to grow in a culture medium. The resistance gene present in the backbone helps in proper selection of plasmid DNA from the culture medium and removes the impurities (Maja Velhner, 2002). The

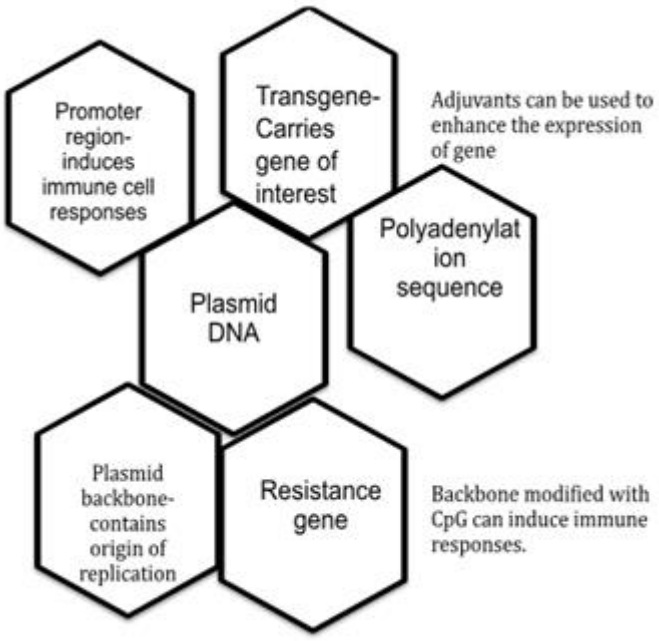
transcriptional unit represents a promoter region which shows APC specific activity and enhances the highest gene expression in the host cell, a transgene part which consists of encoded gene of interest and polyadenylation sequence. The plasmid DNA along with encoded genes of interest to be inserted into the host cell. The plasmid reaches the nuclei to the particular cell and the encoded gene gets transcribed to induce the antigen of interest. This antigen gets recognised as foreign compound and this enhances the immune response of the body. For enhancing the plasmid DNA uptake by target cell and gene expression adjuvant can be added (Sidgi Syed Anwer Abdo Hasson, 2015). In addition, a specific number of unmethylated CpG motifs can be added to it. This helps in greater immune response for the foreign antigen by producing Th1 cytokines and enhance the costimulatory molecule like CD80, CD86 (Hawkins *et al.,* 1994, MacGregor *et al.,* 2000, Mariana Ingolotti 2010, Perales *et al.,* 2008, Akira et al 2001; Shimada et al 1985; Tdokunaga *et al.,* 1984).

Preparation of Vaccine:

The modern vaccines are designed on the basis of successful transfection, proper antigen design to put the gene or antigen of interest, successful vector designing and cloning with bacterial DNA and delivery principle. Plasmid DNA is the way by which the target antigen is to be sent to the subject for the trial. The step includes:

1. Vector Designing: the promoter region of the plasmid carries the gene and also enhances the in vivo transcription and translation. Vector which is used as a vehicle generally target for the maximum protein expression by optimizing the codon usage of pathogenic DNA or alteration of gene sequence to express the antigen of interest. In case of nucleic acid vaccine, the antigen of interest releases continuously into the cell for maintaining a memory immunogenicity (Benjamin Yang, 2015).

2. Vaccine Preparation: In case of preparing the vaccine, the vectors and copied genes are taken and got cut into specific regions by restriction enzymes to make the vector open and the gene will be trimmed. After alteration these vectors are then treated by bacteria to get replicated. The newly replicated vectors form many copies along with genes sliced into loops. It becomes self-replicating while present within the bacterial host and makes many copies. The vectors and bacteria need



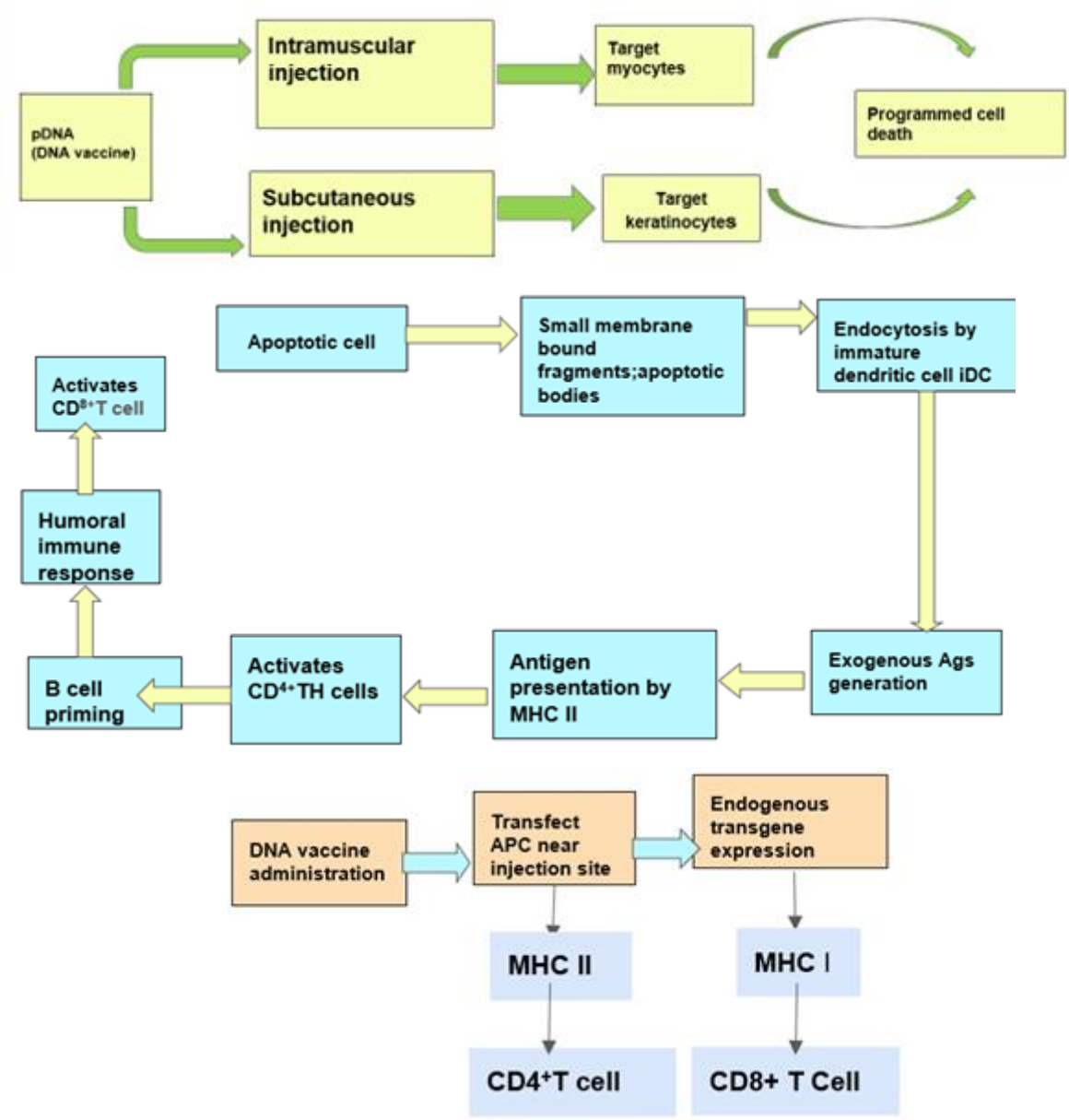
to be separated after enough copies are produced. Detergent can be used for this process which will rupture the cell wall and exceed the DNA is to be separated from the larger loop. The copies of altered vectors are to be injected by which only one percent will reach to the nuclei.

3. Activation of Immune Response: The pathogenic DNA that is carried in by the vector will reach to the nuclei and get transcribed to form mRNA which gradually move to the cytosol and translated into protein. The host body recognizes it as a foreign protein in presence of either major histocompatibility complex (MHC) class 1 or class 2 and stimulates the immune response (Williams, 2013).

Delivery Methods: Intramuscular delivery is the initially induced and most common technique for DNA vaccine (Gang Wang, 2011). But the result of this method is quite disappointing because it creates very low immune responses. This method includes gene gun delivery by using nanoparticles. Other than this needle free induction, electroporation is highly demanding for the process (Prazeres and Monteiro 2014, Rice *et al.,* 2008, Scheiblhofer *et al.,* 2018). Electroporation (EP) is the skilled method for transferring the sample as it increases the rate of plasmid DNA intake by the cell, enhances the formation of target protein and boosts up immunogenic cell activation including production of interferon (Wang *et al.,* 1993).

Mechanism of Action of DNA Vaccine:

After reaching to the target place the vaccine can introduce both cellular and humoral response to the host immune system through CD4+, CD8+ cells or B**.** The detector and the effector cells determine the type of immune response. After entering to the host cell, the antigen is presented to the CD4+ and CD8+ cell by antigen presenting cell (APC) through a major histocompatibility complex (MHC) class 1 or class 2 molecule. This a protein molecule presents on the cell surface which enable the T cell receptor to identify the target antigen.t The professional APC is required for presenting the antigen because only professional APC like dendritic cell and Langerhans (LNs) can induce signalling molecule such as CD80 and CD86 for initiating primary innate response (Banchereau and Steinman, 1998). In case of life vaccines, a peptide form of antigen is generated by the host cell to prevent the viral infection and attached with MHC molecules that get identified by CD8+ and induce CTL response. On the other hand, the nonlive vaccine is presented to the immune cell through MHC class 2 molecule endogenously and is recognised by CD4+ cell and shows humoral response. The existence of direct presentation of antigen by DC is also seen and elicits an immune response (Takashima and Morita, 1990). The plasmid DNA may bound with host cell DNA to enhance the immunization by producing type 1 interferons (Cevayir, 2013; Wang, 2011).



Clinical Trials of DNA Vaccine for Several Disease:

Clinical trials are performed to assess the efficiency and its therapeutic approaches in treating diseases in humans. The first clinical trials of DNA-based vaccines for cancer initiate immunisation against B cell receptors (Hawkins *et al.*,1994) expressed by a human B cell lymphoma. A specific idiotypic DNA vaccine preparation for each patient is laborious and costly thus DNA vaccines are developed against the widespread tumour antigens like HE2-2/ her for breast cancer (Rice *et al.*, 2008), E7 for cervical cancer (Disis *et al.*, 2004), gp100 for melanoma (Trimble *et al.*, 2009), mammaglobin-A (Mam-A) (Valilou, 2019). Preclinical trials of DNA vaccines in prostate cancer patients target prostatic acid phosphatase (PAP) and exhibit PAP-specific CD8+ T cell immune responses. The advantages of cellular responses through DNA

vaccine is getting utilized for some critical diseases. The fact of DNA vaccines that are safe for humans with a high tolerance and producing CTL responses encourages the trials.

HIV:

The first human HIV trial was done at the end of the 90's era (MacGregor *et al.,* 1998). From the first trial it was reported that people with 100 and 300 mg doses increase their antibody against gp120 and induce CTL response. Overall, the patient with the highest dose (300mg) shows antigen specific immune response by inducing antigen specific lymphocytes along with IFN and b-chemokine. In HIV-1gp 160 vaccine trials were done with an infected patient with less than 500 lymphocytes/ml but didn't have a significant response (Weber *et al.,*2001). After all the trials forming proper immune specific vaccine formation become quite difficult so recombinant vaccine composed of DNA based and viral based vaccine along with regulatory genes (Calarota *et al.,* 2001) was designed. This vaccine shows some antibodies response and T cell response and enhances HIV-1 specific CTL immune response. The first trial of recombinant vaccine was RV144, which shows the rapid upregulation of cellular response, antigen specific CD8+, T cell response along with humoral response (MacGregor *et al.,* 2000). The first level of HIV vaccine used to provide insufficient responses but RV144 with gp120 protein boost showed almost 31% efficiency to prevent the disease (Weber *et al.,* 2001, Calarota *et al.,* 2001, Lundholm *et al.,* 1999, Pitisuttithum *et al.,* 2006, Buchbinder *et al.,* 2008, Rerks-Ngarm *et al.,* 2009, Catanzaro *et al.,* 2006). For the new generation of the vaccine different molecular adjuvants are getting used in the vaccine to give better immune results and decrease the viral load into the vaccine.

sample	patients	Doses	Duration	Observation and Conclusion
HIV-1 env and rev gene	Fifteen HIV infected patient	Three dose trial. (30,100, 300 mg)	10 weeks intervals per dose trials	No significant changes in CD4 and CD8 lymphocytes. CTL responses is noticed to some patient with higher do

HPV:

Human Papilloma Virus is the main reason for worldwide spread of cervical cancer as well as causing anal dysplasia (WHO,2010). Initially, two preventive vaccines, Gardsil and Cervix, were made but couldn't be fruitful due to higher economic value and major distribution problems from the US. These vaccines also couldn't form proper cellular responses against HPV. For clinical trials of HPV16 and HPV17 vaccines the E6 and E7 protein is targeted as antigen because these proteins have a major role in disease formation and HPV associated cancer (Lin *et al.,* 2010). Currently the fusion vaccine associated with HPV 16 and HPV18 consist of multiple

antigens undergoing phase 1 clinical trial (Klencke, 2002). The other microencapsulated vaccine ZYC101 is also undergoing clinical phase 1 and phase 2 trials including HPV 16 and HPV 18 derived epitopes that can induce CTL responses (Rerks-Ngarm *et al.*, 2009, Catanzaro *et al.*, 2006).

Vaccine sample	**component**	**Doses**	**Duration**	**Result**
ZYC101	HPV 16 and HPV 17. Consisting of E6 and E7 oncoproteins	50- 400 mg of ZYC101by four injection	3 weeks of intervals per trial.	Vaccine is well tolerated but failed to enhance proper T cell response. The patient with 200 and 400 mg doses shows an increasing immune response.

Cancer:

The DNA vaccine shows CTL immune response, workers use this phenomenon and induce clinical trials for different cancer using tumour specific antigen (TSAs) and tumour associated antigen, TAA (Mincheff *et al.*, 2000, Conry *et al.*, 2002, Timmerman *et al.*, 2002, Rosenberg *et al.*, 2003). The results are as following:

Disease	**Component of vaccine**	**Doses**	**Duration**	**Result**
Prostate cancer	Prostate specific membrane antigen PSMA/CD86	100-800 mg	Weekly intervals	No immediate immune response. The patient with regular observation shows 50% immunization lately (Mincheff, 2000)
Metastatic colorectal carcinoma	Carcinoemal bryonic antigen (CEA)with HBsAg	0.1, 0.3,1.0mg-single dose -3 patient	nil	HBsAg induced immune response is noticed in case of repetitive dosage. CEA specific antibody is not seen in any patient (Conry *et al.*, 2002)
		0.3, 1.0 mg-repetitive dose-3 patient	3 weeks of intervals	
		2 mg – repetitive dose-2 patient	3 weeks intervals	

B cell lymphoma	IgG2a and k mouse immunoglobulin (MsIg)	200, 600 1800 mg to each patient	Monthly for 3 months	Shows either humoral or T cell induced immune response.
		1800 mg dose delivered by bio injector	nil	Same as previous and half cases shows both T Cell and humoral response. (Timmerman *et al.*, 2002)
Metastatic melanoma	gp 100 melanoma melanocyte	200, 400 and 800 mg	Pump intake for 96 hours every 14 days of four cycle	Treatment was well tolerated but Patient developed the cancer even after the vaccine dose, no sign of immunization. (Rosenberg *et al.*, 2003; Tagawa *et al.*, 2003)

The cancer cell loses MHC 1 molecule that works as a defence mechanism against CTL immune response.

Influenza:

Influenza is one of the most common diseases. The current vaccines show only 30% of efficiency because influenza shows various strains which show mismatched results with the antigen (Jones *et al.*, 2009). The vaccines' first trials were done into mice for H5N1 and H1N1 lethal stains (Minor, 2010). H5N1 DNA vaccines with H5 antigen were treated to the mouse through a PMED device. Among them 47% showed antibody responses and almost 75% mice showed T cell mediated immunity against targeted antigen (Laddy *et al.*, 2011, Smith *et al.*, 2010, Evans *et al.*, 2009). The first trial of the vaccine shows great success so the ultimate success of the vaccine is not so far away.

Safety Profiles:

Recent studies demonstrated that the rate of DNA integration into host chromosome *in vivo* is three times lower than the rate of spontaneous mutagenesis. Thus the activation of oncogenes or inactivation of tumour suppressor genes upon DNA integration is low. There is no reported study of induction of antibiotic resistance upon administration of DNA vaccines. (David B Weiner and Plotkin's, 2018) Highly safe for being non-live and non-replicating. There is no antibody generation against the DNA (autoimmunity) even after multiple immunization.

Challenges:

Higher amounts of DNA within the range of 5-20 mg need to be injected in an average sized human to increase the immunogenicity. Optimization of transfection can be achieved by hybrid viral/ eukaryotic promoter on antigen codons.

Advantages:

- Naked DNA vaccines can induce both humoral and cell-mediated immune responses.
- Naked DNA is much stable than conventional vaccine platforms.
- The production of purification of large quantities of a desired DNA sequence are much easier a cost effective than proteins, peptides or viral/ microbial vectors (Mak and Mary 2006).
- The DNA sequence for a particular antigen can be easily modified to optimise the immunogenicity, immunosuppressivity or intracellular localization (Mak and Mary 2006).
- DNA vaccines containing single antigen from multiple pathogens or multiple antigens from single pathogen are easy to manufacture (Mak and Mary 2006).
- DNA vaccines can generate endogenous antigens that induce CD8+ T cell responses (Mak and Mary 2006).
- Targeted protein is properly folded.
- Easy storage on a large scale.

Discussion:

DNA vaccine is the new hope for medical science and safer than live viral vaccines with almost negative side effects. It can be also designed by multiple genes of interest to target several problems through a single plasmid. workers have seen it only shows immune responses against the antigen of interest so risk of another unexpected reaction is lesser in this case. This vaccine induces different immune responsive cells and presents the antigen through both class 1 and class 2 MHC. The unmethylated CpG present in the plasmid backbone act as PAMP molecule and enhance the immune cell through the interaction with TLR9 (Akira et al 2001). Even DNA vaccines are economically supportive and the production of its copies is easier and can be stored for a long time and logistically easy to port. Equally this vaccine has multiple drawbacks which includes its effectiveness on larger animals. The main problem lies in the delivery approaches of the plasmid. The intramuscular injection was quite effective to the smaller animal only. Later on gene gun delivery, electroporation reflect a better result for the larger animal still a lot of improvement is needed to get 100% success in human treatment (Conry *et al.*, 2002). Current trials show that it provides a very low immunogenic effect and the cells can be highly antigen tolerant, atypical growth of parasitic protein can be seen.

Conclusion:

Conventional vaccines prevent the spread of numerous highly infectious diseases. For conventional vaccine manufacturing researchers had to handle live pathogens, that increases the risk of contamination. The time taken for vaccine designing and cost of making are high also. These challenges had led to the development of alternative vaccine like DNA-based vaccine. A DNA vaccine is composed of a bacterial plasmid containing the target antigen (expressed in the

host) along with the mammalian promoter. The promoter enables it to transfect mammalian cells. DNA vaccine is more stable, cost efficient & easier to handle. DNA vaccine induce an adaptive immune response. Since early 1992, scientists are finding promising techniques to make the DNA vaccine useful in every possible way. Thousands of trials have summed up to a conclusion that it can provide immunogenicity. The autoimmune disease, influenza, malaria, HIV, HPV shows a positive response during the trials. Cancer trials are showing more or less immunogenic activation. As it is highly effective to the smaller animal and some of the vaccines are used for veterinary treatment. Workers are focusing on the efficient DNA uptake, proper antigen designing, using molecular adjuvants, plasmid delivery by immunomodulatory molecules to boost up the immune system. FDA, WHO and many European countries have already set up guidelines and protocols to achieve 100% success in future. There is more research needed for the development of an ideal DNA vaccine that will not degrade extracellularly and will enter the nucleus of target cells successfully.

Acknowledgement:

The authors acknowledge their departments and Institute. This review received no external funding.

References:

1. Baba, T. W., Liska, V., Khimani, A. H., Ray, N. B., Dailey, P. J., Penninck, D., Bronson, R., Greene, M. F., McClure, H. M., Martin, L. N., & Ruprecht, R. M. (1999). Live attenuated, multiply deleted simian immunodeficiency virus causes AIDS in infant and adult macaques. *Nature Medicine, 5*, 194–203.
2. Bernadette Ferraro, Matthew P. Morrow, Natalie A. Hutnick, Thomas H. Shin, Colleen E. Lucke, & David B. Weiner. (2011). Clinical Applications of DNA Vaccines: Current Progress. *Clinical Infectious Diseases, 53*(3), 296–302. https://doi.org/10.1093/cid/cir334
3. Fynan, E. F., Webster, R. G., Fuller, D. H., Haynes, J. R., Santoro, J. C., & Robinson, H. L. (1993). DNA vaccines: protective immunizations by parenteral, mucosal, and gene-gun inoculations. *Proceedings of the National Academy of Sciences of the United States of America*, *90*, 1147.
4. Gary, E. N., & Weiner, D. B. (2020). DNA vaccines: prime time is now. *Current Opinion in Immunology*, *65*, 21–27.
5. Jain, S., Batra, H., Yadav, P., & Chand, S. (2020). COVID-19 vaccines currently under preclinical and clinical studies, and associated antiviral immune response. *Vaccines, 8*(4), 649.
6. Leitner, W. W., Ying, H., & Restifo, N. P. (1999). DNA and RNA-based vaccines: principles, progress and prospects. *Vaccine, 18*(9-10), 765-77. https://doi.org/10.1016/s0264-410x(99)00271-6

7. Stenler, S., Blomberg, P., & Smith, C. E. (2014). Safety and efficacy of DNA vaccines: plasmids vs. minicircles. *Human Vaccines & Immunotherapeutics, 10*(5), 1306–1308.
8. Tang, D. C., DeVit, M., & Johnston, S. A. (1992). Genetic immunization is a simple method for eliciting an immune response. *Nature, 356*, 152–154.
9. Ulmer, J. B., Donnelly, J. J., & Parker, S. E. (1993). Heterologous protection against influenza by injection of DNA encoding a viral protein. *Science, 259*, 1745–1749.
10. Wolff, J. A., Malone, R. W., Williams, P., Chong, W., Acsadi, G., Jani, A., & Felgner, P. L. (1990). Direct gene transfer into mouse muscle in vivo. *Science*, *247*, 1465–1468.
11. Akira, S., Takeda, K., & Kaisho, T. (2001). Toll-like receptors: Critical proteins linking innate and acquired immunity. Nature Immunology, 2, 675–680.
12. Banchereau, J., & Steinman, R. M. (1998). Dendritic cells and the control of immunity. Nature, 392, 245–252.
13. Bender, B. S., Ulmer, J. B., DeWitt, C. M., Cottey, R., Taylor, S. F., Ward, A. M., Friedman, A., Liu, M. A., & Donnelly, J. J. *et al.*, (1998). Immunogenicity and efficacy of DNA vaccines encoding influenza A proteins in aged mice. Vaccine, 16, 1748–1755.
14. Calarota, S. A., Kjerrstrom, A., Islam, K. B., & Wahren, B. (2001). Gene combination raises broad human immunodeficiency virus-specific cytotoxicity. Human Gene Therapy, 12, 1623–1637.
15. Cevayir Coban, S. K. (2008). Molecular and cellular mechanisms of DNA. Human Vaccines, 4, 453-457.
16. Disis, M. L., Schiffman, K., Guthrie, K., Salazar, L. G., Knutson, K. L., Goodell, V., dela Rosa, C., & Cheever, M. A. (2004). Effect of dose on immune response in patients vaccinated with an her-2/neu intracellular domain protein--based vaccine. Journal of Clinical Oncology, 22(10), 1916–1925.
17. Fioretti, D., Iurescia, S., & Rinaldi, M. (2014). Recent Patents on Anti-Cancer Drug Discovery. Recent Patents on Anti-Cancer Drug Discovery, 9(1), 66–82.
18. Hawkins, R. E., Zhu, D., Ovecka, M., Winter, G., Hamblin, T. J., Long, A., & Stevenson, F. K. (1994). Idiotypic vaccination against human B-cell lymphoma. Blood, 83(11), 3279–3288.
19. MacGregor, R. R., Boyer, J. D., Ciccarelli, R. B., Ginsberg, R. S., & Weiner, D. B. (2000). Safety and immune responses to a DNA-based human immunodeficiency virus (HIV) type I env/rev vaccine in HIV-infected recipients: Follow-up data. Journal of Infectious Diseases, 181, 406.
20. Mariana Ingolotti, O. K. (2010). DNA vaccines for targeting bacterial infections. Expert Review of Vaccines, 9(6), 747–763.

21. Perales, M. A., Yuan, J., Powel, S., Gallardo, H. F., Rasalan, T. S., Gonzalez, C., Manukian, G., Wang, J., Zhang, Y., Chapman, P. B., Krown, S. E., Livingston, P. O., Ejadi, S., Panageas, K. S., Engelhorn, M. E., Terzulli, S. L., Houghton, A. N., & Wolchok, J. D. (2008). Phase I/II study of GM-CSF DNA as an adjuvant for a multipeptide cancer vaccine in patients with advanced melanoma. Molecular Therapy, 16(12), 2022–2029.
22. Prazeres, D. M. F., & Monteiro, G. A. (2014). Plasmid Biopharmaceuticals. Microbiology Spectrum, 2(3).
23. Rice, J., Ottensmeier, C. H., & Stevenson, F. K. (2008). DNA vaccines: precision tools for activating effective immunity against cancer. Nature Reviews Cancer, 8(2), 108–120.
24. Scheiblhofer, S., Thalhamer, J., & Weiss, R. (2018). DNA and mRNA vaccination against allergies. Pediatric Allergy and Immunology.
25. Tang, D. C., DeVit, M., & Johnston, S. A. (1992). Genetic immunization is a simple method for eliciting an immune response. Nature, 356, 152–154.
26. Trimble, C. L., Peng, S., Kos, F., Gravitt, P., Viscidi, R., Sugar, E., Pardoll, D., & Wu, T. C. (2009). A phase I trial of a human papillomavirus DNA vaccine for HPV16+ cervical intraepithelial neoplasia 2/3. Clinical Cancer Research, 15(1), 361–367.
27. Valilou, S.F. and Keshavarz-Fathi M. (2019). Vaccines for Cancer Immunotherapy: Genetic Vaccine for Cancer., 129–143. https://doi.org/10.1016/B978-0-12-814039-0.00010-2.
28. Wang, B., Agadjanyan, M. G., & Srikantan, V. (1993). Molecular cloning, expression, and biological characterization of an HTLV-II envelope glycoprotein. HIV AIDS Research and Human Retroviruses, 9(9), 849–860.
29. Weber, R., Bossart, W., Cone, R., Luethy, R., & Moelling, K. (2001). Phase I clinical trial with HIV-1 gp160 plasmid vaccine in HIV-1-infected asymptomatic subjects. European Journal of Clinical Microbiology & Infectious Diseases, 20, 800–803.
30. Williams, J. A. (2013). Vector Design for Improved DNA Vaccine Efficacy, Safety and Production. Vaccines, 1(3), 225-249.
31. Buchbinder, S. P., Mehrotra, D. V., Duerr, A., *et al.*, (2008). Efficacy assessment of a cell-mediated immunity HIV-1 vaccine (the Step Study): A double-blind, randomized, placebo-controlled, test-of-concept trial. *The Lancet, 372*, 1881–1893.
32. Catanzaro, A. T., Koup, R. A., Roederer, M., *et al.*, (2006). Phase 1 safety and immunogenicity evaluation of a multi-clade HIV-1 candidate vaccine delivered by a replication-defective recombinant adenovirus vector. *Journal of Infectious Diseases, 194*, 1638–1649.
33. Conry, R. M., Curiel, D. T., Strong, T. V., Moore, S. E., Allen, K. O., Barlow, D. L., Shaw, D. R., *et al.*, (2002). Safety and immunogenicity of a DNA vaccine encoding

carcinoembryonic antigen and hepatitis B surface antigen in colorectal carcinoma patients. *Clinical Cancer Research, 8,* 2782–2787.

34. Klencke, B., Matijevic, M., Urban, R. G., Lathey, J. L., Hedley, M. L., Berry, M., Thatcher, J., Weinberg, V., Wilson, J., Darragh, T., Jay, N., Da Costa, M., & Palefsky, J. M. (2002). Encapsulated plasmid DNA treatment for human papillomavirus 16-associated anal dysplasia: A phase I study of ZYC101. *Clinical Cancer Research, 8,* 1028–1037.
35. Lin, K., Russinovich, E., Ma, B., Hung, C. F., & Wu, T. C. (2010). Therapeutic HPV DNA vaccines. *Immunologic Research, 47,* 86–112.
36. Mincheff, M., Tchakarov, S., Zoubak, S., Loukinov, D., Botev, C., Altankova, I., Georgiev, G., Petrov, S., & Meryman, H. T. *et al.,* (2000). Naked DNA and adenoviral immunizations for immunotherapy of prostate cancer: A phase I/II clinical trial. *European Urology, 38,* 208–217.
37. Pitisuttithum, P., Gilbert, P., Gurwith, M., *et al.,* (2006). Randomized, double-blind, placebo-controlled efficacy trial of a bivalent recombinant glycoprotein 120 HIV-1 vaccine among injection drug users in Bangkok, Thailand. *Journal of Infectious Diseases, 194,* 1661–1671.
38. Rerks-Ngarm, S., Pitisuttithum, P., Nitaya Phan, S., *et al.,* (2009). Vaccination with ALVAC and AIDSVAX to prevent HIV-1 infection in Thailand. *New England Journal of Medicine, 361,* 2209–2210.
39. Rosenberg, S. A., Yang, J. C., Sherry, R. M., Hwu, P., Topalian, S. L., Schwartzentruber, D. J., Restifo, N. P., Haworth, L. R., Seipp, C. A., Freezer, L. J., Morton, K. E., Mavroukakis, S. A., & White, D. E. (2003). Inability to immunize patients with metastatic melanoma using plasmid DNA encoding the gp100 melanoma-melanocyte antigen. *Human Gene Therapy, 14,* 709–714.
40. Timmerman, J. M., Singh, G., Hermanson, G., Hobart, P., Czerwinski, D. K., Taidi, B., Rajapaksa, R., Caspar, C. B., Van Beckhoven, A., & Levy, R. (2002). Immunogenicity of a plasmid DNA vaccine encoding chimeric idiotype in patients with B-cell lymphoma. *Cancer Research, 62,* 5845–5852.
41. World Health Organization. (2008). Cervical cancer incidence and mortality worldwide in 2008. GLOBOCAN. Retrieved from http://globocan.iarc.fr/factsheets/cancers/cervix.asp. Accessed 10 May 2010.
42. Evans, K., McElwaine-Johnn, H., & Sharpe, M. (2009). DNA vaccination protects against an influenza challenge in a double-blind randomized placebo-controlled phase 1b clinical trial. *Vaccine.*
43. Laddy DJ, Yan J, Kutzler M, Kobasa D, Kobinger GP, Khan AS, Greenhouse J, Sardesai NY, Draghia-Akli R, Weiner DB. Heterosubtypic protection against pathogenic human and

avian influenza viruses via in vivo electroporation of synthetic consensus DNA antigens. PLoS One. 2008 Jun 25;3(6):e2517. https://doi.org/10.1371/journal.pone.0002517.

44. Jones S, Evans K, McElwaine-Johnn H, Sharpe M, Oxford J, Lambkin-Williams R, Mant T, Nolan A, Zambon M, Ellis J, Beadle J, Loudon PT. (2009). DNA vaccination protects against an influenza challenge in a double-blind randomised placebo-controlled phase 1b clinical trial. Vaccine. 21;27(18):2506-12. https://doi.org/10.1016/j.vaccine.2009.02.061.
45. Minor, P. (2010). Vaccines against seasonal and pandemic influenza and the implications of changes in substrates for virus production. *Clinical Infectious Diseases, 50*, 560–565.
46. Smith, L. R., Wloch, M. K., & Ye, M. (2010). Phase 1 clinical trials of the safety and immunogenicity of adjuvanted plasmid DNA vaccines encoding influenza A virus H5 hemagglutinin. *Vaccine*, *28*, 2565–2572.
47. Weiner DB, Gary JN, (2018). Plotkin's. Development of Gene-Based Vectors for Immunization Vaccines, 7th Edn, https://doi.org/10.1016/B978-0-323-35761-6.00067-5.

URBAN BIODIVERSITY: LIFE AMIDST CONCRETE JUNGLE

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Abstract:

Urbanization led to alteration in the land use pattern, that result into development of a unique ecosystem. Such altered ecosystem often supports wide range of biodiversity that provides valuable ecosystem services. The effect of anthropogenic activities on the species richness and abundance is not always detrimental. Different groups of species show different level of response to the changed environmental situation. As, such they can be categorized into urban- exploiters, adapters and avoiders according to their ability to utilize the urban resources efficiently. Urbanization often led to the replacement of native species with non-native species due to introduction of several exotic floral and faunal species. Homogenisation of species assemblages in urban areas appears to be driven by invasions or introductions of generalist, urban-adapted species leading to local extinctions of specialist species. The biodiversity in the urban landscapes can be conserved by appropriate ecological planning along with their efficient implementation. Identifying the existing blue green spaces on a priority basis and zone-based approach involving the locals is the most efficient in managing the urban biodiversity. Ecological planning not only highlight the linkages between urbanization and biodiversity, but also helps integrate this understanding into urban planning, strategy, and investment. All the available resources should be taken into account while establishing a sustainable city. Cutting-edge science, inclusive, expansive visioning, comprehensive and strategic planning are to be considered because sustainable development works with and not against nature.

Keywords: Urbanization, Biodiversity, Richness, Abundance, Homogenisation, Sustainable Development.

Introduction:

Urbanisation leads to a near-permanent alteration of land use pattern, which eliminates the locally dominant natural ecosystem that poses a serious threat to global biodiversity. Habitat degradation and fragmentation increasingly challenges wildlife persistence and movement in human-dominated landscapes, due to urbanization and the erosion of blue (i.e., aquatic) - green (i.e., terrestrial) spaces to accommodate growing human population. As a result, key biological processes such as breeding, dispersal, migration and resource utilization are disrupted (Fletcher *et al.*, 2018), that led to ultimate reduction in gene flow between populations with profound implications for genetic diversity and adaptive processes.

The positive effects of the urban biodiversity on ecosystem services, including human well-being very often remain concealed under the negative impact of urbanisation on ecosystems, biodiversity hotspots or protected area. This stigmatisation of the urban landscape can distract from the high levels of biodiversity that may flourish inside cities.

Biodiversity conservation and human well-being are tightly interlinked. Ecosystem services linked to biodiversity, in turn, are crucial for ensuring long-term human well-being (Seppelt *et al.,* 2013).

Current Scenario of Urban Biodiversity

Across the planet, about three-quarters of the land surface has been transformed by human interventions, two-thirds of the oceans are under severe threat, and over 85 percent of wetlands have been destroyed. The average abundance of nonhuman species in their native home regions has declined by more than 20 percent, and approximately 1 million species face imminent extinction (IPBES 2019b).

Some Case Studies:

The effects of various anthropogenic activities on species diversity and distribution are virtually impossible to ignore in urban systems but still there are evidences of strong, positive population effect sizes between biodiversity and human population density (an indicator of urbanization). However the degree of impact varies across different taxonomic groups. In a number of studies human population density is found to be positively correlated with the number of threatened species, geographically restricted species (endemic to a localised region) and introduced species. While the correlation with threatened species infers that increasing urbanisation adversely affects species persistence, such spatial correlations are weak causal explanations. Lower species diversity with increasing urbanisation has been found for birds (Cam *et al.,* 2000; Sandstrom *et al.,* 2006), bats (De Cornulier & Clergeau 2001), terrestrial mammals (Tait *et al.,* 2005) and amphibians (Gagne´ & Fahrig 2007), but the occasional study does not fit this trend.

It is evident that species richness tends to increase for plants, birds and introduced species, this may be due to the fact that increase in the number of exotic species in human domesticated form adds to the indigenous species.

Comparisons of species richness between urban areas and those dominated by agriculture or native vegetation at the outskirts of the cities find the richness to be lower in urban areas, while total species abundance is higher with a handful of opportunist species contributing the majority of individuals.

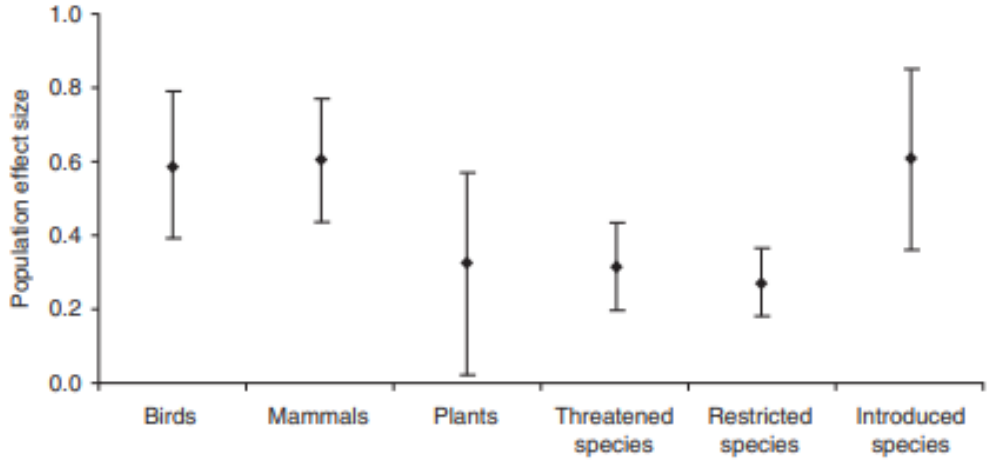

Figure 1: Population effect sizes (combining correlation coefficients across studies) between human population density and the species richness of birds, mammals and plants, and threatened, restricted and introduced species

Exotic species ↑	Sedentary species ↑?
Habitat generalists ↑	Short-distance migrants ↓?
Habitat specialists ↓	Widely distributed species ↑
Ground-nesters ↑	Narrowly distributed species ↓
Cavity-nesters ?	Omnivores ↑
Shrub-nesters ↓?	Insectivores ↓?
Tree-nesters ↓?	Granivores ↑?

Figure 2: General trends in the bird's diversity observed with increasing urbanization (↑: increase, ↓: decrease, ?: Questionable)

Some species thrive very well in urban habitats. For example, birds with bigger brains (Maklakov *et al.*, 2011) and broader environmental tolerances (Bonier *et al.*, 2007) are more likely to make cities their homes. In many cases, urban development leads to the replacement of native species with non-native species that are well adapted to urban environments globally technically referred to as 'alien invasion'. This shift leads to biotic homogenization, threatens to reduce the biological uniqueness of local ecosystems (Blair 2001). For plants, birds, and butterflies along urban gradients, the number of non-native species increases toward centres of urbanization while the number of native species decreases.

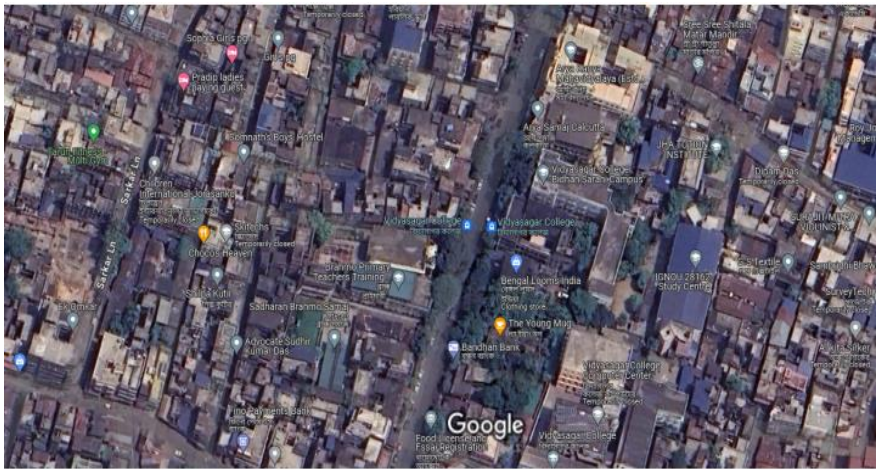

Figure 3: Aerial view of Urban landscape dominated by concrete structure

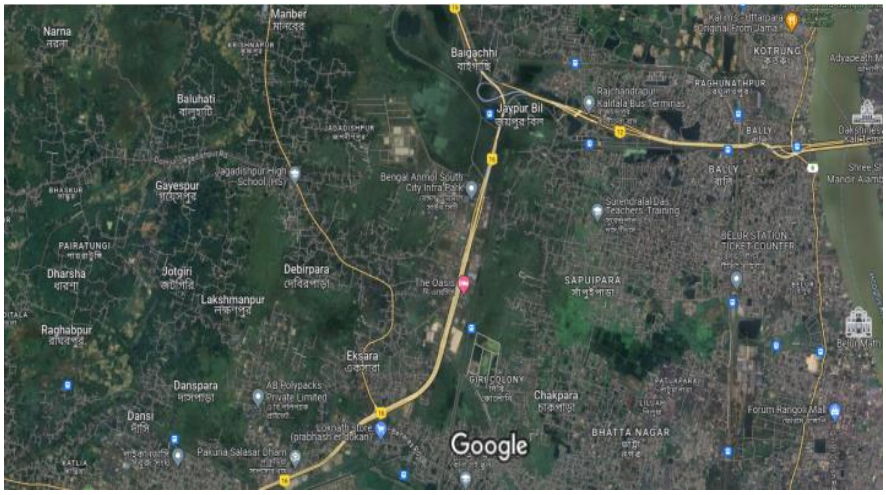

Figure 4: Aerial view of the outskirt of city areas, a transitional zone with interspersed green landscapes

Figure 5: Roosting bats in Urban environment. (Kolkata, West Bengal)

Figure 6: Urban adapted birds during breeding season (Kolkata, West Bengal)

Figure 7: Urban blue spaces support high diversity of species (Kolkata, West Bengal)

Figure 8: Urban landscape attracts large population of migrants (Howrah, West Bengal)

Biodiversity Shift:

Homogenisation of species assemblages in urban areas appears to be driven by invasions or introductions of generalist, urban-adapted species leading to local extinctions of specialist species. The process of homogenisation raises substantial challenges for protecting diverse species assemblages within human settlements. Species richness is found to be highest at intermediate levels of disturbance. For an urban settlement the outskirts comprising of the suburban belts are supposed to have highest diversity due to the phenomenon of 'edge effect'. Many studies have observed this relationship for a variety of taxonomic groups including birds (Chace & Walsh 2006), bats (Duchamp *et al.,* 2004) and lizards. This response may be the result of increased resources at moderate levels of urbanisation with diversified niche structures. More blue-green infrastructures in the form of gardens, parks, reserves, agriculture, aquatic bodies and other land uses characterising these areas and providing habitat for more groups of species (Young *et al.,* 2007).

Species display different tolerances to urban disturbance and have been grouped as 'exploiters', 'adapters' or 'avoiders' of urbanisation (Croci *et al.,* 2008). The exploiters are fittest members to successfully thrive and flourish the urban landscapes followed by the adapters. The avoiders are the worst affected, they diminish and gradually replaced within due course of time. Species classified as adapted to moderate levels of disturbance will tend to be dominant at the rural–urban interface where landscapes are the most heterogenous (Caula *et al.,* 2008). This is a distinct group of species able to use resources typical in this landscape, but the assemblage is very different from the species that occurred in the area prior to development (McKinney 2006). Another recurring pattern along rural–urban gradients is the greater abundance of species observed in bats and birds at the urban centre, with a few urban exploiters contributing the majority of individuals. Other taxonomic groups show a different pattern even when a few species are dominant. For example, abundance has been observed to decrease at the urban centre for amphibians (Pillsbury & Miller 2008), lizards (Germaine & Wakeling 2001), butterflies (Blair 1999) and ground beetles (Gaublomme *et al.,* 2008).

The difference in responses of certain taxa may be related to their ability to disperse through the landscape, their habitat preferences and the location of habitat along the rural–urban gradient. White *et al.,* (2005) found that parks and streetscapes with native vegetation supported more bird species than recently developed streetscapes or those with exotic vegetation.

Urban landscapes not only can this promote species conservation, but vegetation offers human residents a range of additional benefits including microclimate regulation (Harlan *et al.,* 2006), control of air and water pollution, carbon storage, recreational opportunities (Miller 2006) cultural and health benefits (Fuller *et al.,* 2007). An increasing number of studies demonstrate a relationship between the socioeconomic profile of neighbourhood residents or householder

behaviour and vegetation cover and plant species diversity (Grove *et al.,* 2006). These studies often show that income or some other measure of social 'status' (e.g. education) is positively correlated with species richness or vegetation cover.

The amount and spatial distribution of area dedicated to urban green and blue spaces forms the backbone of any city's plan for conserving urban biodiversity and ecosystem services. There are two metrics that can best measure the baseline of urban nature. First, cities can evaluate the percentage of their landscape that is currently dedicated to green and/or blue space. Second, planners can assess what proportion of this space is permanently protected through legislation or zoning. To maintain healthy levels of biodiversity within a city, it is not enough simply to have areas of dedicated green and blue space; species must be able to move between these areas in order to maintain healthy populations—that is, there must be connectivity. A general framework for decision-making is essential to guide urban ecological planning.

Conceptual framework to guide urban ecological planning:

1. Foundation of set up:

- The initial step includes preparing an expert team, a strategic, inclusive vision, and a work plan with clear objectives of the ecological planning process at hand.
- A clearly articulated goal for proposed nature-based solutions with metrics and indicators with which to assess success should be framed.
- Participation and realistic expectations of local residents and stakeholders should be taken into consideration. Compilations or assessments of relevant data and other resources to taken into account.

2. Analyse and compare:

- This step includes the mapping of current biodiversity, ecosystem types, ecosystem services and to articulate possible alternatives and evaluate likely outcomes against stated goals
- The data about original species diversity, ecosystem types and services should be gathered from the existing literature (if available).
- Alternative future maps of the area of interest should be constructed.
- Maps and summary tables reflecting agreed-upon metrics of urban nature, urban biodiversity, and urban ecosystem services is to be compared across alternatives.

3. Synthesize and inform: Summarize results, inform decisions, and iterate

- Construction of interactive maps of urban nature and biodiversity including the key biodiversity areas, simple diagrams showing projected changes in urban nature.
- local workshops to communicate the city's vision for the future to be conducted involving the locals. An interpretation guidebook for nature education to be prepared.

- An updated version of the desired future and a process for how to derive plans to reach that future

The rise of popular citizen science platforms such as iNaturalist or the Global Biodiversity Information Facility (GBIF) can fill a key void of the biodiversity data. The most popular citizen science platform for reporting species occurrences record the latitude, longitude, time of sample, and identity of all species in their database (GBIF 2017). From this, city managers can conduct annual surveys of how many vertebrate and invertebrate species are found within their city each year. This data can serve as the baseline of the local biodiversity profile.

Implementation.

1. Improve existing blue and green spaces for local biodiversity (Beninde, Veith, and Hochkirch 2015). The available green spaces and the aquatic bodies should be identified and steps is be taken for improvement of the environmental health of the said habitats.
2. Identify habitats that used to exist in the city and restore them (Blaustein 2013). There are several patches of native habitats that may be existing till dates and are vulnerable to extinction. Every possible effort should be done to restore such patches of natural ecosystem, because they are the representative of the original biodiversity of the region.
3. Enrich and/or reintroduce native plant and animal species (Burghardt, Tallamy, and Shriver 2009). Introduction of the native plants and animals are to be encouraged especially in the private domain. This will ensure enriching and restoration of the local and original biodiversity.
4. Plant native plants in parks, roadsides, and gardens. Planting more native plants in public areas such as parks, roadsides, gardens etc. for beautification purposes instead of alien exotic plants. It helps in niche diversification and resource partitioning thereby restoring local biodiversity.
5. Participation of the locals. (Soga *et al.,* 2017). Awareness amongst the locals regarding the importance and benefits of the biodiversity is to be developed. The peoples should be encouraged for urban gardening in the form of rooftop or vertical gardening for food security, food for pollinators and mental health and other benefits. Vertical gardening in multi-storeyed buildings under both the private or public domain should be encouraged.
6. The fragmented ecosystems should be connected by expanding green spaces near one another, particularly by adding corridors of vegetation or other forms of connectivity (Beninde, Veith, and Hochkirch 2015). This will ensure free movements of the animal species which will help in maintaining a steady state population with good numbers.
7. Expand tree canopy using native species (Shackleton *et al.,* 2015). Tree canopies supports a wide range of biodiversity. However, the native species should be of preferred instead of exotic species as such communities supports and sustain more biodiversity.

8. Build tunnels or overpasses to enable movement of animals throughout the city, particularly across roads or other linear features (Riley *et al.*, 2014; Teixeira *et al.*, 2013). Tunnels and overpasses ensure free movement of the animals amongst the metapopulation that can ensure exchange of genetic materials thereby preventing the genetic drift.
9. Add parks and other green spaces to the city (Beninde, Veith, and Hochkirch 2015). New areas are to be identified for the establishment of green spaces, parks etc. to increase the green patches for sustenance of the local biodiversity.
10. Use nature-based solutions, when possible, for stormwater and flood management (Ishimatsu *et al.,* 2017). This process will help in ground water recharge and will reduce the depletion of the ground water resource.
11. Use transdisciplinary collaborations between urban planners, engineers, and ecologists to design stormwater and flood management plans (World Bank 2019).

Identification of the key drivers of spatial congruence and the development of intra- and inter-regional management strategies that ensure species persistence through appropriate settlement planning should be the focus of future research. More field-based works are needed to assess the ecological, social and environmental (e.g. energy use) relationship between concentrated, high-density living in increasingly large cities versus more dispersed, smaller regional centres

Better planning of urban growth, identification of priority areas, zone-based management of protected areas near cities, integration of habitat for biodiversity within cities, and use of nature-based solutions to urban problems can all help reverse the negative impacts of cities on biodiversity (The Nature Conservancy 2018). Aligning ecological findings with administrative boundaries, or existing policy is very much needed to increase the utility of prioritization exercises.

Ecological planning not only highlight the linkages between urbanization and biodiversity, but also helps integrate this understanding into urban planning, strategy, and investment. Now a days, we have the knowledge, data, tools, and approaches to direct investment in nature to solve many different types of urban problems. Using these approaches at present will help cities of the future become more sustainable, liveable, resilient, and equitable.

Leadership to address the escalating risks and costs of destabilizing Earth's life-support systems and climate must come from cities. All the available resources should be taken into account while establishing a sustainable city. Cutting-edge science, inclusive, expansive visioning, comprehensive and strategic planning are to be considered because sustainable development works with and not against nature.

References:

1. Beninde, J., Veith, M., & Hochkirch, A. (2015). Biodiversity in cities needs space: A meta-analysis of factors determining intra-urban biodiversity variation. Ecology Letters, 18(6), 581–592. https://doi.org/10.1111/ele.12427
2. Blair, R. B. (1999). Birds and butterflies along an urban gradient: Surrogate taxa for assessing biodiversity? Ecological Applications, 9, 164–170.
3. Blair, R. B. (2001). Birds and butterflies along urban gradients in two ecoregions of the U.S. In J. L. Lockwood & M. L. McKinney (Eds.), Biotic homogenization (pp. 33–56). Norwell, MA: Kluwer.
4. Blaustein, R. (2013). Urban biodiversity gains new converts: Cities around the world are conserving species and restoring habitat. BioScience, 63(2), 72–77. https://doi.org/10.1525/bio.2013.63.2.3
5. Bonier, F., Martin, P. R., & Wingfield, J. C. (2007). Urban birds have broader environmental tolerance. Biology Letters, 3(6), 670–673.
6. Burghardt, K. T., Tallamy, D. W., & Shriver, W. G. (2009). Impact of native plants on bird and butterfly biodiversity in suburban landscapes. Conservation Biology, 23(1), 219–224. https://doi.org/10.1111/j.1523-1739.2008.01076.x
7. Cam, E., Nichols, J. D., Sauer, J. R., Hines, J. E., & Flather, C. H. (2000). Relative species richness and community completeness: Birds and urbanization in the Mid-Atlantic states. Ecological Applications, 10, 1196–1210.
8. Caula, S., Marty, P., & Martin, J. (2008). Seasonal variation in species composition of an urban bird community in Mediterranean France. Landscape and Urban Planning, 87, 1–9.
9. Chace, J. F., & Walsh, J. J. (2006). Urban effects on native avifauna: A review. Landscape and Urban Planning, 74, 46–69.
10. Croci, S., Butet, A., & Clergeau, P. (2008). Does urbanization filter birds on the basis of their biological traits? The Condor, 110, 223–240.
11. De Cornulier, T., & Clergeau, P. (2001). Bat diversity in French urban areas. Mammalia, 65, 540–543.
12. Duchamp, J. E., Sparks, D. W., & Whitaker, J. O. (2004). Foraging-habitat selection by bats at an urban–rural interface: Comparison between a successful and a less successful species. Canadian Journal of Zoology-Revue Canadienne De Zoologie, 82, 1157–1164.
13. Fletcher, R. J., Didham, R. K., Banks-Leite, C., Barlow, J., Ewers, R. M., Rosindell, J., ... Haddad, N. M. (2018). Is habitat fragmentation good for biodiversity? Biological Conservation, 226, 9–15.

14. Fuller, R. A., Warren, P. H., Armsworth, P. R., Barbosa, O., & Gaston, K. J. (2008). Garden bird feeding predicts the structure of urban avian assemblages. Diversity and Distributions, 14, 131–137.
15. Gagne, S. A., & Fahrig, L. (2007). Effect of landscape context on anuran communities in breeding ponds in the National Capital Region, Canada. Landscape Ecology, 22, 205–215.
16. Gaublomme, E., Hendrickx, F., Dhuyvetter, H., & Desender, K. (2008). The effects of forest patch size and matrix type on changes in carabid beetle assemblages in an urbanized landscape. Biological Conservation, 141, 2585–2596.
17. GBIF (Global Biodiversity Information Facility). (2016). Final report of the Task Group on GBIF data fitness for use in distribution modelling. http://dx.doi.org/10.13140/RG.2.2.27191.93608
18. Germaine, S. S., & Wakeling, B. F. (2001). Lizard species distributions and habitat occupation along an urban gradient in Tucson, Arizona, USA. Biological Conservation, 97, 229–237.
19. Grove, J. M., Troy, A. R., O'Neil-Dunne, J. P. M., et al. (2006). Characterization of households and its implications for the vegetation of urban ecosystems. Ecosystems, 9, 578–597.
20. Harlan, S. L., Brazel, A. J., Prashad, L., Stefanov, W. L., & Larsen, L. (2006). Neighbourhood microclimates and vulnerability to heat stress. Social Science and Medicine, 63, 2847–2863.
21. IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services). (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. In S. Diaz, J. Settele, E. S. Brondízio, H. T. Ngo, M. Guèze, J. Agard, A. Arneth, et al. (Eds.), IPBES secretariat.
22. McKinney, M. L. (2001). Effects of human population, area, and time on non–native plant and fish diversity in the United States. Biological Conservation, 100, 243–252.
23. Miller, J. R. (2006). Restoration, reconciliation, and reconnecting with nature. Biological Conservation, 127, 356–361.
24. Pillsbury, F. C., & Miller, J. R. (2008). Habitat and landscape characteristics underlying anuran community structure along an urban–rural gradient. Ecological Applications, 18, 1107–1118.
25. Riley, S. P., Brown, J. L., Sikich, J. A., Schoonmaker, C. M., & Boydston, E. E. (2014). Wildlife friendly roads: The impacts of roads on wildlife in urban areas and potential remedies. In Urban Wildlife Conservation (pp. 323–360). Springer.

26. Sandstrom, U. G., Angelstam, P., & Mikusin´ski, G. (2006). Ecological diversity of birds in relation to the structure of urban green space. Landscape and Urban Planning, 77, 39–53.
27. Seppelt, R., Lautenbach, S., & Volk, M. (2013). Identifying trade-offs between ecosystem services, land use, and biodiversity: A plea for combining scenario analysis and optimization on different spatial scales. Current Opinion in Environmental Sustainability, 5, 458–463.
28. Shackleton, S., Chinyimba, A., Hebinck, P., Shackleton, C., & Kaoma, H. (2015). Multiple benefits and values of trees in urban landscapes in two towns in northern South Africa. Landscape and Urban Planning, 136, 76–86.
29. Soga, M., & Gaston, K. J. (2016). Extinction of experience: The loss of human–nature interactions. Frontiers in Ecology and the Environment, 14(2), 94–101.
30. Tait, C. J., Daniels, C. B., & Hill, R. S. (2005). Changes in species assemblages within the Adelaide metropolitan area, Australia, 1836–2002. Ecological Applications, 15, 346–359.
31. Teixeira, F. Z., Printes, R. C., Fagundes, J. C. G., Alonso, A. C., & Kindel, A. (2013). Canopy bridges as road overpasses for wildlife in urban fragmented landscapes. Biota Neotropica, 13(1), 117–123.
32. The Nature Conservancy. (2018). Nature in the Urban Century. Arlington, VA: The Nature Conservancy. https://www.nature.org/content/dam/tnc/nature/en/documents/TNC_NatureintheUrbanCentury_FullReport.pdf
33. White, J. G., Antos, M. J., Fitzsimons, J. A., & Palmer, G. C. (2005). Non-uniform bird assemblages in urban environments: The influence of streetscape vegetation. Landscape and Urban Planning, 71, 123–135.
34. World Bank. (2019). Chongqing 2035: Spatial and economic transformation for a global city. Overview. Washington, DC: World Bank.
35. Young, K. M., Daniels, C. B., & Johnston, G. (2007). Species of street tree is important for southern hemisphere bird trophic guilds. Austral Ecology, 32, 541–550.

EXAMINING THE POLITICAL BUDGET CYCLE: A CASE STUDY OF MEDICAL AND PUBLIC HEALTH EXPENDITURE IN VIDHAN SABHA ELECTIONS IN INDIA

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Abstract:

This study investigates the dynamic relationship between state government elections and Revenue expenditure on Medical and Public Health. The regression results reveal a significant positive coefficient for the Election Year variable, indicating an increased allocation of resources to the specified sectors during election years. This aligns with the strategic approach of governments to enhance public welfare perception among voters. However, the subsequent years exhibit a consistent decrease in expenditure, suggesting a post-election fiscal restraint strategy. The statistical significance of the coefficients reinforces the reliability of these observed patterns. The implications of the political budget cycle underscore the need for policymakers to understand and adapt to these dynamics for effective resource management. This study contributes to the discourse on the impact of electoral cycles on public spending, emphasizing the importance of context-aware policy formulation.

Keywords: Political Budget Cycle, State Government Expenditure, Vidhan Sabha Elections, Revenue Expenditure, Medical and Public Health

Introduction:

A political budget cycle refers to the theory that politicians manipulate government fiscal policies, spending and budgets according to the electoral cycle. Incumbent politicians have an incentive to stimulate the economy and increase spending right before elections to improve their re-election chances. For example, increasing spending on public services, welfare benefits, or infrastructure projects just as voters head to the polls. After elections, they then may impose austerity measures or spending cuts to control deficits and debt accumulation. Politicians may loosen fiscal policy and allow deficits to rise when they first take office, then tighten closer to the next election. Evidence of political budget cycles has been found in many countries when studying patterns of government spending, revenues, deficits across electoral cycles. However, the existence and size of cycles depends on factors like information available to voters, strength of institutions that constrain politicians, type of electoral system etc. Budget cycles can create macroeconomic instability and suboptimal fiscal policy from a long-term economic perspective, if spending is driven too much by short-term political incentives.

So, in summary, incumbent politicians often engage in opportunistic increases or decreases in government spending and budgets timed around elections to improve their chances of re-election, even if these budget cycles are not optimal economic policy in the longer run.

Literature Survey and Objective:

A sizable body of theoretical and empirical literature provides evidence for opportunistic political budget cycles, where incumbent politicians manipulate fiscal policies, including taxation, spending, and deficits, to bolster economic conditions before elections and thus improve re-election odds (Rogoff, 1990). Theoretical models demonstrate how such cycles emerge rationally in democratic systems due to information asymmetry between voters and governments about actual competence and effort levels (Alesina *et al.,* 2000). Voters evaluate politician performance at election time based on recent economic trends (Powell, 2000), but cannot perfectly determine the degree of skill or diligence contributing to outcomes. Consequently, the impending election incentivizes incumbent politicians to engineer temporary economic booms by utilizing expansionary fiscal policies (Tufte, 1978).

Support for these opportunistic models has been found across various empirical contexts. Seminal research by Tufte (1978) revealed pre-electoral economic interventions under different U.S. administrations aimed at accelerating growth before presidential elections. Additionally, global evidence of more pronounced deficit cycles in established rather than nascent democracies, as spending increases or taxes decline ahead of ballots (Brender *et al.,* 2005). The prevalence of such cycles depends partly on institutional attributes like the delineation of responsibilities across government branches and tiers (Alesina *et al.,* 1997). Local analysis applying a novel methodology uncovered increased spending prior to municipal elections in Portugal (Aidt *et al.,* 2011). Moreover, we saw Colombian incumbent politicians strategically shift public spending toward more noticeable consumption preceding elections (Drazen *et al.,* 2010). Thus, existing analysis presents extensive proof that political budget cycles manifest due to the incentives for opportunism inherent in imminent elections.

The existence of political budget cycles - where incumbent politicians manipulate fiscal policy for electoral advantage - is a well-documented phenomenon in the literature. Much of the scholarly focus has focused on studying cycles in aggregate spending, revenues fiscal deficits at the national level. However, an open question exists as to whether targeted spending in areas like healthcare is subject to similar election-driven fluctuations.

The objective of our study is to investigate the presence of political budget cycles in the allocation of resources to medical and public health expenditure across Indian state governments. Given the high salience of public health and healthcare performance for electoral outcomes, politicians may have an incentive to channel greater funding to these areas in the lead up to state-level elections. On the other hand, fiscal balancing motives or debt constraints may dampen

opportunism. Understanding the dynamics of healthcare spending around the election cycle has important welfare implications in terms of both efficiency and equity of service delivery.

Data Collection and Methodology

We compile a new state-level panel dataset on medical and public health expenditures as well as state assembly elections over the period 1996 to 2020 across 31 states. This allows us to carry out an empirical test for political budget cycles after controlling for potential economic and demographic drivers of health spending. Given the documented importance of fiscal institutions in moderating budget cycles, we pay particular attention to analysing the differential impact of election timing across states with varying fiscal rules and constraints.

The results will help assess both the reality of election-motivated manipulation as well as the potential mechanisms states have at their disposal to encourage fiscal discipline - even in a politicized arena like public health resourcing. More broadly, the analysis will expand understanding of how budget cycles manifest across different areas of state expenditure and shed light on the nature of tactical redistribution of government funds in developing countries.

The data of state-government expenditure on expenditure on Medical and Public Health is collected from "State Finances: A Study of Budgets", which is an annual publication by The Reserve Bank of India (RBI). It provides information, analysis and an assessment of the finances of state governments on the basis of primary state level data. We have particularly taken the data from Appendix II: Revenue Expenditure of Individual States. The data of state-government's expenditure on Medical and Public Health is available from year 1996 to 2020. No data is available for year 2017. All the data are in Rs. Lakh except from 2010 to 2016 are given in Rs. Million, which we have converted to Rs. Lakh.

Our hypothesis is that the political budget cycle is generated by incumbent in state assembly to increase their own re-election prospect. In other words, we want to test the existence of a cycle in terms of per capita expenditure on medical and public expenditure

$$\text{Ln (HE)}_{s,t} = \alpha + \beta E_{s,t} + \gamma X_{s,t} + \delta_s + \omega_t + \varepsilon_{s,t}$$

We perform a panel regression across 31 states of India over 24 years, where $\ln(HE)_{s,t}$ is the natural log of per capita real State government's revised planned revenue expenditure on Medical and Public Health of state s at time t, E_{st} is a set of variables representing the state government electoral cycle, $X_{s,t}$ is the set of state level covariates (several age groups 5to 19, 20 to 34, 35 to 59 and 60 up, per-capita net state domestic product, birth rate, death rate, total fertility rate) which vary by state and time, δ_s are state effects, and φ_t are year effects.

If the election was held after 30th June of the n-th year then we have considered n-th year as the election year and if the election was held before 30th June of the n-th year, we have considered (n-1)-th year as the election year. This election year variable is our focal regressor. Usually, a state releases its state budget within first three months of a financial year. If the

election is held within 30th of June there is no or little time for the incumbent to use the revenue expenditure as a policy variable. The incumbent in power must have increased the state government spending or expenditure of the previous year to lure the voters desires to re-elect himself or his party in this year. So, in such scenario, we have considered the immediate year before or the previous year as the election year. On the other hand, when the election is held after the month of June, the incumbent in power gets much time to lure the voters, so he must have used the state government expenditure as a policy variable by increasing the expenses, in order to be re-elected.

In India a Vidhan sabha is held every five years, so, the period of election cycle is five years. However, we have also analysed that the gap between two elections was less than 5 years for an early election, and the gap between two election was more than 5 years for a delayed election. In case if the election cycle was more than five years, then we have considered all the years after the 5th year as the last year of election.

The main coefficient of interest is β which would capture political budget cycle effects of increased health spending in election years and potential post electoral reversals.

Table 1: Effect of state government elections on Revenue expenditure on Medical and Public Health, 1996–2020

Model	**[1]**		**[2]**	
Independent Variable	**Coef. (Robust Std. Err.)**	**Sig.**	**Coef. (Robust Std. Err.)**	**Sig.**
Election year	.1364758 (.0657136)	**		
One year after election			-.0687187 (.0822461)	
Two years after election			-.2081504 (.0909275)	**
Three years after election			-.148749 (.079059)	*
Four year after election			-.116314 (.0568052)	**
N	443		442	
F-test	30.49	***	36.66	***
R-sq	0.2865		0.2858	
Significance levels: *** p<0.01, ** p<0.05, * p<0.1; Robust std. errors are clustered by states				

Results:

This table presents results from two fixed effects regression models examining the impact of state election timing on public health expenditures by state government in India. Several key findings emerge:

Model 1 shows that Vidhan Sabha election years are associated with a statistically significant (at 5% level) increase in public health spending, compared to non-election years. This provides evidence of a political budget cycle, where health expenditures rise leading up to elections.

Model 2 suggests this Vidhan Sabha election year boost tends to be reversed in the years immediately following elections. Coefficients of non-election years are negative indicating a fall in the post-election years by the state governments. More notably, the state government spending significantly decreases in the second and third year after an election, respectively. Both are significant at 5% level or higher.

The positive coefficient for the Election Year suggests an increase in Revenue expenditure on Medical and Public Health during election years. The negative coefficients for the subsequent years indicate a decrease in expenditure in the years following the election, with varying significance levels. Thus, we can say that there is a political budget cycle in Medical and Public health by state government in Vidhan sabha election. This pattern is consistent with political budget cycle theories of fiscal manipulation. Incumbents expand health expenditures to signal competence and curry favour with myopic voters ahead of elections. But spending is cut back once the election passes and immediate pressure eases.

Overall, the results suggest Indian state health budgets systematically reallocate resources over the state government election cycle, with citizens likely facing spending reductions in post-election periods compared to election lead ups. Institutions encouraging fiscal restraints outside election years may be beneficial.

Conclusion:

The results of the regression analysis provide insights into the political budget cycle observed in the context of state government expenditure during Vidhan Sabha elections. The positive coefficient for the Election Year variable indicates a statistically significant increase in Revenue expenditure on Medical and Public Health during election years. This aligns with the notion of governments strategically boosting spending in key sectors, such as healthcare, to appeal to voters and demonstrate a commitment to public welfare in the lead-up to elections. However, the subsequent years show a consistent pattern of decreased expenditure, as indicated by the negative coefficients for one, two, three, and four years after election. This post-election reduction in spending may reflect fiscal restraint measures implemented by the government to manage budgets and address concerns about financial sustainability. The statistical significance levels associated with the coefficients enhance the reliability of these observed effects.

A surge in government expenditure for Medical and Public Health can catalyse multifaceted positive transformations in the healthcare sector. Firstly, increased funding empowers the government to fortify healthcare infrastructure, augment facilities, and expand

services, fostering an environment conducive to improved medical care. This financial boost enables the implementation of preventive healthcare measures, immunization programs, and disease control initiatives, thereby contributing to better health outcomes, reduced mortality rates, and an overall enhancement of public health. Furthermore, expanded access to healthcare becomes a reality as additional resources facilitate the establishment of medical facilities in underserved and rural areas, ensuring that a broader segment of the population can avail themselves of essential health services. The financial injection also facilitates the development and sustenance of a skilled healthcare workforce through training and hiring initiatives. Simultaneously, increased government expenditure may propel medical research and development, fostering innovation in healthcare technologies, treatments, and pharmaceuticals. Public health programs, including awareness campaigns and disease prevention efforts, can be strengthened, reinforcing the nation's capacity to tackle health challenges comprehensively. Economically, the positive impact on productivity, stemming from an improved health profile, contributes to long-term economic benefits. Additionally, augmented healthcare spending offers an opportunity to address disparities in healthcare access and outcomes among diverse demographic groups, fostering a more equitable distribution of health resources. While increased expenditure holds significant potential for positive change, its effectiveness hinges on prudent resource allocation, efficient policy implementation, and effective governance of the healthcare system. Sustainable fiscal responsibility remains paramount for the enduring success of endeavours aimed at enhancing healthcare outcomes.

Elevating government expenditure for Medical and Public Health emerges as a strategically advantageous move in the political arena, particularly for winning elections. This approach carries inherent benefits that resonate with voters and contribute to a positive electoral outcome. By channelling additional funds into healthcare, political candidates and parties demonstrate a commitment to public welfare, a crucial factor in appealing to the electorate. Improved healthcare services, enhanced facilities, and increased accessibility to medical care present tangible and visible benefits that can sway voters' sentiments in favour of the governing party or candidate.

The perceived responsiveness of the government to pressing societal needs becomes a key factor influencing voter decisions. The strategic decision to boost healthcare spending creates an image of a government attuned to the concerns of its citizens, fostering trust and confidence. Popularity and trust in political leaders are further bolstered as citizens witness direct improvements in their health outcomes and access to medical facilities.

Increased healthcare expenditure becomes a central theme in political messaging, providing a compelling narrative for campaigns. By highlighting advancements in public health services, governments can shape positive perceptions and differentiate themselves from

competitors. This strategy is particularly effective in appealing to swing voters, as health-related policies have broad appeal across diverse demographics.

During times of health crises, such as pandemics, governments allocating additional resources to address pressing challenges can be perceived as proactive and decisive. Crisis management through increased healthcare spending not only addresses immediate concerns but also positions the government as capable and responsive, potentially translating into electoral support.

Ultimately, the impact of heightened healthcare expenditure on electoral success is contingent on effective communication of policies, transparent governance, and the broader political context. Genuine and thoughtful resource allocation is essential to avoid the perception of opportunistic behaviour solely for electoral gain. Nevertheless, the positive changes in healthcare services contribute significantly to shaping public perception and can be a compelling factor in securing electoral victory.

ReferenceS:

1. Drazen, A., & Eslava, M. (2010). Electoral Manipulation via Expenditure Composition: Theory and Evidence. *Quarterly Journal of Economics, 125*(4), 1437–1468.
2. Alesina, A., Roubini, N., & Cohen, G. D. (1997). Political Cycles and the Macroeconomy. *MIT Press*.
3. Powell, G. B. (2000). Elections as Instruments of Democracy: Majoritarian and Proportional Visions. *Yale University Press*.
4. Tufte, E. R. (1978). Political Control of the Economy. *Princeton University Press*.
5. Alesina, A., & Tabellini, G. (2000). Political Economics: Explaining Economic Policy. *MIT Press*.
6. Brender, A., & Drazen, A. (2005). Political Budget Cycles in New versus Established Democracies. *Journal of Political Economy, 113*(1), 1–45.
7. Aidt, T. S., Veiga, F. J., & Veiga, L. G. (2011). Election Results and Opportunistic Policies: A New Test of the Rational Political Business Cycle Model. *European Journal of Political Economy, 27*(1), 181–190.
8. Klomp, J. & Haan, J. (2013). Political Regime and Human Capital: A Cross-Country Analysis. *Social Indicators Research: An International and Interdisciplinary Journal for Quality-of-Life Measurement, Springer*, 111(1), 45-73.
9. Rogoff, K. (1990). Equilibrium Political Budget Cycles. *American Economic Review*, 21-36.

STUDIES ON PATHOGENIC BACTERIAL DIVERSITY IN SUBHAS SAROBAR, KOLKATA CONCERNING PUBLIC HEALTH

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Abstract:

Subhas Sarobar is a medium-sized artificial lake situated in the northeastern region of Kolkata, West Bengal which is controlled by the Calcutta Improvement Trust. This body of water is home to a variety of organisms, including bacteria, benthos, nekton, phytoplankton, and zooplankton, all of which contribute to a healthy and interdependent ecosystem. Seasonal variations in temperature, precipitation, and humidity have an impact on the physicochemical characteristics of the water, which could lead to a shift in the faunal population. Additionally, residential effluents are used on this aquatic system. Therefore, in addition to seasonal variations, home spills, washing clothes and utensils, taking baths, and disposing of plastic garbage next to the lake water all affect the physico-chemical characteristics of the water. The lake water quality ultimately declines as a result of all these human activities. The combination of high nutrient content and low DO creates an ideal habitat for the growth of bacteria in the lake system, including pathogenic bacteria that might potentially harm public health as well as other aquatic creatures. Pathogenic bacteria species found in water are dangerous and can cause several illnesses to human beings. It is possible to successfully stop the spread of disease(s) if the traits and specifics of pathogenic bacteria are understood.

Keywords: Bacterial Diversity, Water Pollution, Subhas Sarobar.

Introduction:

In aquatic ecosystems, lakes are the most productive. They support life and also aid in environmental regulation and the management of the water cycle (Figure 1). Urban freshwater lakes also have an important recreational and aesthetic role. The vegetation and faunal composition of lakes generally exhibit a wide range of diversity and is very dynamic, responding to perturbations in the natural ecological balance. East Calcutta's lung is Subhas Sarobar, administered by the Calcutta Improvement Trust, which enjoys substantial environmental support. The environment surrounding the lake is used for athletic, recreational, and cultural activities in addition to being an essential part of the oxygen balance. Furthermore, by removing

contaminants from the surrounding environment, this ecosystem is functioning as a natural sink. The impact of human activity on the Subhas Sarobar has intensified significantly in recent times. Daily, more than 3,000 individuals use it for bathing and washing clothes and utensils. Additionally, trash made of plastic is being disposed of next to the lake. The natural elements, particularly the lake water quality, have deteriorated because of all these human activities. Consequently, the area's terrestrial and aquatic ecosystems are at risk of not developing sustainably due to environmental degradation. One of the biggest threats to the aquatic environment worldwide is thought to be microorganism-mediated water pollution (Percival and Willium, 2014). A water body's bacterial burden is heightened by the effluent from hospitals, industries, livestock farms, and fecal matter disposal sites. Coliform bacterial groups have long been used as a common indicator organism for water pollution by microorganisms, which has historically influenced public perceptions of public health security (Rayan and Ray, 2004). Subhas Sarobar is exposed to a variety of pollutants, which alters the parameters governing water quality and increases the diversity of microorganisms (Khan and Sen, 2002)

Status of Water Body:

The Lake ecosystem possesses a diverse array of flora and fauna which make it a dynamic aquatic ecosystem (Figure 1).

Geographical Status:

Figure 1: Geographical location of Subhas Sarobar

East Calcutta's lung, Subhas Sarobar, is a manmade lake managed by the Calcutta Improvement Trust and benefits greatly from the surrounding environment (Figure 1). Its latitude is between 220 34′ and 220 34′ 30″ N and its longitude is between 880 24′ and 880 24′ 30″. About 6.04 ha of the 39.6 ha total area of the Subhas Sarobar is covered by water. Two islands—one little and the other large—make up a fantastic home for a variety of living things. The total area is 39.6 ha including the lake and the surrounding vegetation of which 16.29 ha. of the

area stands for the water body, according to CMC 1986. The total volume of the water body is an average of 634 m^3 due to seasonal changes across the year and the mean depth is 4.8m (Samal *et al.,* 2004).

Physicochemical Status:

Temperature (Hanna, Romania), pH (Hanna, Romania), Dissolve oxygen (Lutron, Taiwan), Salinity (Erma, Japan), Ammonia (Himedia kit), Nitrite (Himedia kit), Nitrate (Himedia kit), Hardness ((Himedia kit), *Vibrio* sp. (Himedia kit), were measured and recorded for determining the health condition of cultured pond water on the spot instantly and collection of water in bottle for determination of bacterial population and species. Throughout the study period, five sampling locations were designated for the monthly collection of water samples to determine the water quality. One-liter polythene cans were carefully waded into the water to get surface water samples. The analysis was completed through the standard methods (APHA,1992; Saha, 2000) (Table 1).

Table 1: Physicochemical Factors (Adapted from Khan *et al.*, 2002)

Physicochemical Factors	
Water temperature (^{0}C)	30.2^{0}C
pH	8.24
Turbidity	16.42
Conductivity	417.37
Dissolved Oxygen (ppm)	5.7
Total alkalinity(mg/lit)	216.47
Chloride (mg/l)	42.82
Phosphate (mg/l)	0.04
Nitrite (mg/l)	0.12
Nitrate (mg/l)	0.29
Ammonium (mg/l)	0.20

Temperature: It is the primary factor influencing the great diversity of species found in the lake ecosystem. Every aquatic organism, including macrophytes, zooplankton, and phytoplankton, has a preferred temperature range within which they can develop to their maximum population. The cause of the increased chemical reactions in the water body that result in the release of additional nutrients from the sediments is typically high temperatures.

Light: It provides the energy needed for green plants to carry out photosynthesis. Several variables, including the size of the water body, the existence of an algae bloom, climatic conditions, and dissolved particles, affect light penetration in the lake.

pH: pH is the measure of acidity or alkalinity in the lake water. It is an important indicator of water if any chemical change occurs in water.

Turbidity: High turbidity levels can inhibit the growth of submerged aquatic plants.

Zooplankton Status:

A wide range of zooplankton inhabited in the water body among which the Cladocerans are the most dominant followed by rotifers and copepods. Some of the zooplanktons are listed below (Saha *et al.,* 2001) (Table 2).

Table 2: List of few Zooplanktons (Adapted from Khan *et al.*, 2002)

Group	Name of Zooplankton
Copepoda	1. *Cyclops* sp. 2. *Mesocyclops* sp. 3. *Heliodiaptomus* sp.
Rotifer	1. *Brachionus* sp. 2. *Testudinella* sp. 3. *Lacane* sp.
Cladocera	1. *Sida* sp. 2. *Moina* sp. 3. *Allona* sp. 4. *Pseudosida* sp.

Bacterial Diversity of The Lake:

The detrimental effects of human activities have increased dramatically in the last few years. The high concentration of nutrients that Subhas Sarabor receives from the surrounding environment as a result of human activity makes it a eutrophic lake. These nutrients contribute to the growth of the lake's phytoplankton and algae populations and decrease the amount of oxygen available for other aquatic organisms. This condition of the water body can give rise to several pathogenic bacteria that can cause serious waterborne diseases in humans (Dutta *et al.,* 2018; Saha *et al.,* 2023) (Table 3).

- **Salmonella**

There are multiple species in the genus, and each species contains a variety of antigenic kinds. There are about 1800 recognized serotypes. Typhoid fever is caused by Salmonella typhi. The symptoms include weakness, headache, and a fever that keeps getting worse. After a while, the abdomen develops rose-colored patches and diarrhea happens. From the intestine, the organism travels to the blood and other organs. In severe circumstances, there may be a deadly intestinal perforation and hemorrhage. It is mostly water-borne, and severe infection requires high concentrations of the bacterium. The antigens boost immunity in the person who has been

exposed, but because of their wide range, control is challenging. During the first week of the illness, blood culture is a helpful diagnostic technique (Cabral, 2010).

- ***Shigella***

Shigella species contamination is a common cause of diarrhoea. They are limited to the gastrointestinal system. The type species is *S. dysenteriae*. *S. flexneri*, *S. boydi*, and *S. sonnei* are the others. They are facultative anaerobes that are gram-negative, non-lactose fermenting, and non-gas-forming. Based on *S. dysenteriae* lipopolysaccharides and '0' antigens, over 40 serotypes are recognized. They induce mucous membrane necrosis, which leads to superficial ulceration. Abdominal pain, fever, and watery diarrhea are the symptoms. In healthy adults, symptoms go away in two to three days, but in children and the elderly, electrolyte infusion is required to prevent dehydration. The bacteria produces both an exotoxin and an endotoxin. Antibiotics (ampicillin, tetracycline, and chloramphenicol) are administered to maintain control. *Shigella* spp. are transmitted through contamination of food and water by faecal matter (Cabral, 2010).

- ***Vibrio***

*Vibrio*s are facultative anaerobes; gram-negative bacteria present in saline and fresh water. Abdominal pain, frequent diarrhea, and abrupt nausea and vomiting are the hallmarks of the illness of *Vibrio*s. The stools have a distinctive appearance similar to rice water (rice stools). The intestinal system is the only place the bacteria can grow. It causes a hypersecretion of chlorides and water. Dehydration and electrolyte loss consequently happen, leading to death. Owing to the disease's quick transmission, numerous nations have seen widespread outbreaks (Saha and Dash, 2021). Prevention by good hygiene, the use of clean water and food, and good sanitation practices is the best management strategy. As a preventative precaution, cholera toxoid vaccinations are administered anytime the illness manifests. Patients who are afflicted receive replacement electrolytes and water (Cabral, 2010).

- ***Escherichia***

Although *Escherichia coli* is frequently found in the intestinal tract, it can also infrequently turn harmful, particularly in the urinary tract. Because coliform bacteria are common intestinal inhabitants, they are tested for bacterial contamination in water. O and K antigens are formed by pathogenic strains. They make people sick, especially kids (Cabral, 2010).

- ***Yersinia***

As a food-borne infectious agent pathogen, *Y. enterocolitica* can cause a wide range of gastrointestinal disorders in people, from moderate diarrhea to inflammation of the mesenteric glands. In children and people with underlying medical conditions, it can also cause appendicitis and septicemia, with potentially serious symptoms. Yersiniosis ranks third among the many foodborne infections, following salmonellosis and campylobacteriosis. Pestis is the culprit of the

plague. The rod is Gram-negative and exhibits bipolar staining, which is stain limited to the poles. The optimal temperature for this facultative anaerobe is 28°C. The membrane made of lipopolysaccharides is poisonous (endotoxin). A surface protein inhibits the function of macrophages. The bacteria live in rodent reservoirs, and fleas carry it by sucking on their blood. Pneumonic plague arises when the bacterium finds a center in the lungs; septicaemic plague is characterized by hypotension, vomiting, and diarrhea. Bubonic plague is characterized by swollen lymph glands, or "bubos." If the plague is not treated quickly, it can cause cardiac arrest and death. Tetracyclines and streptomycin work well. Controlling rats is a prophylactic approach (Cabral, 2010).

- **Tetanus**

An obligatory anaerobe that is common in nature is *Clostridium*. Certain species provide a health risk to both people and animals. It is a spore-forming genus with a distinctive drumstick-like morphology that is observed in culture. when endospores develop in cells in the terminal stage. *Clostridium botulinum* causes food poisoning, *Clostridium perfringens* causes gas gangrene, and *Clostridium tetani* causes tetanus. Contamination of wounds with dirt or other contaminated materials is the cause of localized C. tetani infection. Being an anaerobe, it grows in hidden places such as deep wounds; in surgical procedures, it occurs in approximately 50% of cases. The primary cause of the impact is the bacterium's toxin, tetanospasmin (Cabral, 2010).

Table 3: List of few pathogenic bacteria

Diseases	**Causative Bacteria**
Cholera	*Vibrio cholerae*
Gastroenteritis caused by *Vibrio*s	*Vibrio parahaemolyticus*
Typhoid fever and other serious salmonellosis	*Salmonella* sp.
Bacillary dysentery or shigellosis	*Shigella* sp.
Acute diarrheas and gastroenteritis	*Escherichia coli*
Gastroenteritis	*Aeromonas* sp.

Method for Observation of Water Borne Bacteria:

The microbe must be brought into pure culture, which is devoid of any other organisms, to start the culture. By cultivating it in confined containers on a sterile media, the pure culture is obtained and maintained for additional research (Saha and Dash, 2021; Saha *et al.*, 2023).

- **Media Preparation:** Essential minerals and a carbon source, like dextrose, are included in a culture medium. By adding complex proteinaceous material like vitamins, amino acids, and other nutrients, this medium's nutrition is enhanced. For the majority of the

bacteria, the medium's pH is adjusted to be between 7.2 and 7.4. The components are added to water in appropriate amounts and then moved to culturing vessels. The liquid medium is referred to as nutritional broth, and the microbial culture cultured within it is called broth culture. Before sterilizing, the medium is mixed with gelatin or agar agar to create a semi-solid gel. Upon cooling a solid surface is created for the formation of microbial colonies by this type of agar medium.

- **Isolation and Inoculation:** Millions of microorganisms can be found in samples taken from natural ecosystems such as soil, water, and sewage. Before being isolated, collected samples are diluted with nutritional medium or water. Millions of microorganisms can be found in samples taken from natural ecosystems such as soil, water, and sewage. Before being isolated, collected samples are diluted with nutritional medium or water.

There are two common techniques to obtain pure cultures:

  - **Streak plate Method:** An inoculation needle is used to streak the diluted sample in the Petri dish and draw a straight line on the medium's surface. From the distal end of the first streak, another streak is formed at a right angle to it. The third and fourth streaks are constructed such they don't come into contact with one another in the middle. Bacterial cells split and form different, independent colonies when the streaks are drawn.
  - **Single Cell Isolation:** To calculate the density of cells, the sample is inspected under a counting chamber. Next, the concentration is reduced until a single cell is present in every two drops of liquid. Agar media is covered with discrete liquid droplets. On agar slants, discrete colonies are subcultured when they form. These techniques are useful for culturing most bacteria into pure culture.

- **Staining Techniques:** One of the most important staining techniques is Gram Staining which separates gram-positive and gram-negative bacteria. In this method, the gram-positive bacteria retain the crystal violet color whereas the gram-negative bacteria lose the violet color.
- **Maintenance and Preservation of Culture:** After a pure culture has been obtained, it is preserved for further research.

  Glycerol Method: For long-term storage, bacterial glycerol reserves are essential. Glycerol stabilizes the frozen bacteria, protecting the cell membranes and preserving the viability of the cells. Bacteria can be preserved in glycerol at -20°C for several months or at -80°C for many years.
- **Stab Method:** Stab cultures are made using solid agar in a test tube and which resembles agar plates. By stabbing a pipette tip or inoculation needle into the center of the agar, bacteria are introduced. In the perforated region, bacteria proliferate. The most popular use for stab cultures is the transportation or short-term storage of cultures.

Physical Detection of Bacteria (Kit Method):

From the lake, collected water was put into a bacterial identification bottle kit. Incubate the bottle for 24 to 48 hr. in an incubator at 35^0C. The presence of the colour of bacterial colonies helps to recognize water from green to red, pink, blue, and black identity as different bacteria in lake water (Figure 2, Table 4)

Figure 2: Detection of the bacterial population by colour using the kit (Himedia)

Table 4: Colour detection kit for bacteria

Sl. no.	**Colour**	**Detection of bacteria**
1.	Light green	Control
2.	Deep green	*E. coli*
3.	Blackish green	*Shigella* sp.
4.	Pinkish red	*Vibrio* sp.
5.	Light pink	*Enterobacter* sp.
6.	Black	*Salmonella* sp.

Water samples were collected from the lake and at least 0.1 ml of water sample was taken on prepared microbiological culture media (species-specific) by spread plate method. Observe bacterial colonies after 24 hr. incubation at room temperature (35^0C) within a bacteriological incubator. The presence of colour or bacterial colonies (droplets) on plates indicates bacterial contamination of water with bacterial sp. The counts of colonies were considered per ml and were calculated by multiplying the average number of colonies per plate by the reciprocal of the dilution factor. The calculated results are expressed as colony-forming units (CFU) per ml of sample. Each colony, separated by color and size, was counted separately as Colony Forming Unit per 100 µl of blood (CFU/100µl) thrice and averaged. Then, discrete representatives of each colony type were randomly selected for purification and characterization (Saha and Dash, 2021).

Molecular Detection:

Table 5: Primer selection of bacteria for freshwater bodies

Name of Primer	Sequence	Product Length (bp)	Annealing Temp.	Targets sp
8F 1492R	5'-AGAGTTTGATCCTGGCTCAG-3' 5'-GGTTACCTTGTTACGACTT-3'	**1600**	50^0C 1 min	Universal primer for bacteria
27F 1492R	5'- AGAGTTTGATCMTGGCTCAG-3' 5'- TACGGYTACCTTGTTACGACTT-3'	**1500**	50^0C 1 min	
700F 1325R	5'-CGGTGAAATGCGTAGAGAT-3' 5'-TTACTAGCGATTCCGAGTTC-3'	**663**	57^0C 45 S	*Vibrio* genus (16srRNA)
Vc-F Vc-R	GTTCGCGCTGGTGAAGGTTCA TGGCATACCAGAGTCTTTCTGTG	**192**	57^0C 1 min	*Vibrio cholerae*
16S rDNA-F 16S rDNA-R	5'-AGAGTTTGATCATGGCTTACGACTT-3' 5'-GGTTACCTTGTTACGACTT-3'	**1542**	55^0C 30 sec	*Enterobacter* sp.
uidA-F uidA-R	5'-AAAACGGCAAGAAAAAGCAG-3' 5'-ACGCGTGGTTAACAGTCTTGCG-3'	**371**	55^0C 30 sec	*E. coli*
Aero-F Aero-R	5'-TGTCGGSGATGACATGGAYGTG-3' 5'-CCAGTTCCAGTCCCACCACTTCA-3'	**720**	55^0C 30 sec	*Aeromonas hydrophila*
IpaB-F IpaB-R	5′-GGACTTTTTAAAAGCGGC GG-3′ 5′-GCCTCTCCCAGAGCCGTC TGG-3′	**314**	55^0C 30 sec	*Salmonella enterica*
IpaH-F IpaH-R	5'-TGGAAAAACTCAGTGCCTCT-3' 5'-CCAGTCCGTAAATTCATTCT-3'	**423**	55^0C 30 sec	*Shigella* sp.
Ail-F Ail-R	5'-CTATTGGTTATGCGCAAAGC-3' 5'-TGGAAGTGGGTTGAATTGC-3'	**354**	57^0C 30 sec	*Yersinia enterocolitica*
HP-F HP-R	5′-TCTGTCTGATTCGCTTTTCTG-3′ 5′-AAGCTCGCTAAAAACGACC-3′	**132**	54^0C 5 Sec	*Helicobacter pylori*

DNA extraction:

From the media agar, selected colonies were transferred onto tryptone soy agar and finally purified into TSB after incubating at 35^0C for 24 hr. After final purification and growth in TSB cultured bacterial samples are to be centrifuged and transferred into a pellet in the bottom of a micro centrifuge tube. The pellet of bacteria was used for genomic DNA isolation by using a bacterial genomic DNA isolation kit according to the manufacturer's protocol. After 70% ethanol wash, followed by centrifugation, the DNA pellet was dissolved in TE buffer and subsequently

sored at -20^{0}C for further use. The quality and quantity of isolated genomic DNA for each sample are to be evaluated by measuring and calculating the ratio of optical densities at 260 nm and 280 nm wavelengths respectively, using a NanoDrop^{TM} spectrophotometer. The aqueous phase contained purified DNA and is to be directly used for the subsequent experiments (Saha and Dash, 2021).

PCR Amplification and Agarose Gel Electrophoresis and Documentation:

The PCR reaction is to be carried out by using 100ng of genomic DNA as a template. Each reaction mix contained Phusion reaction buffer with 1 X final concentration, 0.2 U of Phusion^{TM} high fidelity DNA polymerase, 200 µM dNTPs, Forward primer and Reverse primer with a final concentration of 0.5 µM each, and template DNA. Primers are selected from available literature (Mookherjee *et al.,* 2015) (Table 5). The amplification was performed in a thermal cycler (Gene Amp 9700, ABI). After completion of PCR amplification steps, the amplified products are to be analyzed on 1%agarose gels containing 0.5 µg/ml ethidium bromide in 1X Tris-acetate- EDTA (TAE) buffer, and after electrophoresis, the gel is to be visualized and images are to be captured in gel documentation system (Saha *et al.,* 2023).

Factors Responsible for The Lake Pollution:

The neighborhood slum residents' unlimited access to the lake and its natural resources has been one of the main annoyances within the lake premises. Due to the lack of infrastructure, the impoverished villages have become increasingly reliant on the lake's water and surrounding resources for their daily needs. This includes routinely using the lake's limited water supply to wash clothes and utensils, bathing, fishing in the lake, urinating along its perimeter, washing various vehicles with the water, and carelessly discarding trash in this water body. Detergents, which are used to wash clothes and utensils, contain harmful chemicals like nonylphenol is one of the main pollutants of the lake water. Other contaminants like excreta and microplastics are also polluting the lake water. These contaminants bioaccumulate, enter the food chain of humans through the fish, and pose serious threats to human health. Laundry detergents are rich in phosphate salts which can also cause water pollution. This phosphate salt prevents the biodegradation of organic substances and causes eutrophication in the water body. Eutrophication results in algal bloom, increases the BOD value causing the death of aquatic organisms. All these together also support the growth of harmful waterborne bacteria in the lake water imposing a serious threat to human health as they utilize the water daily (Khan and Sen, 2002).

Conclusion:

Subhas Sarobar, also known as Beliaghata Lake is a man-made lake located in the eastern part of Kolkata and maintained by Calcutta Improvement Trust (CIT). This lake contains two islands that support a diverse array of biological organisms. Due to anthropogenic activities, the

water body becomes rich in nitrogen and phosphorus which makes it a eutrophic lake. As a result, there is a huge growth of phytoplankton and algae populations. Not only that, this lake also supports zooplankton and other aquatic organisms like fish, mollusks, etc. This water body supports a huge array of living organisms and so, the amount of decomposition at the bottom of the water body is also high. As a result, the amount of oxygen gets depleted for the survival of aquatic organisms. This high BOD value of the water body provides a suitable environment for the growth of pathogenic bacteria. Since this water body is extensively used by local people there is a threat to their health. These pathogenic bacteria can cause different types of gastrointestinal diseases in humans. So, there is a need for vast studies to detect all the pathogenic bacteria and also to control the pollution level of the lake water. To understand the diversity of the bacterial population differential culture of the pathogens and molecular detection of them is also needed.

Acknowledgment and Funding:

The authors are thankful to the principal of Vidyasagar College for Women, for providing funding and facilities to continue the research work entitled "Studies of bacterial diversity in Subhas Sarobar, Kolkata" and "Impact of seasonal water physico-chemical parameters on bacterial diversity in Subhas Sarobar (Lake)" as a Teacher-Student research grant. Dr Sanjib Saha is also grateful to the WBDSTBT for funding support of the Project entitled "Diversity and impact of zoonotic strains of *Vibrio* sp. in aquacultured *Scylla serrata* in West Bengal" in the category of Animal Science and Fishery for Research Development Program [Sanction no. 1406(Sanc.)/STBT-11012(27)/21/2021-ST SEC dated 25/03/2022].

References:

1. APHA. (1995). Standard Methods for the Examination of Water and Wastewater. 19th Edition, American Public Health Association Inc., New York.
2. Cabral, J.P.S. (2010). Water Microbiology. Bacterial Pathogens and Water. *Int. J. Environ. Res. Public Health, 7*, 3657-3703; doi:10.3390/ijerph7103657
3. Dutta, S., Chakraborty, S. and Srivastava, R.C. (2018). Environmental Impact Assessment & Incidence of Occurrence of Disease among the Public Health in East Kolkata Wetland Area. International Journal of Bioinformatics and Biological Science, Vol 6, 55-63.
4. Jones, K. E. Nikkita G. Patel, N. G., Levy, M. A., Storeygard, A., Balk, D. Gittleman, J. L. and Daszak, P. (2008). Global trends in emerging infectious diseases. *Nature,* 451: 990 – 994.
5. Khan, R. A. and Sen, S. (2002). Studies on physicochemical and biological properties of two man-made lakes, Kolkata. Rec. zool. Surv. India: 100 (Part 3 - 4) : 1-19.
6. Percival, S. L., & Williams, D. W. (2014). *Vibrio*. *Microbiology of Waterborne Diseases (Second Edition)*, pp. 237-248.Elsevier.

7. Ryan, K.J. and Ray, C.G. (2004). Sherris Medical Microbiology: An introduction to infectious diseases. The Mc Graw-Hil Companies, Inc.
8. Saha, S. and Dash, G. (2021). Climatic Stress on Cultured *Scylla* sp.: Impact on livelihood and Public Health in West Bengal. *International Journal of Researches in Biosciences, Agriculture & Technology*, S17: 331 – 344.
9. Saha, S. and Dash, G. (2021). Zoonotic *Vibrio* diversity and diseases in mudcrab fishery: impacts on public health in India. Uttar Pradesh Journal of Zoology, 42(19): 48-58.
10. Saha, S., Pradhan, D. and Dash, G. (2023). Studies on diversity of bacterial diseases and occupational risks through mudcrab aquaculture in West Bengal. *Journal of Pure and Applied Microbiology*. 17(2):722-731. doi: 10.22207/JPAM.17.2.23.
11. Saha, T., Manna, N. K., Majumder, S. S., Bhattacharya, I. N. (2001). Primary Productivity of the Subhas Sarobar Lake in East Calcutta in Relation to Some Selected Physico-Chemical Parameters.Pollution Research 20: 47-52.
12. Samal, N. R., Roy, D., Mazumdar, A. & Bose, B. (2004). Influence of thermal stratification on dissolved oxygen in Subhas Sarobar, Kolkata. Journal of Curriculum Sciences 7 (1), 259–266.
13. Saha, T. (2000). Monitoring of environmental studies of Subhas Sarobar, Calcutta and Preparation of management action.

ECO-REHABILITATION OF DEMATERIALIZING ORCHIDS THROUGH *IN VITRO* SEED CULTURE

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Abstract:

The world's most wonderous plants belonging to family Orchidaceae are Orchids with over 25,000 species found in almost all habitation around the globe. Many of these species contain compounds with potential medicinal value making them important targets for conservation efforts to preserve biodiversity and potentially valuable genetic resources. These unique plants have been utilized for centuries in various cultures for their medicinal properties and they continue to be of great importance today. The substantial use of orchid is ornamental because of their exquisitely attractive flowers or inflorescences. Subsequently, the rate of germination is very poor in natural habitat. This study is about conventional preservation through *in-vitro* seed culture and micropropagation.

Keywords: Orchids, *in-vitro*, Micro-propagation, Conservation.

Introduction:

Orchids occupy a special position in the plant kingdom due to its specialization and modification in their vegetative and floral characters. They are perennial, herbaceous epiphytic and occasionally terrestrial plants with long lasting flowers in myriad varieties of colors, shapes, sizes, architecture and fragrance. These group of plants comprise a unique and distinctive portion of plants. Taxonomically, these plants belong to the most highly evolved family Orchidaceae in the plant group monocotyledons with 750 genera and 18000 species (Heywood, 1993) or 788 genera and 18500 species (Mabberley, 1998) constituting second largest family of flowering plants in the world. Raj Bhandari & Bhattarai (2001) documented 53 species having medicinal value from north eastern region of India.

The most significant use of orchid is ornamental because of their exquisitely attractive flowers or inflorescences remain fresh for longer period of time in comparison to other flowers. These qualities have made orchid growing a high profitable industry all over the world. So, orchids are cultivated in a large scale for cut flowers and potted plants. On the other hand, a large number of species bear attractive flowers and their capacity for inter specific as well as intergeneric breeding has generated tremendous possibilities producing hybrids or diverse floral characters. There are about 70 species of Indian orchids that have been used in breeding

programs for producing hybrids in and outside the country for example *Dendrobium nobile,* an Indian orchid species extensively used in hybridizing over 77 hybrids registered so far in which it was parent. Today more than 1.2 lakh hybrids are known all over the world. The wild native orchids are likely to play a unique role in the development of new cultivars or hybrids and also existing with one or more attributes. India constitutes invaluable reservoir of these genes or germplasm of orchids that are needed for the development of new varieties.

Maximum orchids are important floricultural and ornamental plants, some of which have pharmacological interests. They have been used to cure various ailments. The Chinese Materia Medica of the Mythical Emperor prepared during Han Dynasty (200 B.C.- A.D. 200) mentions *"Shih-hu"* or the Dendrobium, whose dried stems were widely used as tonic, astringent, analgesic, anti-inflammatory and for curing a number of other diseases. The Indian orchids have also been used in various indigenous system of medicines since the Vedic period (Handa, 1986; Kaushik, 1983; Kirttikar and Basu, 1935; Trivedi *et al.,* 1961; Vij *et al.,* 1997). Orchids have been integral to traditional medicine systems in many cultures, where they are used to treat ailments such as coughs, fever, inflammation, microbial infection, cardiovascular diseases, digestive disorders and are often included in formulations for their therapeutic effects.

As the over exploitation of orchids raises, it is essential to promote sustainable harvesting and cultivation practices to ensure the long-term availability of these valuable resources. *In vitro* seed culture & micropropagation plays a vital role in orchid conservation, offering resolution to the challenges of preserving genetic diversity, propagating rare and endangered species and supporting sustainable trade.

Literature Review:

The pioneer work of Bernard (1909) is important in the development of *in vitro* culture techniques of orchids. Knudson's work showed for the first time that germination of orchid seeds could be possible *in vitro* without fungal association, Knudson (1951). Besides medicinal importance, orchids are used in the breeding program to develop new varieties and hybrids to improve their horticultural aspects. Once a hybrid is made, the only problem is the large-scale propagation because of its slow growing vegetative propagation. The advantage of using seeds from capsules or pods for micropropagation is that, virus diseases etc. present in the capsule may be eliminated when they are transferred to culture, Mitchell (1989). The mature seeds, on the other hand either fail to germinate or germinate very poorly due to loss of growth promoting factors and accumulation of inhibitory and other dormancy factors (Burgeff 1959, Kano 1965, Stoutamire 1974, Withner 1959). Asymbiotic germination of selected orchid seeds was obtained and the effect of different media on germination was studied by Raghuwanshi. Sterile propagation of *Cypripedium reginae* from seeds was possible after a chilling treatment. The occurrence of germination in presence of charcoal which binds toxic polyphenolics was

suggested by several authors (Waterman and Mole 1994; Miyoshi and Mii 1995). other authors have suggested different nutrient solution suitable for different stages of growth for various species (Talukdar, 2001). Plant growth regulators and coconut water promotes germination. It has been reported that plantlets growth was vigorous and survives well when they were germinated in combination with 20% coconut water (Michel 2002). The same action of coconut water enhancing vigorous growth was found in the species of *Dendrobium* orchid (De *et al.*, 2006). Other than economic consideration; orchids have some inherent capacities for drought resistance, nutrient conservations and long self-life of the flowers etc. These characters are very peculiar and not present in common crops. Therefore, the germplasm of orchids should be conserved because they may act as important gene donor in future for the improvement of other crops through genetic manipulation.

Objective & Methodology of the Study:

Although orchids belong to one of the largest families, they are also perhaps most seriously threatened plants on the globe. Their vulnerability depends upon following reasons:

1. Orchids have specialized life cycle. The vegetative propagation and multiplication of orchids is very slow process and it takes a long duration. In case of vegetative propagation through separation of stem and pseudobulbs one may not get more than a few plants after 4-5 years.
2. The pollination of orchid flower depends on the pollinators.
3. In the seeds of orchid, there is lack of reserve food material i.e., absence of endosperm, cotyledon etc.
4. The seed germination of orchid is always dependent on the association of mycorrhizal fungi, in some cases they are species specific. Therefore, only less than 1% of seed germinate in their natural environment due to non-availability of specific fungi, so slow vegetative propagation through asexual method and the need of mycorrhizal fungi for seed germination make their life cycle more vulnerable.
5. Owing to ornamental and therapeutic values which they possess has made them so sought after the man.

Due to human pressure on land and developmental activities, orchid wealth is depleted sadly and seriously. The epiphytic species of orchids are faced with the maximum danger due to cutting of host tree serving as a substrate. The natural process of extinction of orchids is also accelerated by the global warming as a result due to increasing aridity or decreasing moisture in the climate by deforestation and global warming cause a serious threat to the survivalists of epiphytic orchids.

The orchid seeds are unique in several respects, they are extremely small and usually undifferentiated. They are produced in large numbers ranging from 1300-40000 per capsule.

Each seed contains, an undifferentiated embryo composed of 80-100 cells without any functional endosperms. The entire embryo is covered by a membranous transparent loose air-filled seed coat or testa. The embryos are situated in the middle of the testa being attached to it by few fine strands. Testa cells are dead, vary in size and have longitudinal and transverse walls of different thickness which gives them a net like appearance, this is a marked character and is species specific. Since there is no cotyledon and no endospermic nutrient reserve for the embryo, the seed germination and the subsequent germination of the seedlings in orchids are extremely low. This process is activated in the presence of suitable fungus in nature. The fungus digests the seed coat while breaking the starch and cellulose into usable sugar for the embryo to ensure germination. The orchid seeds generally do not germinate in nature and the common practice is to reproduce asexually by pseudobulbs or cuttings. Thus, huge commercial demand of planting materials is difficult to achieve. However, successful in vitro germination of Cattleya, Laelia seeds on a sugar rich medium by Knudson (1921,1922,1925) laid the foundation of asymbiotic seed germination as an aid to orchid propagation. The culture of green seed pod has opened new vistas in conservation and commercialization of orchid genetic resources and has been successfully employed in a large number of commercially important taxa. Significantly, the orchid ovules are also capable of development in vitro, prior to being fully ripe and their capacity to germinate drops progressively as the seeds ripen (Arditti, 1967; Withner, 1943). The plantlets developed through embryo culture or seed culture is generally subjected to micropropagation for rapid multiplication. This technique is helpful for commercialization of orchids.

Seed culture technique and micropropagation is taken into consideration of this study. The seed culture technique helps in germination of plants where the normal growth is difficult. This technique ensures much better germination particularly in the genera where germination is not possible due to some abnormality within the seeds (Arditti *et al.*, 1982; Linden, 1980; McIntyre *et al.*, 1972; Pathak, 1989; Pathak *et al.*, 1992; Vij and Pathak, 1988; Vij *et al.*, 1995; Yam and Weatherhead, 1988). The orchid seeds are minute and exhibit very poor level of differentiation. The development of the embryo is suppressed as such that the embryo is arrested at a bulbous stage. In spite of being insubstantial embryo, they can germinate in nature if infected with a suitable fungus (Bernard, 1904). However, the germination can bypass the fungal requirement by supplying an appropriate sugar rich nutrient medium *in vitro* (Knudson, 1925). Significantly, the orchid ovules are also capable of development *in vitro*.

Micropropagation Technique:

The technique of orchid micropropagation has been originated since many years, its origin lies in several lines of research and came from the work of many well-known scientists, (Arditti and Krikorian, 1996). Method for the *in vitro* culture of isolated plant cells, leaves and organs or seeds are not difficult or complex but they do require some equipment and certain

skills and knowledge. More than one hundred years ago the method of propagating *Phalaenopsis* was viewed by simply placing an explant on a medium and cultured until it produced a plantlet or died. Micropropagation when done from a plantlet developed through any technique of plant tissue culture, it is called clonal micropropagation. Clonal micropropagation is very popular in commercial horticultural plants and orchids. The major advantages of micropropagation are i) propagation can be carried out under disease free conditions throughout the year, ii) sub-culturing of *in vitro* plantlets can be done after a defined intervals and each time one plantlet can give at least 3 to 4 nodal cuttings. This was necessary for meeting the huge demand of planting materials and also for survival of some wild orchids *in vitro* and for mass multiplication. After the survey of the orchids in the present study area twenty plants were selected for seed culture and also for micropropagation. Hence the objectives of the present study were set forth as:

- Production of plants in large scale through *in vitro* seed culture.
- Micropropagation of the plants developed through *in vitro* seed culture.

Conclusion:

Plant tissue culture and micropropagation is such a technique where orchids can be rapidly multiplied allowing the production of large quantities. This will also enable the future scientists to preserve the rare, endangered and medicinal species contributing to conservation efforts. Orchid seed pod culture and micropropagation plays a crucial role in advancing orchid cultivation, conservation and further research, thus helps eco-rehabilitation.

References:

1. Arditti, J. (1967). Factors affecting the germination of orchid seeds. Botanical Review, 33, 24–29.
2. Arditti, J., Clements, M. A., Fast, G., Hadley, G., Nishimura, G., & Ernst, R. (1982). Orchid seed germination and seedling culture – A manual. In J. Arditti (Ed.), Orchid biology, reviews and perspectives (Vol. II, pp. 243–370). Ithaca, NY: Cornell University Press.
3. Arditti, J., & Krikorian, A. D. (1996). Orchid micropropagation: The path from laboratory to commercialization and an account of several unappreciated investigators. Botanical Journal of the Linnean Society, 122, 183–241.
4. Bernard, N. (1904). Recherches expérimentates sur les orchidées. La germination des orchidées. Revue Générale de Botanique, 16, 405–475.
5. Bernard, N. (1909). L'éevolution dans La Symbiose. Les Orchideséet Leurs champignons commensaus. Annales des Sciences Naturelles, Paris, 9(1), 196.
6. Burgeff, H. (1959). Mycorrhiza of orchids. In C. L. Withner (Ed.), The orchids: A scientific survey. Ronald Press.

7. De, K. K., Majumdar, S., Sharma, R., & Sharma, B. (2006). Green capsule culture and rapid micropropagation of *Dendrobium chrysanthum* Wall., a horticultural and medicinal Orchid. Folia Horticulturae, 18(1), 81–90.
8. Handa, S. S. (1986). Orchids for drugs and chemicals. In Biology, conservation and culture of orchids (pp. 89–100). Affiliated East West Press.
9. Heywood, V. H. (Ed.). (1993). Flowering plants of the world. B.T. Batsford Ltd.
10. Kano, K. (1965). Studies on the media for orchid seed germination. Memoirs Faculty Agri. Kagawa Univ., 20, 1–68.
11. Kaushik, P. (1983). Ecological and anatomical marvels of the Himalayan orchids. Today and Tomorrow's Printers and Publishers.
12. Kirttikar, K. R., & Basu, B. D. (1935). Indian medicinal plants (2nd ed.). Bishen Singh Mahendra Pal Singh.
13. Knudson, L. (1921). Non-symbiotic germination of orchid seeds. Botanical Gazette, 73, 1–25.
14. Knudson, L. (1922). Further observations on non-symbiotic germination of orchid seed. Botanical Gazette, 77, 212–219.
15. Knudson, L. (1925). Physiological study of the symbiotic germination of orchid seeds. Botanical Gazette, 79, 345–379.
16. Knudson, L. (1951). Nutrient solutions for orchids. Botanical Gazette, 112, 528–532.
17. Linden, B. (1980). Aseptic germination of seeds of northern terrestrial orchids. Annales Botanici Fennici, 17, 174–182.
18. Mabberley, D. J. (1998). The plant (2nd ed.). Cambridge University Press.
19. Michel, E. E. (2002). Asymbiotic propagation of tropical terrestrial orchid species. In J. Clark, W. M. Elliott, G. Tingley, & J. Biro (Eds.), Proceedings of the 16th World Orchid Conference. Vancouver Orchid Society.
20. Mitchell, R. B. (1989). Growing hardy orchids from seed at Kew. The Plantsman, 11, 152–169.
21. McIntyre, D. K., Veitch, G. J., & Wrigley, J. W. (1972). Australian terrestrial orchids from seed. American Orchid Society Bulletin, 41, 1093–1097.
22. Miyoshi, K., & Mii, M. (1995). Enhancement of seed germination and protocorm formation in Calanthe discolor (Orchideaceae) by NaOCl and polyphenol treatments. Plant Tissue Culture Letters, 12, 267–272.
23. Pathak, P. (1989). Asymbiotic germination and clonal propagation of some commercially important and endangered orchids using tissue culture techniques (Ph.D. Thesis). Panjab University.

24. Pathak, P., & Vij, S. P. (1992). Ovule culture in *Goodyera biflora* (Lindl.) Hk.f.: A study in vitro. Journal of Orchid Society of India, 6, 49–53.
25. Rajbhandari, K. R., & Bhattarai, S. (2001). Beautiful orchids of Nepal. Kishore Offset Press.
26. Stoutamire, W. P. (1974). Terrestrial orchid seedlings. In C. L. Withner (Ed.), The orchids – A scientific survey (pp. 101–128).
27. Talukdar, A. (2001). Multiple shoot induction in *Dendrobium aphyllum* Roxb. Journal of Orchid Society of India, 15, 35–38.
28. Trivedi, K. P., Garg, D. S., Agarwal, J. P., & Garg, D. D. (1961). Ridhi-Vridhi, Jeevak and Rishbhak. Dhanvantari Vanaushadhi Bisheshank, Part I, 529–533.
29. Vij, S. P., & Pathak, P. (1988). Asymbiotic germination of saprophytic orchid *Cymbidium macrorhizon*: A study in vitro. Journal of Orchid Society of India, 2, 25.
30. Vij, S. P., Vaidya, N., & Kondo, K. (1995). Chromosomes of *Neottia listeroides* Lindl. (Orchidaceae), a reinvestigation. Chromosome Information Service, 58, 27–30.
31. Vij, S. P., Kaur, S., & Dev Manjari. (1997). Orchid breeding: Possibilities and achievements. Botanica, 47, 168–176.
32. Waterman, P. G., & Mole, S. (1994). Methods in ecology: Analysis of phenolic plant metabolites. Blackwell Scientific Publications.
33. Withner, C. L. (1943). Ovule culture: A new method for orchid seedlings. American Orchid Society Bulletin, 11, 261–263.
34. Withner, C. L. (1959). Orchid physiology. In The orchids – A scientific survey (pp. 315–360). Ronald Press.

AN OVERVIEW OF SUSTAINABLE DEVELOPMENT IN INDIAN PERSPECTIVE

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Abstract:

Sustainable development which deals with the reasonable management of natural, human and economic resources, aims to assure the essential requirements of humanity in the very long term, has become a matter of growing interest among researchers. India being 7th largest country in the world in terms of area covered and most populous country in the world is considered as a developing country. It possesses diverse kinds of ecosystems as well as several mega diversity zones and huge comparatively poor rural population. Sustainable development may play a very crucial role in the development of India. By protecting the human resources, natural resources, ecosystem and biodiversity, sustainable development, in terms of present generation may prove to be a very good practice to improve the economic conditions of people and boost up their quality of life. At the same time, by adopting this practice we can leave economically prosperous and nature friendly India and world for future generations.

Keywords: Sustainable Development, Economic Development, Biodiversity, Future Generation

Introduction:

Though the concept of sustainable development is continuously being revised, extended, and modified, according to United Nations it can be defined as "A sustainable development is the development which achieves the requirements of the present, without compromising the ability of the future generation to meet their own needs". Currently United Nation provides clarification regarding sustainable development as per 2030 agenda. The United Nation also refers three main components of sustainable development acting as its main pillars. In 2015 by considering the fundamental and common needs of the living organisms, the United Nation constituted 17 goals which is also known as the global goals. This will act to finish poverty, protect the planet, and make sure that by 2030 global population enjoy peace and prosperity. India is focusing largely on five aspects to attain sustainable development goals. India constitutes 2.4 percent of the earth's land, while sustaining 16 percent of the global population, which leads to an extremely unsustainable exploitation of natural resources for several generations. At present, India is facing rapid and extensive environmental degradation at alarming pace. Country's land and natural resources are experiencing huge pressure to nurture the massive overpopulation. Poverty and

exclusion, unemployment, climate change, conflict and humanitarian aid, building peaceful and inclusive societies, building strong institutions of governance, and supporting the rule of law are considered as the major challenges to sustainable development which are also global in character [1, 2].

Purposes and Goals of Sustainable Development (SDGs):

United Nations General Assembly in which India is a member country, in 2015 has set 17 goals for sustainable development in its 2030 agenda. These 17 Goals fall into 169 heads which encompass all aspects to attain the sustainable development [3].

The SDGs and their main focus area summarized below:

Sl. No.	Goals	Focus Areas
SDG 1	**No Poverty**	Elimination of poverty in all forms is the main purpose of this goal. It also plans to provide basic requirements to all the people.
SDG 2	**Zero Hunger**	Removal of all dimensions of malnutrition and boost the agricultural productivity is the focal point of this goal.
SDG 3	**Good Health and Well-being**	It aims in decreasing maternal mortality ratio and fortifies the prevention and treatment measures for premature mortality.
SDG 4	**Quality Education**	This goal ensures quality education for all devoid of any discrimination.
SDG 5	**Gender Equality**	This goal ensures equal rights in liberty, education, political empowerment, to live in nonviolent society for women.
SDG 6	**Clean Water and Sanitation**	This goal is all about to provide clean water and to extend proper sanitation facilities.
SDG 7	**Affordable and Clean Energy**	This goal is aiming to make clean resources and sources of energy accessible to all at reasonable rates.
SDG 8	**Decent Work and Economic Growth**	Reaching economic growth in sustainable ways is the eventual goal of sustainable development. So, everybody should get work opportunities. In this connection, to end the problem of unemployment adequate number of industries and MSMEs should be established.
SDG 9	**Industry, Innovation, and Infrastructure**	This is an approach to endorse sustainable industrialization by means of environment friendly techniques to enhance manufacture. Financial assistance should be extended for the purpose of building small scale industries.
SDG 10	**Reduced Inequality**	This goal helps to finish all kinds of inequalities within the country and among the countries.

SDG 11	**Sustainable Cities and Communities**	Natural heritage must be preserved during the establishment of cities and communities.
SDG 12	**Responsible Consumption and Production**	Policies should be taken to avoid overuse and to encourage reuse, recycle and reduce techniques.
SDG 13	**Climate Action**	This particular goal is all about intimidation of climate hazards and requirement to fix it as early as possible. Hence, this goal focuses on to make people aware about the risk of climatic changes and take on necessary measures to protect it.
SDG 14	**Life below Water**	Marine pollution must be reduced to safeguard underwater lives. Special measures should be taken to prevent overfishing and scientific methods must be adopted to improve the aquatic life.
SDG 15	**Life on Land**	Conservation of wildlife, ecosystem and the whole biodiversity is the prime essence of sustainable development. This goal focuses on restoration of terrestrial life, maintaining the quality of soil, reduction in degradation of land due to deforestation and increasing the capacity of natural resources to facilitate sustainable development.
SDG 16	**Peace and Justice Strong Institutions**	All types of violence like trafficking, abusing and exploitation of any age group must be abolished. For this purpose, legal framework must be strong enough and justice must be accessible to all.
SDG 17	**Partnerships to achieve the Goal**	This is the main aspect as these goals cannot be achieved by only one nation or institution or isolated measures taken separately by different countries. To fulfill these goals the collective and inclusive efforts of all countries are required.

Pillars of sustainable development: The sustainable development comprises 3 main pillars. This are-

Social Development:

It is the capacity of a community to develop measures which not only fulfill the requirements of its present generations but also help to sustain the ability of upcoming generations to keep up a healthy community, quality of life, education, equal opportunities, law and ethics, environmental law, public involvement in social development [3, 4].

Environmental Development:

It deals with the type of development that reduces environmental problems and achieves the requirements of the current generation without harming or disturbing the ability of the future generation to attain their own needs [3, 4].

Economic Development:

Sustainable development has several economic aspects. Sustainable development focuses on creating sustainable enhancement in the quality of life of entire population. Sustainable development also helps to increase economic growth and fulfill the basic requirements of people resulting in the improvement in their standard of living. Thus, it helps to increase in economic development. The quality of life and economic development of future generations largely depends on the natural resources and quality of the environment including the quality of air, water and land [3, 4].

Sustainable development in Indian Context:

Environment and environment related issues have long been considered as an essential part of Indian culture which has been reflected in key Government policies and Constitution of India. The Article 21 of Indian Constitution refers the Right to Life which mentions right to clean environment, right to livelihood, right to live with pride and a number of other associated rights. The National Environment Policy of India is "Only such development is sustainable, which respects ecological constraints and the imperatives of social justice." Government of India considering sustainable development a crucial one made its important presence in The Seventh Five Year Plan (1985-1990) [2, 3].

Measures of Sustainable Development:

Strategies for sustainable development in India are given below:

(i) Technology

Technologies which will be used should be locally adaptable, resource efficient, biodegradable and culturally suitable. The technologies should be designed in such way that they will consume minimal resources and produce least waste [2, 3].

(ii) Reduce, reuse, and recycle approach

This 3-R approach promotes minimum resource use; reuse them as much as possible and finally recycling the materials in such a way that it can achieve the goals of sustainability [2, 3].

(iii) Promoting environmental education and awareness

Environmental education and awareness will help people to change their thinking pattern and approach towards the planet earth and the environment. Environment related studies should be introduced right from the school level to boost this awareness campaign [2, 3].

(iv) Resource utilization as per carrying capacity

The concept of carrying capacity, unlike other animals, becomes much more complex in human beings as they not only need food to live, but also many other things are required to maintain their quality of life. When the carrying capacity of a system is breached, environmental degradation begins and doesn't stop until it reaches a point of no return. In order to attain sustainability it is essential to utilize the resources depending upon the supporting capacity and assimilative capacity of a system [2, 3].

(v) Improving quality of life including social, cultural and economic dimensions

Development must focus on both the rich and poor section of the society and all the beneficial measures must be equally shared between them. The tribal, ethnic people and their cultural heritage should also be conserved [2, 3].

India's status:

The Sustainable Development Goals of India Index released by NITI Aayog and the United Nations in December, 2018 show that the Indian Nation has a score of 58%, which is slight beyond the halfway mark to achieve the target of 2030 agenda. In a ranking system of 0-100 for all the Indian states and Union territories, the data show status of different states. Himachal Pradesh, Kerala and Tamil Nadu achieved top performance with 69%. Assam, Bihar and Uttar Pradesh are lagging behind with 0-49%. In achieving zero hunger goal Goa, Kerala, Manipur, Mizoram and Nagaland were emerged as top performers [3].

Steps taken by government: The following steps have been taken by Government of India for successful achievement of sustainable development goals:

Ratifying Paris agreement, the clean development mechanism projects in India, state action plans on climate change, coal cess and the national clean energy fund, national adaptation fund for climate change [3].

Challenges encountered in sustainable development:

Excessive Population, poverty among large section of population, unequal distribution of resources among poor and rich, shortage of drinking water, excessive consumption of energy especially those derived from fossil fuel, deforestation etc pose great challenges in sustainable development [2].

Conclusion:

The vision and concept of sustainable development is not only for the benefit of present day world but also it encompasses the efforts taken today for benefit and wellbeing of future world. Future generations on earth may face extreme threats of extinction or their quality of life may decline severely if efforts to establish successful sustainable development is failed today. For this reason, all the stakeholders, entire global population and all nations of the world must work collectively for establishment and finally successful achievement of sustainable

development. Ultimately, the goal will become true when all the major three aspects of sustainable development can be achievable throughout the world.

References:

1. Tushar Kumar Gandhi and Shailendra Kumar Sharma. (2012). Study of environmental imperatives of sustainable development in India. *International Journal for Environmental Rehabilitation and Conservation*, *III*(2), 72–79.
2. Vinati S. Dhankhar. (2016). India and sustainable development. *International Journal of Computing and Corporate Research*, *6*(2), March-April. 2249054XV6I2032016-89.
3. S. Srimathi. (2019). Sustainable development of India – an overview. *JETIR*, February 2019, *6*(2). ISSN: 2349-5162. www.jetir.org.
4. Rashmi R K and Thippesh K. (2023). Sustainable development in Indian perspective. *Quest Journals. Journal of Research in Humanities and Social Science*, *11*(7), 195-197. ISSN (Online): 2321-9467. www.questjournals.org.

AQUAPONICS: AN ADVANCED INTEGRATED FARMING

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Abstract:

A nation's robust economy is based on its agricultural industry. The two recent, massive processes of urbanisation and population increase have made the growing disparity between supply and demand more problematic. Agricultural land is decreasing while demand of food products is continuously increasing. To solve this problem researchers are looking for ways to produce more using less resource. Aquaponics or vertical integrated farming is one such alternative, though still in its developing stage towards perfection. It is the bio-system that integrates recirculated aquaculture with hydroponics that creates a symbiosis between fish and plants. This technology could thus be used in urban areas or regions with scarcity of other resources like water. With research, training and awareness aquaponics may revolutionize agriculture by promoting resource efficiency, food security and environmental sustainability.

Keywords: Aquaponics, Integrated Farming, Food Security, Environmental Sustainability

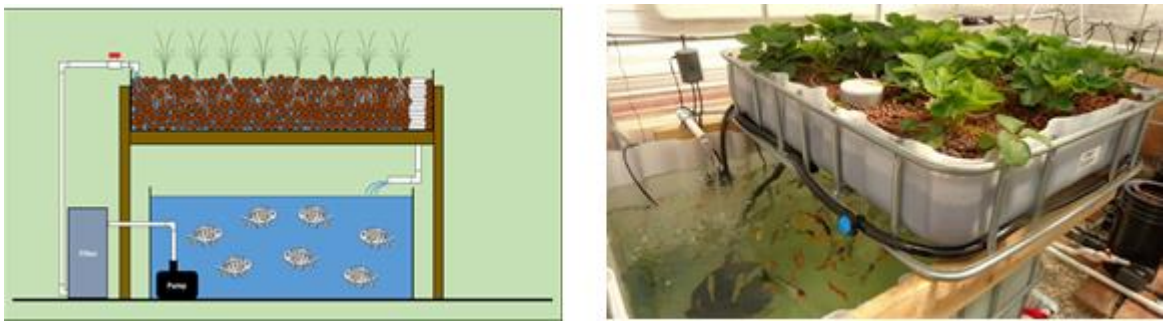
Introduction:

Aquaponics is an agricultural system that combines aquaculture and hydroponics for production of fish and plants in a more sustainable way. This food production system raises aquatic animals like fish, crayfish, snails and prawn along with cultivating plants in water (without use of soil). The development of modern aquaponics is attributed to German scientist Ludwig C.A. Naegel in 1977 for his publication of 'Combined production of fish and plants in recirculating water'.

In aquaponics farming, plants are cultivated in a grow bed and fishes are placed in a fish tank. The nutrient rich water of fish tank feeds the plant grow bed where billions of bacteria break toxic ammonia of the waste water into less harmful nitrates that the plants absorb and their roots filter out water before refilling the fish tank. At this postpandemic era, the aquaponics system represents an efficient green farming and eco-friendly alternative to sustainable agricultural production [1].

The principle of the system consists of - aquatic effluents (resulting from uneaten feed and excreta that accumulate in water), due to closed-system recirculation in most cases of aquaculture, becomes toxic to aquatic animals in high concentration but this contains nutrients essential for plant growth. In recirculatory aquaculture systems large quantities of fish are raised in small volumes of water by treating the water to remove the toxic waste products and thus reuse again [2] Nitrifying bacteria convert toxic ammonia and nitrite into less toxic nitrate in

specialized biofilters, but, disturbances to the biofilter or ammonia production that exceeds the capacity for the biofilter, toxic waste can accumulate to levels that are deleterious to the fish and can't be removed [3]. If by introducing plants, the toxicity is removed and the said nutrients could be used, the fresh water could be returned to aquaculture. Removal of solid wastes and conversion of toxic substances like ammonia into nontoxic nitrates are the most important intermediate steps that helps in the successful coexistence of aquaculture and vegeculture on each other. An effective aquaponic system thus require solid waste removal, neutralization and oxygenation of the aquatic medium that is essential for both the animals and the plants. Hence, the main objective of such farming is to grow plants using aquatic animal waste.



Representation of a simple aquaponics system

System set up

To set up a basic aquaponic system one needs the following typical components:

- **Space** (land or rooftop)
- **Rearing tank** for raising fishes or other aquatic animals
- **Settling basin** for catching uneaten food and settling out fine particulates
- **Biofilter**, where nitrification bacteria can grow and convert ammonia into nitrates
- **Hydroponic subsystem**, where plants are grown by absorbing nutrients from the water and
- **Sump** or the lowest point in the system where the water flows to and from which it is pumped back to rearing tanks.
- **Plant and animal species, water and electricity**

Types

Modern aquaponics can be classified according to different hydroponic form and the fact whether the water cycle is closed or not. Media-Based Growing Bed (MBGB), Deep Water Culture (DWC), Nutrient Film Technique (NFT) are the common types. The three have their own characteristics:

- **Media-based growing bed aquaponics system**: This system uses a growing medium, such as bed of gravel or expanded clay pellets, to support the plant roots while providing a surface for beneficial bacteria to live. This media acts as a biological filter that helps maintain water quality.

- **Nutrient film technique (NFT) aquaponics system**: In this system, a thin film of nutrient-rich water continuously flows over the plant roots, providing them with the necessary nutrients.
- **Deep water culture (DWC) aquaponics system:** This is also called the raft system and involves suspending the plant roots directly in a nutrient-rich water solution.

MBGB is space-saving but difficult to maintain and clean. DWC is easier to clean and has a higher removal rate of nitrate, but it requires extra biofilters, aeration devices, and a larger volume of water. NFT has higher efficiency for water use but lower yield [4].

Advantages of aquaponics farming over other agricultural systems:

- This is more sustainable, intensive and carbon-neutral, high yielding (nearly six times more than traditional farming) system
- cultivation could be accomplished all year-round which is one of the biggest benefits
- It can offer multi-channel income source for farmers
- It is water efficient, accounts for 90% less water usage than conventional farming Similarly, does not require soil or large spaces of land and is a great option for anyone with limited space
- As practiced in a controlled environment it has fewer chances of pests and diseases
- Almost no artificial fertilizer is needed since fish waste is used as the source of natural fertilizer for plants
- Efficient and reusable resources decrease the operating cost of aquaponics farming

Disadvantages of aquaponics farming:

Challenges to the domestication of the system, however, include moderately high start-up capital, the need for stable electricity to operate the system, nutrient availability, as well as treatment of diseases in the system.

- Aquaponics farming system is expensive to set up
- It requires daily maintenance
- Proper knowledge of fish, bacteria and plants are required for efficient production
- This farming requires reliable electricity source

Global status of aquaponics farming

Aquaponics is a relatively modern concept and still under trial. It is being tested out in places where the unfavorable weather does not allow crop growth. However, it is yet to become a universal solution.

Interestingly, rearing fishes in paddy fields or growing rice and fodder on floating wooden rafts in various provinces of China during 13^{th} century or earlier was a common practice. During 1970s to the '90s. several farms and institutes in North America developed modern aquaponics systems. The Urban Farming Company in Switzerland has created a method of

rooftop based aquaponic systems aiming to offer fresh, sustainable produce to local urban areas. In 2018 the European Aquaponics Association was established. At the Bangladesh Agricultural University, M.A. Salam has created plans for low-cost aquaponics system to provide organic produce to people of Bangladesh. Aquaponic systems are also growing in countries like Malayasia and India. Various non-profit organizations and research institutes globally are involved in implementation and improvement of this practice as well.

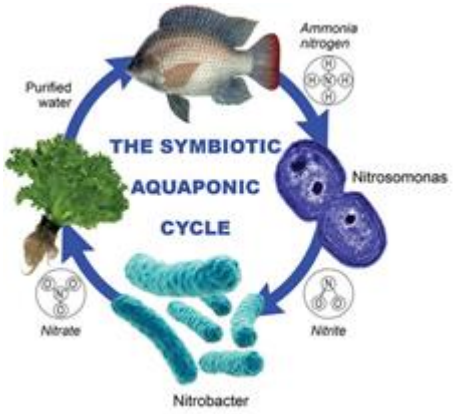
Scenario in India

In India Aquaponics system is still evolving. It is becoming popular with individuals, entrepreneurs, educators, missions and governments interested in modern farming. This system is commonly used in resource limited and urban areas. Vegetables and horticulture plants with low to medium nutrient requirement are grown along with fishes. India is known to lead in freshwater fish production using traditional methods; however, Aquaponics system may produce up to five-six times the quantity of fish in same area per year with good crop of vegetables in addition. Even if the system requires high initial investment, the recurring cost is less and one would get reasonable return. Establishment and operation of such units is quite demanding in our country, in terms of technology, techniques, biology of life forms and water quality parameters.

Beneficiaries of such farming may include women self-help groups (SHGs), fisherman societies and entrepreneurs. Technical supports are provided by several technology service provider and department of Fisheries of the state government whereas financial assistance in form of subsidy from government was provided to the beneficiaries.

To set up the aquaponics systems one needs to select and arrange different components wisely. Tilapia, ornamental fish, catfish, and leafy vegetables are the most common fish and plant species for aquaponics cultivation [5]. Hydroponic types, fish and plant density [6], flow rate, water quality parameter, feeding and planting strategies are important factors affecting yield. The components can be broadly divided into living and non-living:

Living components



a) Aquatic animals to be reared (fish, shellfish etc.): Targeted fish species are Monosex Tilapia (*Oreochromis niloticus*), Pangasius (*Pangasiandon hypophthalmus*) or any species that can tolerate high density stocking.

b) Plants to be cultivated: any kind of plants that are suitable to grow in that region and require low to medium nutrient are good targets for cultivation. Leafy vegetables like mint, basil, lettuce, spinach or fruit plants like tomato, chilly, brinjal, ladies' finger, lemon, gourds etc. and also horticultural plants of various kinds are grown depending on the seasonal and climatic condition as per requirement.

c) Biofiltering bacteria: Beneficial bacteria play important role in the optimal development of species in aquaponics. They transform fish excrement and food debris into macronutrients and micronutrients that plants can assimilate. Ammonium nitrogen undergoes conversion to nitrite through biological nitrification by ammonia oxidizing bacteria such as *Nitrosococcus*, *Nitrosospira* and *Nitrosomonas*. Then nitrite-oxidizing bacteria such as *Nitrobacter*, *Nitrospira* etc. transform toxic nitrite to relatively harmless nitrate.

Non-living components

a) Water: Water is the main medium for aquaponics and hence the success of such integrated farming depends on quality of the water used. For this reason, several parameters of water, like temperature, dissolved oxygen, pH, salinity, alkalinity etc. are to be monitored and optimal levels are maintained on a regular basis.

b) In addition, other important non-living components are - Fish Pond/tank with proper technological arrangements, plant grow-beds, moving bed biofilm reactor and filtration unit, pumps and oxygenation tools, electricity supply and pipelines, sand and gravel, fish feed, cleaning apparatus, transportation arrangement etc.

Government, non-government organization as well as several companies in India are helping individuals in setting up this sustainable agriculture practice for domestic as well as commercial purposes. Researchers are also busy developing newer more efficient systems. Aquaponics in India is being implemented in the following forms:

- Urban backyard or roof top Gardens: Rooftop gardens and aquaponics vertical farming systems allow the urban population to grow fresh vegetables and fish in a controlled environment in a limited space. These contribute to local high-quality food production in cities.
- Organic farming: Aquaponics system is an attractive option for farmers who aim to produce organic, chemical free food. The farming could be open or within net house or polyhouse. The closed ways, though more expensive option, yield more profitable as the production is less attacked by pests and diseases.
- High value crop production: A wide range of high value crops including leafy greens like lettuce, herbs, strawberries and exotic vegetables can be grown using this method. These crops have high demand in urban areas. Farms in different states of India has opted for this system and are cultivating such exotic plant products in addition to various fish species. Farmers thus could increase their profitability and diversify their income.
- Farming in adverse environmental conditions: Many regions in India face water scarcity (drought prone areas) or with water unsuitable for growing different plant products (coastal areas). Since aquaponics conserve water by recycling it within a closed-loop system it could be an ideal option of farming in such areas. It has also been suggested [7]

instead of open fishing in brackish water fisherman and farmers of Sundarbans may opt for aquaponics system to culture prawn and other aquatic organisms along with mangrove cultivation. That would help conserve both the animals and mangrove plants that are known to be threatened by various means. This thus could act as an example of conservation of water, plant and animal by a single system.

Rooftop garden

Backyard garden

Aquaponic farming in India presents a sustainable approach to addressing the challenges faced by traditional agriculture. However, this system is progressing in a low pace and the reasons for such stagnant growth rate is the high capital requirement. The increasing urbanization and population growth demand high global food production but the land under cultivation is decreasing so is water resource. This problem of increasing gap between demand and supply is needed to be solved. With further research, training, awareness towards more cost-effective innovative techniques, aquaponics has the potential to revolutionize Indian agriculture by promoting resource efficiency, food security and environmental sustainability.

A recent study identified [8] prolific authors, journals, and affiliations in the field of aquaponics. The USA, Europe, and some Asian countries, especially China and India, seemed to be the most innovative regions with significant research in this area. The Fisheries Science Division of the Indian Council of Agricultural Research, New Delhi in collaboration with its 8 Fisheries Research Institutes launched the National Campaign on "System Diversification in Aquaculture" in February 2021 where speakers stated that the Hi-end novel technologies like RAS, Biofloc, Aquaponics, FIMTA and Flow-through, etc., are increasingly attracting the attention of Young Entrepreneurs. [9].

In order to meet human demand for aquatic products, total global aquatic production increased by 27.5% in 2010–2018, during which aquaculture and capture output increased by 29.8% and 10.4%, respectively (FAO, 2018). During this time of shrinking resources of land and water, growing population, urbanization and change in life style aquaponics seems to have immense potential for fish and plant production in urban, suburban as well as rural settings. Since it is an environmentally-friendly aquaculture and planting system, aquaponics has attracted

attention in fisheries, agriculture, and ecology. At present, the aquaponics development is facing many pressures from management and market. Future needs more in-depth research in the system construction, management of nutrient and microbial community structure to provide a theoretical basis [10]. Incorporating aquaponics into the category of green infrastructure can provide it with research directions, development environment, and policy support.

References:

1. Okomoda *et al.* (2023). Aquaponics production system: A review of historical perspective, opportunities, and challenges of its adoption. *Food Science & Nutrition*, *11*(3), 1157–1165.
2. Rakocy, J. E., & Hargreaves, J. A. (1993). Integration of vegetable hydroponics with fish culture: A review. In J. Wang (Ed.), *Techniques for modern aquaculture*. American Society of Agricultural Engineers.
3. Yildiz, H. Y., Robaina, L., Pirhonen, J., Mente, E., Domínguez, D., & Parisi, G. (2017). Fish welfare in aquaponic systems: Its relation to water quality with an emphasis on feed and faeces–a review. *Water (Switzerland)*, *9*, 9–17. https://doi.org/10.3390/w9010013
4. Goddek, S., Delaide, B., Mankasingh, U., Ragnarsdottir, K. V., Jijakli, M. H., & Thorarinsdottir, R. (2015). Challenges of sustainable and commercial aquaponics. *Sustainabilty*, *7*, 4199–4224.
5. Love, D. C., Fry, J. P., Genello, L., Hill, E. S., Frederick, J. A., Li, X., & Semmens, K. (2014). An international survey of aquaponics practitioners. *PLoS ONE*, *9*, e102662.
6. Surnar, S. R., Sharma, O. P., & Saini, V. P. (2017). Nutrient harvesting through aquaponics: Growth of labeo rohita and production of plant (spinach). *J. Exp. Zool. India*, *20*, 389–396.
7. Chakravartty, D., Mondal, A., Raychowdhury, P., Bhattacharya, S. B., & Mitra, A. (2017). Role of aquaponics in the sustenance of coastal India – Aquaponics is a solution for modern agriculture in ecologically sensitive Indian mangrove Sundarbans: A review. *International Journal of Fisheries and Aquatic Studies*, *5*(2), 441–448.
8. Basumatary, B., Verma, A. K., & Verma, M. K. (2023). Global research trends on aquaponics: A systematic review based on computational mapping. *Aquaculture International*, *31*, 1115–1141.
9. ICAR. (n.d.). https://icar.gov.in/node/12782
10. Hao, Y., Ding, K., Xu, Y., et al. (2020). States, trends, and future of aquaponics research. *Sustainability (Switzerland)*, *12*, 1–14. https://doi.org/10.3390/SU12187783

ANTHROPOCENE AQUATIC BODIES: THREATS AND CONSERVATION

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Abstract:

Water is one of the vital needs of all living things. Humans need water in their daily activities like drinking, bathing, washing, cooking, etc. Presently, anthropogenic activities bring contamination and subsequent pollution to our varied ecosystems, especially aquatic. Poor quality of water is unfit for drinking and other activities. Polluted water affects aquatic life as well as the surrounding environment.

The quality of water of an aquatic body is usually described by its physical, chemical, and biological properties. Hence it becomes essential to find the suitability of water for the purpose of its use like drinking, irrigation or industry etc. The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life.

Assessing the quality of an aquatic body requires knowledge about the different physicochemical parameters such as colour, temperature, hardness, acidity, pH, odour, chloride, sulphate, dissolved oxygen, biological oxygen demand, chemical oxygen demand, alkalinity etc. All these factors interacting among themselves determine the complex community structure. Maintenance of a good quality water environment requires pollution prevention and water reuse in combination with the recycling of nutrients in a controlled manner, especially in an urban context, that can help in biodiversity conservation as well as enhance the socioeconomic status of the surrounding people.

Keywords: Physicochemical Parameters, Variations, Seasonal, Fresh Water, Pollution.

Introduction:

Water is the most precious resource on the earth, without which life would not have existed. A water body not only affects the physical and climatic environment in its nearby areas but also affects the socio-economic conditions of the area[1]. Variability in physicochemical parameters determines the distribution of the aquatic organisms in different aquatic habitats according to their adaptation that allows them to live in a specific habitat[2]. A stagnant or lentic water body is more vulnerable to pollution as self-purification processes are very poor in them[3]. Any contamination or pollution of an aquatic body affects greatly the flora and fauna and also human health if the water is used for domestic purposes[4,5]. In the last few decades, there has been a vigorous increase in the demand for freshwater due to the fast growth of the human population

and the accelerated pace of industrialization on earth. According to WHO, about 80% of all diseases in human beings are caused due to contaminated water[6]. Water-borne disease infections occur due to consumption of polluted water[7]. Discharge of urban, industrial, and agricultural wastes with nutrients like phosphorous, nitrogen and potassium accelerate the process of eutrophication[8].

The proper functioning of an aquatic ecosystem depends on the physicochemical characteristics of its water [9]. Variability in physicochemical parameters is responsible for the diversity and distribution of organisms according to their adaptation, which allows them to survive in a specific habitat [10]. It is essential to assess water quality. Temperature, dissolved oxygen, pH, free carbon dioxide, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), phosphate, phosphorus, nitrate-nitrite, and total alkalinity are significant parameters used to study the water quality [11]. Maintaining the quality of aquatic ecosystems represents one of the most tough challenges facing global society in the twenty first century.

Some physicochemical parameters as indicators of water quality

Commonly analyzed physicochemical parameters for the study of aquatic body involve the study of following parameters:

Temperature:

The water temperature controls the rate of all chemical reactions and affects fish growth, reproduction and immunity. Drastic temperature changes can be fatal to fish. The rates of chemical and biological processes depend on temperature. Temperature affects the oxygen content, rate of photosynthesis, metabolic rates of water organisms and sensitivity of organisms to toxic wastes, parasites, and diseases[12].

pH:

The pH of is measured as a negative logarithm of H^+ ions for many practical practices. Mainly drinking water pH lies from 4.4 to 8.5. The pH is most important in determining the corrosive nature of water. The lower the pH value the higher is the corrosive nature of water[13].

Turbidity:

The suspension of particles in water interfering with the passage of light is called turbidity. Turbidity is caused by a wide variety of Suspended particles. As per IS: 10500-2012 the acceptable and permissible limits are 1 and 5 NTU respectively[13].

Total Dissolved Solids (TDS):

The difference between total solids and suspended solids is used to determine the filterable solids with the help of filtrate. The acceptable and permissible limits as per IS: 10500-2012 are 500 and 2000 mg/l respectively[13].

Dissolved Oxygen:

The presence of dissolved oxygen is essential to maintain the higher forms of biological life and to keep the proper balance of various pollutions thus making the water bodies healthy. The chemical and biochemical processes undergoing in the water body are largely dependent upon the presence of oxygen. The permissible value recommended for DO is 5mg/L as per Indian standard[14].

Free Carbon Dioxide:

In water, CO_2 may exist in three states- 1. Unbound state simply dissolved in water known as free CO_2; 2. As bicarbonate ions (HCO_3^-) known as half bound state; 3. As carbonate ions (CO_3^{2-}) known as a fixed state. Free CO_2 has interdependence with pH and bicarbonate-carbonate equilibrium.

Biological Oxygen Demand (BOD):

BOD is a measure of the dissolved oxygen consumed by microorganisms during the oxidation of reduced substances in waters and wastes. BOD directly affects the amount of dissolved oxygen in aquatic bodies. The greater the BOD, the more rapidly oxygen is depleted in the water that causes aquatic organisms become suffocate, stressed leading to death. In chlorinated waters, it is essential to neutralize the chlorine with sodium thiosulphate[15].

Electrical Conductivity:

Conductivity is the ability of water to carry an electrical current and depends on the presence of ions their total concentration, mobility, valence, relative concentration, and the temperature of the liquid. Solutions of most inorganic acids, bases, and salts are relatively good conductors[16].

Total Hardness:

As per IS: 10500-2012 Desirable limit and Permissible limit for hardness lie between 200 to 600 mg/l. The effect of hardness varies in scale in the different purposes of the use of water. Sources are dissolved calcium and magnesium from soil and aquifer minerals containing limestone or dolomite. The hardness value of drinking water is classified in terms of equivalent $CaCO_3$ concentration as follows: Soft - 0-60mg/l, Medium - 60-120 mg/l, Hard - 120-180 mg/l, Very hard - >180 mg/l[16].

Sulphate:

Natural water contains sulphate ions and most of these are soluble in water. Most of the sulphate ions are produced by the oxidation process of their ores, they are also present in industrial wastes. As per IS: 10500-2012 the desirable limit for Sulphate is 200 and 400 mg/l in the Permissible limit[13].

Nitrate:

Nitrate is found in raw water and mainly in the form of N_2 compound (of its oxidizing state). The chief sources of nitrate are fertilizer and chemical factories, the matter of animals, kitchen waste or domestic and industrial discharge. As per IS: 10500-2012 Desirable limit for nitrate is max.45 and no relaxation is the permissible limit[13].

Total Alkalinity:

Alkalinity is the total of components in the water which tend to elevate the pH to the alkaline side of neutrality. It is measured by titration with standardized acid to a pH value of 4.5 and is expressed commonly as milligrams per liter of calcium carbonate (mg/l as $CaCO_3$). Commonly occurring materials in water that increase alkalinity are carbonate, phosphates, and hydroxides[16].

Chloride:

All type of natural and raw water contains chlorides. It comes from activities carried out in the agricultural area, Industrial activities, and from chloride stones. As per IS: 10500-2012 Desirable limit for chloride is 250 and 1000 mg/l in the Permissible limit[16].

Phosphate:

Phosphorus is an important plant nutrient and most often controls aquatic plant growth in freshwater. Normally groundwater contains only a minimum phosphorus level [17].

Chemical Oxygen Demand (COD):

COD is a measure of the oxygen required for complete chemical oxidation of organic matter with the help of a strong chemical oxidant. High COD results in oxygen depletion due to large scale microbial decomposition to a level detrimental to aquatic life[17].

Adverse effects of Contaminated Aquatic Ecosystems due to human activities:

Human activities like deforestation, filling and construction of canals, dams, roads and bridges, agricultural and industrial and domestic activities lead to contamination of water bodies.[18]

In most developed countries, agriculture is one the major factor in the depletion aquatic ecosystems. In the European Union, 38% of aquatic bodies are mostly under agricultural pressure. In the USA, agriculture is the leading source of pollution in water bodies.

Agrochemicals:

Population increase has increased the food demand, which results in the increase in the use of agrochemicals in the fields. Agrochemicals in the form of fertilizers, pesticides, herbicides and plant hormones diffuses into the aquatic bodies. This contributed to the more pollution in the water bodies.

Table 1: Sources and entry route of pollutants into aquatic environment:

Type of pollutants	Source	Route of entry
Organic pollutants	Domestic sewage, like wastes from cattle farm and wood pulp mills etc.	Inflow into the water bodies by run-off from drains, gutter.
Infectious disease agents	Domestic sewage, human and animal wastes	Washing, swimming or working in paddy rice fields and on irrigated land
Plant nutrients such as nitrate, phosphate and others	Fertilized farm lands, ashes and detergent	Run-off from fertilized farmlands
Pesticides (insecticides and herbicides)	Organic and inorganic chemical	Run-off from pesticides associated with farmlands
Eroded sediments	Deforestation and accelerated soil erosion	Soil erosion
Industrial effluents which include DDT, dyes, mercury, cadmium	Textile factories and other industries,	Human discharges
Other solid wastes	Metals, plastics, artificial fibers etc	Dumping by humans due to mismanagement of waste disposal
Petroleum products	Drill cuttings, drilling mud , accidental discharges of crude petroleum, refinery effluents which include oil and grease, phenol, cyanide, sulphide, suspended solids, chromium, and biologically oxygen demanding organic matter	Petroleum, exploration, exploitation, refining, transportation, storage, marketing, use and ruptured oil pipelines

Nutrients:

Fertilizers are used at a higher rate than they are fixed by the soil, and or taken up by the plants or when they are taken off through surface runoff from the soil surface to water bodies and leads to water pollution. Excess nitrogenous fertilizers and phosphate fertilizers enter into groundwater or reach into surface aquatic bodies through surface runoff. This results in the nutrient enrichment eutrophication of lakes, reservoirs, ponds, and coastal waters, which leads to

more growth of aquatic plants—algae blooms that destroy other aquatic plants and animals. The excessive nutrients may also increase the adverse effects on health.

Pesticides:

Pesticides such as insecticides, herbicides, and fungicides are applied in fields in several nations and run-off into aquatic ecosystems and pollute the water bodies. They contain carcinogens and other poisonous substances which may destroy aquatic life. These long chemicals often enter the food chain causing to bio-accumulation and bio-magnification.

Salts:

Salinization is caused by transporting accumulated salts into receiving water bodies by drainage water. Highly saline waters change the geochemical cycles of elements such as carbon, iron, nitrogen, phosphorus, silicon and sulphur and have impacts on ecosystems. Salinization can affect freshwater organisms by causing alters within species and community composition.

Sewage:

The large volume of waste enter into the aquatic environment is sewage. Sewage contains industrial wastes, municipal wastes and domestic wastes that include wastes from baths, kitchens, washing machines and also faecal matter. Fresh water bodies serve as good sinks for the discharge of wastes. It has resulted in extensive ecological depletion of water quality and availability. Sewage effluent contains a variety of pathogenic organisms which may cause in the transmission of waterborne diseases when this water is used for domestic and other purposes and thus is harmful to human health and the community at large.

Heavy Metals:

Heavy metals get incorporated into the aquatic ecosystem due to natural and human activities. It may be due to direct discharges or through indirect routes such as atmospheric precipitation and surface run-off. The main pollutants consist high levels of Lead, Cadmium, Mercury, Chromium, Copper, Zinc, etc. in the aquatic body. Cadmium, Arsenic, Copper, Mercury, and Zinc are the potent heavy metals that have severe environmental impact. These metals enter into the aquatic body due to various agricultural or industrial activity through storm water and wastewater discharges. These pollutants are ecologically highly significant because these tend to accumulate in the water body and enter into the food chain.

Eutrophication:

Eutrophication is one of the main causes of destruction of many freshwater and marine ecosystems in the world. It is characterized by excessive algal growth due to the more availability of limiting growth factors required for photosynthesis. The impact of cultural eutrophication is the production of dense blooms of noxious, bad-smelling phytoplankton which decrease water transparency and decrease water quality. Algal blooms inhibit penetration of

light, limit the growth and cause death of plants and the chance of prey by predators which need light to catch prey.

Plastics and microplastics:

The stor ing of plastic debris in aquatic environment is one of the most important but least studied. Plastics leads to significant benefits of the society but due to its durability, unsustainable and inappropriate use, plastics accumulate extensively in the natural habitats. And has practically entered the global marine ecosystem. The main source of this pollution is the single-use plastics (plastic bags and micro beads). Recently, it has been revealed that microplastics in the marine environment may lead more threat than macroplastics.

Oil spills:

An oil spill is defined as the discharge of liquid petroleum hydrocarbons into the environment, mainly in the marine ecosystem caused by human activity. Environmental pollution caused by an oil spill is detrimental. This is because petroleum hydrocarbons are harmful to all aquatic and terrestrial organisms.

Prevention and Possible Solutions:

Water pollution can be minimised from a personal level to national and international level. Every people have a duty to reduce water pollution. There are various sources of water contamination. Thus, various preventive measures can control of water pollution.

- We should not throw the rubbish in places like the beach, riverside and water bodies rather we put it in a dustbin.
- Water should be used wisely and we should stop the running tap water when not in use.
- We should not throw oils, plastics, paints, chemicals and medicines down the sink drain, or the toilet.
- We should use more environment-friendly and safe cleaning liquids at home and other public places.
- Use of pesticides and fertilizers should be reduced rather organic fertilizers should be promoted.
- We should implement water quality laws to protect our environment.
- Proper use and disposal of chemicals prevent the aquatic environments from contamination.
- Detergents use should be minimised because high phosphate content of it can create eutrophication of lakes.
- We should control storm water run-off as while flowing over surfaces, it carries debris, chemicals, sediments and other pollutants that can have harmful impacts on the water environment if it is left untreated.

- We should not wash our vehicles at home rather we should use appropriate facilities because this reduce the amount of pollutants entering into the drainage by treating the wastewater prior to its release.
- To reduce water contamination in our society we should prevent dumping of waste from industry into the local water bodies
- We should not dispose non-biodegradable products into the drain.

Conclusion:

Human activities are the major causes of the depletion of aquatic environment. Increased industrialization and unplanned urbanization are prime causes of the water contamination. Water pollution is a great concern to this present world. It is essential to test the water quality before its use for any purposes. Environmental education amongst the mass is very necessary to decrease the pollution of aquatic ecosystems.

Proper bioremediation techniques should be used to improve water quality when some pollutants are detected. Stopping the source of pollutants cannot restore the water quality, thus it becomes imperative to regularly monitor the quality of water bodies and to design ways and means to protect it.

References:

1. Kushram, P. (2016). Physico-chemical studies on Narmada River water at Dindori (M.P.) India. *International Journal of Applied Research*, *2*(2), 226–228.
2. Jeffries, M., & Mills, D. (1990). *Freshwater Ecology: Principles and Applications* (1st ed.). London and New York: Belhaven Press.
3. Akabugwo, I. F., Ofoegbu, C. J., & Ukwuoma, C. U. (2007). Physicochemical studies on Uburusalt lake Ebonyi State, Nigeria. *Pakistan Journal of Biological Science*, *10*, 3170–3174.
4. Igbokwe, S. O., Ogueri, C., & Ajima, M. N. O. (2021). Seasonal variation in physicochemical characteristics of Agulu Lake, South Eastern Nigeria. *International Journal of Fisheries and Aquatic Studies*, *9*(2), 91–97.
5. Tamizhazhagan, V., & Pugazhendy, K. (2016). Physico-chemical parameters from the Manappadaiyur and Swamimalai fresh water ponds. *Indo American Journal of Pharmaceutical Sciences*, *3*(5), 444–449.
6. Kavitha, R., & Elangovan, K. (2010). Review article on Ground water quality characteristics at Erode district, (India). *International Journal of Environmental Sciences*, *1*(2), 145–150.
7. Dixit, A. K., Pandey, S. K., Mehta, R., Ahmad, N. G., Pandey, J., et al. (2015). Study of physico-chemical parameters of different pond water of Bilaspur District, Chhattishgarh, India. *Environmental Skeptics and Critics*, *4*(3), 89–95.

8. Kiran, B. R. (2010). Physico-chemical Characteristics of fish ponds of Bhadra project at Karnataka. *Rasayan Journal of Chemistry*, *3*(4), 671–676.
9. Ogueri, C. (2004). Physical and chemical parameters, fish Fauna and Fisheries of River Katsina-Ala, Benue State, Nigeria (Ph.D. Thesis). University of Ibadan.
10. Romin, M., Azad, S., & Saleh, E. (2021). Variations in the Physicochemical Water Parameters and Phytoplankton Community in Coastal Water of Kudat, Sabah, Malaysia. *Journal of Geoscience and Environment Protection*, *9*, 86–99.
11. Venkatesh, N., & Kiran, B. R. (2016). Assessment of heavy metals in sediments of fish culture ponds at Bhadra fish farm, Karnataka. *International Journal of Engineering Research and Modern Education*, I(II), 43–46.
12. Spellman, F. R., & Drinan, J. E. (2012). *The Drinking Water Handbook* (2nd ed.). Boca Raton: CRC Press.
13. Dohare, D., Deshpande, S., & Kotiya, A. (2014). Analysis of Ground Water Quality Parameters: A Review. *Research Journal of Engineering Sciences*, *3*(5), 26–31.
14. Sajitha, V., & Vijayamma, S. (2016). Study of Physico-Chemical Parameters and Pond Water Quality Assessment by using Water Quality Index at Athiyannoor Panchayath, Kerala, India. *Emergent Life Science Research*, *2*(1), 46–51.
15. American Public Health Association. (2005). *Standards Methods for the Examination of Water and Wastewater* (21st ed.). Washington DC: American Public Health Association.
16. Muthukumaravel, K., et al. (2010). Evaluation of Ground Water Quality in Perambalur. *Indian Journal of Environmental Sciences*, *14*(1), 47–49.
17. American Public Health Association. (2012). *Standards Methods for the Examination of Water and Wastewater* (22nd ed.). Washington DC: American Public Health Association.
18. Bashir, I., Lone, F. A., Bhat, R. A., Mir, S. A., Dar, Z. A., & Dar, S. A. (2020). Concerns and Threats of Contamination on Aquatic Ecosystems. *Bioremediation and Biotechnology*, 27, 1–26. https://doi.org/10.1007/978-3-030-35691-0_1. PMCID: PMC7121614.

RECOMMENDATIONS OF BALANCED NUTRITION USING LOCAL FOOD SOURCING FOR SANTHAL TRIBAL COMMUNITIES

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Abstract:

In our dynamic world, essential elements are indispensable for survival, with proper nutrition standing out as a fundamental necessity crucial for both physical and physiological well-being. A balanced diet plays a pivotal role in preventing deficiency disorders arising from insufficient intake of vital vitamins, minerals, and essential nutrients. Astonishingly, a substantial portion of global regions lacks awareness regarding the fundamental dietary requirements for a healthy life. Even in the 21st century, countries like India, undergoing developmental strides, grapple with a significant scale of malnutrition, particularly prevalent in tribal areas. According to the 2011 census, India was home to 104 million tribal individuals, constituting 8.6% of the total population. Among these, the Santhals stand as the largest tribal community in India and West Bengal. Malnutrition, especially on maternal bodies, poses a serious threat to the future of the nation in these tribal regions. Consequently, it is imperative to raise awareness about the health of maternal, neonatal, post-neonatal, weaning infants, and children among tribal communities, educating them on proper nutrition for enhanced physiological well-being. This article aims to delve into the nutritional status, deficiency diseases, and health indicators within these communities. Additionally, it will explore essential indigenous food items, whether foraged or cultivated in their small farms, emphasizing their nutritional composition. The promotion of the cultivation of these indigenous foods not only improves the health of the tribal population but also enhances their economic well-being.

Keywords: Santhal Tribal groups, Essential nutrients, Malnutrition, West Bengal, Indigenous food

Introduction:

To survive in this world with a good health, every period of life requires variable amount of nutritious food. This study aims to provide an appropriate knowledge about significant dietary elements for tribal communities. Therefore, at first, we have to focus on the primary definition of tribes. They are a class of common people who stay together in a geographical area mainly hill and forest and their occupations are also same. According to article 342 of Indian constitution, 705 non identical tribal groups are located in different places, approximately 30 states and Union

Territories of India. They all have their own traditional believes, cultural rules, life practices and have lack of education, lack of nutrition and unorganised sanitation which effect their health (Amit Sengupta, 2019).

In this article, we will discuss about a tribal group among all of these, Santhal. A major reason to choose them is that they belong from different states of India in same type of geographical land. Santhals are completely different in every feature of daily life and even the climates of their habitats are slightly dissimilar from urban locality which change the type of their availability of food. Due to the climate and the soil nature, some types of vitamins or minerals rich foods are not easily available throughout the year in these areas which act on the maternal heath in the gestation period and even after the parturition. In the absence of important substances in body of lactating woman may affect the infant with nutritive disorders [Tulsi Adhikari, 2020]. Sometimes these diseases are protein-energy related and sometimes they are vitamin-mineral related (Stiller *et al.,* 2020). It is fully depended on which type of food is consumed by the mother or pregnant women. So, the availability of proper nutritious food through local food sourcing for tribal communities is pivotal for their healthy life.

Idea about the tribal group: Santhal and their dietary practice

Santhal is one of the largest groups of tribal in India which is widely distributed in the districts of Jharkhand, Odisha, Bihar, and West Bengal (list of notified scheduled tribes). They normally communicate with each other through Santali language, yet with the time span, Santhals are now acquiring languages of the populated areas, such as Oriya in Odisha, Hindi in Bihar, Assamese in Assam, and Bengali in West Bengal. In Bengal, they have been mostly found in the rural areas of Birbhum district and the population is 2,512,331 in all over the state (district wise scheduled tribe population, West Bengal-2011). Santhals are either associated with agriculture not more than one hector of area (Chandramouli, 2011) or both men and women work as daily labourer in agriculture (Kartick Chandra Barman, 2014). Rice cultivation is the most significant economic activity in the community and some of them are with a job in coal mines. Hence, they survive on a very low income or are under poverty. In their own small kitchen garden or backyard, they grow mostly indigenous varieties green leafy vegetables and other vegetables which are integral component of daily dietary intake. Other than cultivation they are engaged in foraging, hunting, livestock breeding to supplement their income as well as daily diet. The most important aspect of their diet is the consumption of locally available, indigenous wild foods comprised of culturally important wild plant foliage, fungi species, vegetables, fruits, locally raised livestock, and small aquatic species. However, due to urbanization there is a shift in food consumption to easily available packaged market food those have less nutrient content than the indigenous variety. As a result, there is chronic energy deficiency, anemia and malnutrition (Stiller *et al.*, 2020a).

Figure:1 native of Santhal community in India [PC-Google]

Malnutrition among Santhal Tribes

The term ‘malnutrition’ has no universally accepted definition. It has been used to describe a deficiency, excess or imbalance of a wide range of nutrients, resulting in a measurable adverse effect on body composition, function and clinical outcome (Lia, 2000). Although malnourished individuals can be under- or overnourished, ‘malnutrition’ is often used synonymously with ‘undernutrition’, as in this article.

The prevalence of malnutrition in Indian tribes can be attributed to a complex interplay of factors. Limited access to essential resources, including education, healthcare, and proper sanitation, compounds the problem. Traditional livelihoods and subsistence practices, often reliant on agriculture or forest-based activities, may not provide a consistently balanced and nutritious diet. Additionally, issues such as displacement due to development projects and changes in land use can disrupt their access to food sources.

Cultural factors also play a role, with certain tribes adhering to specific dietary practices or facing challenges due to food taboos. Lack of awareness about proper nutrition and healthcare exacerbates the problem, contributing to the cycle of malnutrition in these communities. In this paper, we only consider the significance of nutrients. So now we will discuss about the present scenario of malnutrition in pregnant and young mothers, infants (neonatal and post neonatal) and children.

Malnutrition in Santhal pregnant and young mothers

A uterine body goes through many switching stages on those particular trimesters. Uncountable hormonal changes take place from 1st day to 280th day of gestation period (A.M. Jukic, 2013). For handling these all course of actions, we stand in need of energy which is obtained from foods. As a consequence, an organised meal for this period of time is highly required. Malnutrition among Santhal tribal pregnant women and young mothers is a critical concern that requires targeted interventions addressing various interconnected factors. The Santhal tribe, like many other tribal communities, faces unique challenges that contribute to the vulnerability of pregnant women and young mothers to malnutrition. Here are key factors influencing this issue:

- **Limited Healthcare Access:** Santhal tribal communities often reside in remote areas with limited access to quality healthcare facilities. This is been reported to result in inadequate prenatal care, nutritional counselling, and maternal health services for pregnant women and young mothers (Stiller *et al.,* 2020a; Sengupta *et al.,* 2020).
- **Traditional Dietary Practices:** Santhals have their own traditional dietary practices that lack diversity and essential nutrients. Dependency on locally available foods and traditional cooking methods does not provide the necessary nutrition to pregnant women and lactating mothers which has been reflected in several scientific studies elsewhere (Ghosh-Jerath *et al.,* 2016).
- Economic Constraints: Economic challenges within Santhal communities may lead to food insecurity, impacting the availability of nutritious foods. Poverty can limit access to a balanced diet during pregnancy and breastfeeding, affecting both maternal and child health (Adhikari *et al.,* 2020; Stiller *et al.,* 2020b).
- **Lack of Maternal Nutrition Awareness:** Limited education and awareness about proper maternal nutrition practices contribute to malnutrition among pregnant Santhal women and young mothers. This lack of knowledge can affect the health and development of both the mother and the child (Stiller *et al.,* 2020b).
- **Cultural Factors:** Cultural practices, including food taboos and traditional beliefs surrounding pregnancy, can influence dietary choices and contribute to malnutrition among Santhal pregnant women and young mothers.

Malnutrition in Santhal tribal infants and children

According to World Health Organisation (2011), breastfeeding is essential for the initial six months following delivery to carry off the ideal growth and the development of physiological body with emotional health. That means even after parturition, an infant who is in good health, fully depended on their mother for nourishment up to first few moths from birth. This is based on the fact that mother's milk is superior to all other types of animal milk. Breast milks including

colostrum, transitional milk and mature milk are fully packed by essential nutrients vitamins, minerals, digestive enzymes, growth factors and immunoglobins, antibacterial agents for defence in beginning of life.

Table 1: Essential nutrients of mother's milk (Olivia Ballard, 2013)

1	Nutrients	Lactose, lactalbumin, casein
2	Minerals	Sodium, calcium, Potassium, iodine, iron
3	Vitamins	A, B, D, K
4	Immunoglobulins	IgA, IgA, IgM
5	Growth factors	Growth factor β

After six months from parturition, little one starts to consume liquid foods from external world which means that they become weaning infant. At that period, teeth begin to appear in the buccal cavity. After a while they finally start eat solid foods and proper development of body go ahead. In this stage to growth all the essential and semi essential organs, need proper organised nutrients. The physiological body craves additional minerals and vitamins, which are essential for the formation of bones. To overcome growth retardation in this initial stage of life, appropriate nourishments are vital. Santhals, being one of the largest tribal communities in India, face unique challenges that contribute to the prevalence of malnutrition among their youngest members. Here are key factors:

- **Traditional Dietary Practices:** Santhals, like many tribal communities, may have traditional dietary practices that might lack diversity and essential nutrients. Dependence on specific locally available foods and traditional cooking methods can contribute to nutritional gaps in the diet of infants and children (Singh *et al.*, 2023).
- **Economic Challenges:** Economic constraints in Santhal communities may lead to food insecurity, affecting the availability of nutritious foods. Poverty can limit access to a balanced diet, impacting the growth and development of infants and children.
- **Poor Maternal Nutrition:** The nutritional status of mothers directly affects the health of newborns. Studies have shown that tribal mothers who experience malnutrition during pregnancy or lack awareness about proper nutrition, have contributed to low birth weight and increased vulnerability to malnutrition in infants (Adhikari *et al.,* 2020).
- **Limited Education and Awareness:** Low levels of education and awareness within Santhal communities may contribute to a lack of knowledge about proper infant and child feeding practices. This can result in inappropriate feeding patterns and nutritional deficiencies (Stiller *et al.,* 2020b).
- **Anonymous about Family Planning:** Most tribes are clueless about family planning including the space between child births, unwanted pregnancies and genetic counselling. If a

mother conceives in the lactating period, then first child will be malnourished due to absence of breast milk from that mother.

- **Infectious Diseases:** In rural areas, infectious diseases like malaria, dengue, typhoid are very common. After recovery from these life-threatening diseases, a proper nutrition is needed for leading the normal life again. Otherwise, insufficient nutrients cause malnutrition even after recovery from infection diseases. (Narain JP, 2019)

Dietary requirements and importance of indigenous food for Santhals

A dietary requirement is the minimum quantity of a particular nutrient that an individual needs to eat to sustain an adequate amount of nourishment (Food Safety and Standard Authority of India, 2022). Dietary requirements are not constant throughout of life. Even it changes with work status, gender, and period of life. Food Safety and Standard Authority of India, pays alertness on the balancing of food quantity to improve human health. They have made tabulation form of all the type of nutrients with their respective required quantity.

Studies have shown that despite of various availability constraints, people from the indigenous community who are still consuming more indigenous food in their daily diet have shown better nutritional status than others who are not consuming. A very little contribution of indigenous food in their daily meal have shown less micronutrient deficiency in their diet (Ghosh-Jerath *et al.,* 2016, Singh *et al.,* 2023).

Sources of nutrients from cultivation of Santhal tribes

In the beginning of this chapter, we have discussed that Santhal's are mainly agricultural labourer. Majority of their food comes from the agricultural land and from their own kitchen garden. So following are the food items in brief with their nutritional contributions which are grown in their farming land season wise. However, more will be the diversity in the food source more will be the nutritional supplementation. It has been observed that less diversity in food items in their meal plate have shown more nutrient deficiency in their diet.

Table 2: Dietary sources for Santhal households from farming land and locally raised livestalk (Singh *et al.*, 2023; Kapoor *et al.*, 2022)

Essential nutrients

1. Macronutrients

I. Protein	• Pulses (Urad dal, Arhar dal) • Meat (chicken, goat) • Milk (cow, goat)
II. Carbohydrate	• Potato, Rice, Sugarcane, Wheat
II. Fat	• Oilseed (Mustard oil)

2. Micronutrients

Vitamines	Sources
A	Liver oils, Mango, Papaya, Pumpkin, Milk, Khesari leaves, Mustard leaves
D	Exposure to Sunlight
E	Meat, Wheat germ oil
K	Cabbage, Cauliflower, Tomatoes
B	Oil seeds, Unpolished rice, Liver, Egg yolk, Cabbage
C	Citrus fruits, Guava, Cabbage, Tomatoes

Minerals	Sources
Calcium	Milk, Cabbage
Sodium	Common salt
Magnesium	Cauliflower, Fruits
Iron	Pulses, Milk, Organ meat (liver), Wheat
Iodine	Drinking water, Banana

Own type food preparation and traditional foods

The idea about traditional foods comes with that, these ingredients exist locally from the environment itself rather than being bought (Suparna Ghosh-Jerath, 2016). Other than cultivation Santhals are highly dependent on foraged food from forests. Some of the important foraged food and their nutritional benefits are briefly discussed here.

A. Red ant chutney (Chapra)

A chutney is prepared with red ants with their eggs very common masalas like garlic, chilli, ginger and coriander leaves. This preparation is consumed by santhal and other tribal communities as freshly prepared as well as preserved upto a year in glassware. This savoury food item is rich in valuable proteins, calcium, zinc, vitamin B-12, iron, magnesium, potassium, sodium, copper, fiber and 18 amino acids, is known to boost the immune system and keep diseases at bay. The red ant chutney among the indigenous communities has been known to serve medicinal purposes apart from being a delicacy. The red ants in a dish has the potential to remedy myriad of illness. The dishes are given to people suffering from jaundice, common cold, joint pain, cough and poor eyesight.

B. Wild Fungi

There are various types of wild mushrooms grows in different seasons in forest in huge quantity. Come monsoon, and there is a flood of mushrooms in the jungle. Tribals relish wild mushrooms a lot. They are aware of all the places where mushrooms can thrive-- be it loamy soil, streams and creeks, dying trees, burn sites,under the soil, etc. For example, *Baans khukhri*

(bamboo mushroom) are edible wild mushrooms seen only near bamboo shoots. They grow in plenty in the monsoon. They are considered the tastiest of the lot. *Jamun khukhri* (Indian blackberry or Java plum mushroom), is an edible wild mushroom. The mushroom doesn't look appealing to the eyes but ranks high in the tribal food list. They grow abundantly in monsoon and is known to be a rich source of protein and found only in forest under the Jamun tree (*Syzygium cumini*). *Rugra (puttu*) is an indigenous mushroom of Jharkhand. They look like puffballs or small camphor balls, rough-textured, with an outer shell with soft yolk black or white interior. Rugra grows soon after the first showers of rain hit the thirsty soil followed by 3-4 days of sunshine and humidity. They grow under the soil in the canopies of sal trees. They are collected by tribal women, washed properly, and then cooked into curry. All these varieties of mushrooms are nutritious meal that is low in calories as well as fat while high in minerals and fiber. They are rich in potassium, selenium, and vitamin C (Kapoor *et al.,* 2022)

C. Smal Aquatic Animals

Freshwater small aquatic animals like snails, crabs, fish and turtle are used as indigenous food source for tribal communities in India. These aquatic animals are in high demand as they are a cheap source of protein and provide food security, livelihoods and medicine. They are good source of protein, iron, calcium and vitamin A. The communities across North east Indian states believe consuming them enhances or helps maintain good eyesight and normal functioning of kidneys and reduces joint pain. (Jadhaba *et al.,* 2023; Kapoor *et al.,* 2022)

D. Mahua

Some of the delicious dishes of Mahuwa popular in tribal community are Mahuwa Laddu, Mahuwa Methi Roti, Mahuwa Halwa, Mahuwa Liquor etc. Mahua flower is prepared as laddu with sesame seeds, peanuts and jagarry. It’s a very good source of iron and known as to increase haemoglobin. Even now the tribal pregnant women use them as iron supplement. The fruit of the Mahuwa tree is edible and highly nutritious, rich in protein, carbohydrates, and minerals. It is a valuable source of food for many people in India, especially in tribal areas where other food sources may be scarce. The honey produced from mahua flowers is known for its distinct flavor and aroma and is considered to be a delicacy in some parts of India. The honey is also used in traditional medicine and is believed to have various health benefits (Mishra and Poonia, 2019).

E. Handia/haria

Handia, a rice-based fermented drink, is integral to the tribal lives. They consume handia on every occasion. It is believed that, this rice fermented drink has medicinal and nutritional benefits. The analysis of the nutrient composition of raw (before mixing water) handia shows that raw handia has a high protein content, followed by carbohydrates, alcohol, glucose and fat (Bisai *et al.,* 2023).

F. Concept of thali in Santhal tribals

In a very recent study, it has been observed that two types of plates are present in the Santhal areas. 1st one is Kanhu Thali for winter and 2nd one is Jhano Thali from the end of the summer to monsoon (Armes *et al.,* 2024) where both are having a sufficient nutritional value with rice, flat beans, wild leafy vegetables, dried fish, wild mushroom curry, chicken egg curry, and mango pickle, mahua flower, etc. However, this is been observed that in these thalis are devoid of animal-based protein sources and dairy. It is worth to remember here that these are the representative thalis of their food habitat, may not be their all-different habitual food items are incorporated in these thalis.

Conclusion:

In order to combat malnutrition effectively, it is advisable to integrate a diverse range of indigenous foods rather than relying solely on specific sources. This approach involves incorporating strategies like encouraging the cultivation of native plants, raising indigenous animals, and cultivating aquatic species within existing agricultural policies. Implementing activities that boost indigenous food production through agricultural extension services is crucial. Additionally, integrating indigenous foods into ongoing food security programs, such as the targeted public distribution system, and supplementation initiatives like those under ICDS, is essential. These efforts can be reinforced by behaviour change communication strategies, including nutrition education programs. The aim is to promote the inclusion of indigenous foods in the regular diets of the Santhal community in India.

References:

1. Narain, J. P. (2019). Health of tribal populations in India: How long can we afford to neglect?. *The Indian Journal of Medical Research*, *149*(3), 313–316. https://doi.org/10.4103/ijmr.IJMR_2079_18
2. Sengupta, A., Sahoo, M., Khan, A., Shaikh, R., & Khan, R. (2020). Maternal Health Status in Tribal India: A 5-Year Intervention Program and its Outcome. *Indian Journal of Community Medicine: Official Publication of Indian Association of Preventive & Social Medicine*, *45*(2), 189–193. https://doi.org/10.4103/ijcm.IJCM_158_19
3. Adhikari, T., Yadav, J., Tripathi, N., Tolani, H., Kaur, H., & Rao, M. (2021). Do tribal children experience elevated risk of poor nutritional status in India? A multilevel analysis. *Journal of Biosocial Science*, *53*(5), 683–708. https://doi.org/10.1017/S0021932020000474
4. Stiller, C. K., Golembiewski, S. K. E., Golembiewski, M., Mondal, S., Biesalski, H. K., & Scherbaum, V. (2020). Prevalence of Undernutrition and Anemia among Santal Adivasi Children, Birbhum District, West Bengal, India. *International Journal of Environmental Research and Public Health*, *17*(1), 342.

5. Stiller, C. K., Golembiewski, S., Golembiewski, M., Mondal, S., Biesalski, H. K., & Scherbaum, V. (2020). Maternal nutritional status and child feeding practices: A retrospective study in Santal communities, Birbhum District, West Bengal, India. *International Breastfeeding Journal*, *15*(1), 50. https://doi.org/10.1186/s13006-020-00262-3
6. Chandramouli, C.; General, R. (2011). Census of India 2011. Provisional Population Totals; Government of India: New Delhi, India, pp. 409–413.
7. Barman, K. (2014). Socio-Economic Profile of Tribal Populations in Birbhum District of West Bengal. *Central India Journal of Historical Archaeological Research*, *3*, 187–192.
8. Jukic, A. M., Baird, D. D., Weinberg, C. R., McConnaughey, D. R., & Wilcox, A. J. (2013). Length of human pregnancy and contributors to its natural variation. *Human Reproduction (Oxford, England)*, *28*(10), 2848–2855. https://doi.org/10.1093/humrep/det297
9. Ballard, O., & Morrow, A. L. (2013). Human milk composition: Nutrients and bioactive factors. *Pediatric Clinics of North America*, *60*(1), 49–74. https://doi.org/10.1016/j.pcl.2012.10.002
10. World Health Organisation. (2011, January 15). Exclusive breastfeeding for six months best for babies everywhere.
11. Ghosh-Jerath, S., Singh, A., Magsumbol, M. S., Lyngdoh, T., Kamboj, P., & Goldberg, G. (2016). Contribution of indigenous foods towards nutrient intakes and nutritional status of women in the Santhal tribal community of Jharkhand, India. *Public Health Nutrition*, *19*(12), 2256–2267. https://doi.org/10.1017/S1368980016000318
12. Kiani, A. K., Dhuli, K., Donato, K., Aquilanti, B., Velluti, V., Matera, G., Iaconelli, A., Connelly, S. T., Bellinato, F., Gisondi, P., & Bertelli, M. (2022). Main nutritional deficiencies. *Journal of Preventive Medicine and Hygiene*, *63*(2 Suppl 3), E93–E101. https://doi.org/10.15167/2421-4248/jpmh2022.63.2S3.2752
13. Food Safety and Standard Authority of India. (2022, February 3). Retrieved from https://fssai.gov.in/upload/advisories/2022/03/62414c50d2342Direction_RDA_03_02_2022.pdf
14. Armes, S., Bhanjdeo, A., Chakraborty, D., Kaur, H., Ray, S., & Rao, N. (2024). Aligning Santal Tribe Menu Templates with EAT-Lancet Commission's Dietary Guidelines for Sustainable and Healthy Diets: A Comparative Analysis. *Nutrients*, *16*(3), 447. https://doi.org/10.3390/nu16030447
15. Mishra, A., Poonia, A. (2019). Mahua (Madhucaindica): A boon for tribal economy. *Indian Food Industry Magazine, 38*(1), Jan-Feb.

16. Bisai, S., Dutta, S., & Das Mohapatra, P. K. (2023). Traditional food consumption pattern and nutritional status of Oraons: An Asian Indian indigenous community. *Frontiers in Sustainable Food Systems*, *7*, 969264. https://doi.org/10.3389/fsufs.2023.969264
17. BAPEN. (2000). Guidelines for detection and management of malnutrition. Malnutrition Advisory Group, Standing Committee of BAPEN. Maidenhead: BAPEN.
18. Jadhava, A., Das, N. K., Sila, M., & Aravinda, N. A. (2023). Snails on the plate: Edible freshwater molluscs of Northeast India. *Indian Journal of Traditional Knowledge*, *22*(2), April, 409–419. https://doi.org/10.56042/ijtk.v22i2.55225
19. Kapoor, R., Sabharwal, M., & Ghosh-Jerath, S. (2022). Indigenous Foods of India: A Comprehensive Narrative Review of Nutritive Values, Antinutrient Content and Mineral Bioavailability of Traditional Foods Consumed by Indigenous Communities of India. *Frontiers in Sustainable Food Systems*, *6*, 696228. https://doi.org/10.3389/fsufs.2022.696228
20. Singh, A., Dhasmana, A., Bandhu, A., Kapoor, R., Baalasubramanian, S., & Ghosh Jerath, S. (2023). Contribution of natural food environments to nutritional intake and biomarker status: Insights from the women of indigenous Santhal communities of Jharkhand, India. *BMC Nutrition*, *9*(20). https://doi.org/10.1186/s40795-023-00669-1

SENSITIZATION OF SCHOOL STUDENTS FOR SCHOOL GARDEN AND SUSTAINABLE -UTILIZATION

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Abstract:

Raising awareness or to sensitize students about school garden is the key to progress the school education. Over the period the school garden has been promoted as an important nurturing site for school children. India may be the second largest producer of food but it has its second largest undernourished population. An unbalanced diet and lack of food is directly linked to the high rates of stunting, gaining excessive weight and death in children under five years of age. Govt. of India has implemented programmes for providing food security but to combat with the malnutrition and to geta healthy environment along with healthy life school gardening is important. Gardens engage students by providing environments where they can observe, discover, learn through experiment.

Gardens are the living laboratories which will provide the knowledge of sustainability and the concept of ecofriendly utilization beyond the garden also. So the sensitization programme is vital since the neighbouring places are also dependent on the institution to have light and hope for their lives directly or indirectly through their children.

Keywords: Sensitization, Sustainability, School children, Gardening, Ecofriendly

Introduction:

The students of School are the future citizens of our country. Development of values from the school level will help them to build their character and personality to serve the nation. School garden which gives the opportunity to learn in nature will help the student for all round development. The school garden directly connects the students to plants, soil and gives the opportunities for hands on training, environment of experimental learning. Youth become aware of healthy food. It is the living laboratory. Students acquire knowledge about flower, fruit, and vegetables. Gardening will also develop their responsibility and skill, like problem solving capacity and critical thinking ability (Driscoll *et al.*, 2016).

Lack of proper nutrition and balanced diet can lead to the death of children. To combat this problem a nutrition garden which is a part of school garden can play important role (Suri, 2020).

Students can record the observations of plant growth, collect data, analyse the data. With all of these record they can maintain a science journal. Besides knowledge gaining and experimentation, studentsdo the physical activity in gardening which will build their body. They can burn the calories through the gardening. This school garden will help the students to develop knowledge about ecology and environment (Diclaudio *et al.*, n.d.).

Young adults are interested and curious to learn the nature but for rapid urbanisation students get lesschance to build bond with nature. So this is the need to give opportunities to the students to learn aboutenvironment (Kwasi, n.d).

Research on physical activity and curriculum development of an 'after school gardening programme' were done where A Curriculum of theory based after school gardening club were produced to increase the healthy behaviors with the help of accelerometer study. It showed that garden can be a valuable tool for the physical activity in youth. The target group was to develop Curriculum on theory based after school garden. (Domenghini & Cynthia, 2004).

Here all the research showed the effect and impact of school garden except the last one which mentioned about Curriculum development after school gardening. But to develop a proper mindset for Gardening, sensitization, sustainable utilization and gaining theoretical knowledge before building up a school garden is very much important, which was not found in these literatures. Here the problem of "Sensitizing Students for School Garden" arises.

Objectives:

1. To aware school children about biodiversity, conservation, the sustainable use of biodiversityand Indigenous plant.
2. To develop a mind set about gardening and to grow knowledge about indigenous plant,medicinal plant, healthy food and theories of gardening.
3. To involve students in hands on experimental activities through gardening and applying this practical knowledge in the study of other science subject.
4. To develop values and, critical thinking ability skill.
5. To make them understand the role of plants, in our life and in the existence of earth.
6. To give the students a green breathable space and eco-friendly environment
7. To bring all the stakeholders of the school and to bring other participant under one umbrella to develop social connection.
8. Building community support for the long term garden sustainability.
9. To inspire students from school gardening to make kitchen garden at home
10. Providing the knowledge of holistic health care both in traditional and modern system of medicine through herbal garden

Methodology:

Target group for this activity should be the 7th to 12th standard students of School. Ten schools could be selected, out of which 5 will be of rural area and 5 will be of urban area. The programme will run for two years for direct sensitization and follow up.

The sensitization programme will include the following steps:

1. Selection of School: Consultation with School education department and School Administration (Head master/head Mistress or Principal) and Signing a MoU with School.
2. To hire Farmer and Nursery worker as wells as getting information about Nursery and cultivated land consultation with Gram Panchayat in Rural area and Municipality in urban area will be done.
3. After consultation with School Principal the dates to be decided for 3 days' workshop in eachschool.
4. A list of members of School garden including students, parents, community members, Farmers(2 from each area) and two skilled members from nursery is to be made. Pre - test willbe taken for selection of students to make the group of 18 students. Parents of each studen will also be invited on the 1st Day of workshop.
5. When a group of students will be selected then the 3 days Sensitization Program will begin with another test to know their knowledge on environment, biodiversity, healthy food, balanced food, vitamins, and sustainable utilization.

The details of 3 Days Sensitization Programme are given below.

Day 1:

- Team selection on the basis of pre – test.

Orientation Programme with another Test or survey and lecture in an interactive way on environment, Biodiversity and conservation, changes in environment due to pandemic situation, food and nutrition and health, soil types and preparation of soil, sustainable development, community development, Green campus, importance of plants in our life , experience sharing of students on home gardening

Day 2:

- Field visit: Visit to nursery or cultivated land to see the plants, to know and identify some indigenous plant, medicinal plant and few other vegetables and fruits. In case of urban areasame will be done from nursery, and a visit to any national park or visit to "vegetable and flower show" could be done in the winter and autumn.

Interaction with the concerned person for theoretical knowledge about those plants and plantation process and bringing some plants to school for plantation purpose.

Day 3:

Hands on training on making soil, preparation of garden and planting (with the help of farmer/

nursery worker) and proper bed sizing for garden and how to maintain and conserve.

Follow up:

After each workshop a survey with post-test will be taken and the students will be given the work for a project and they will be asked to write the report and submit it after every 6 months. The final report submission of students about the observation of plant growth, how many plants have survived ,how they prepared soil, what type of manure was used, how they maintained the garden, which types of vegetables, fruits , medicinal and indigenous plant they have planted and were the vegetables and fruits consumed by them, if so how they felt ,which type of physical activity they have done, their health information, their life style changes and the body weight before the start of gardening and at the time of submission which will be after 18 month . A survey after 18 months will also be done to know the progress and the critical thinking ability of the students and to analyse the overall outcome. Then in lastthree months the Report of the whole Programme will be prepared after data analysis.

According to the study published in PubMed central by Timothy et.al.(mar 2023)

- School children will be able to design the garden which will further help them to beenriched with exchanged cultural activities, languages and will help in solving mathematics, health and physical educations, science and technology, art, design, enhancing writing skills.
- Students will enjoy the kitchen and garden experiences.
- Develop leadership, decision making, model building, sustainable behavioral change
- Students will be aware about health and nutrition from the garden and will be able to understand better about food groups.
- Will be encouraged to publish newsletter about food and vegetable intake by family. Opportunity to investigate and compare the basic physical characters of the plants, what hinders their growth, their response to stimuli and environment throughout the season aswell as garden will built enthusiasm about eating fresh and locally grown fruits and vegetables. Reconnects with nature and ecology and environment. Danelle Di Claudio et.al.(2013)
- Students will achieve the knowledge about the ecosystem, pollinators, nutrition and utilize the experience for further study and gardening. Driscoll, et.al.(2016)

Case study from Zimbabwe by Shoba Suri (June 2010) reveals

- Nutrition gardens have a positive impact on livelihood as they provide steady income and curb diet related disease.
- Kitchen gardens as a promising opportunity to grow fruits and vegetables high in micronutrients and to address food security and malnutrition issues (study from rural Tanzania)

Conclusion:

Learning is most effective when the subject matter is immediate and familiar to the learner and presented in a way that takes into account the varied learning styles and even abilities of the student population found in today' classroom. The Govt. of India launched the National Nutrition Mission to ensure attainment of a malnutrition free India by 2022. The national Rural Livelihood Mission is promoting kitchen gardens as part of farm livelihood intervention strategy for national Nutrition mission. School garden which would inspire to kitchen garden creates an accessible environment to investigate science, maths, reading, writing and other creativity. A garden builds a community within a school and its surroundings, creating relationships and that last a lifetime.

References:

1. DiClaudio Denelle *et al.* (2013). Learning Through the Garden, Rutgers, The state University of NewJersy
2. Driscoll Liz *et al.* (2016). Teaching from the Garden: Creating Transformative Learning landscapes atSchools, N C State university
3. Dierickx S (2018). Community sensitization and decision making for trial participation NMPB Scheme for medicinal plants
4. School Gardens: Growing Ideal Children and Future Adults, Springer International Handbooks ofeducation
5. Holloway P. Timothy, *et al.* (2023). PMID 36904189, School Gardening and Health and well-BeingofSchool-aged Children: A Realist synthesis
6. Rozer Emily J (2008). Health Education and Behavior 34(6):846-63. The Effects of School Gardenson Students and Schools
7. Suri Shoba (June 2020), ORF ISSUE BRIEF, Issue No. 369. Nutrition Gardens: A sustainable modelfor Food Security and Diversity
8. Brown Richard and Kathy (2005). Annuals, Bulbs and Perennials, Anness Publishing Ltd

ASIAN SOYBEAN RUST: AN UPCOMING THREAT TO SOYBEAN CULTIVATION

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Abstract:

Annual economic losses resulting from Asian soybean rust, which is caused by the fungal pathogen *Phakopsora pachyrhizi*, are substantial and pose a significant threat to soybean cultivation worldwide. Due to the devastation caused by this disease, which notably impacts significant soybean-producing nations such as India, it was formerly classified as a form of bioterrorism. *Phakopsora pachyrhizi*, an obligate biotrophic pathogen, infects a wide variety of hosts, including 31 species of legume plants, and concludes its asexual life cycle via uredospore production. Particulate lesions ranging in colour from dark brown to shady brown, situated on the ventral surfaces of leaflets, are indicative of the disease, which is predominantly transmitted via wind. Currently, fungicide application is the most effective method of soybean rust control; DMI, SDHI, and QoI are prevalent options. Six resistance genes (R genes) have been identified in diverse soybean cultivars; these genes confer resistance to *P. pachyrhizi*. In addition, resistance-building potential is demonstrated by non-host plants, transgenic soybeans, and genetic engineering. RNA interference and biological control methods that employ beneficial microorganisms provide sustainable protection against Asian soybean rust. In order to mitigate the detrimental effects of Asian soybean rust on soybean cultivation, this article emphasizes the need for effective control measures. It details disease progression, infection occurrences, and control strategies.

Keywords: Demethylation Inhibitor, Phytoalexins, Resistance Gene, *Rpp*, Uredospores

Introduction:

Rapid increase in the world population is a severe threat for various food producing industries including agricultural sectors. Providing sufficient food to all the individuals is an important challenge which has been faced for a long time. Though advancement in the modern agricultural system able to provide considerable food security but still various biotic and abiotic stresses in the crop field is always been a severe problem that leads to huge economic loss. Rapid climate change introduces various abiotic stresses which causes significant yield loss. Beside this, attack of different plant pathogens and pests is also an important issue. One of such recent

instances is the occurrence of Asian soybean rust caused by the fungal pathogen *Phakopsora pachyrhizi.* It is a major disease of soybean crop field that results in huge economic loss every year worldwide. Globally soybean (*Glycine max*) is recognized as an economically important crop, since it is a rich source of both protein (about 40%) and vegetable oil (about 20%). Thus soybean is also called as "two in one crop" (Chander *et al.,* 2019). The dietary fiber and isoflavones present in soybean help to protect several chronic diseases including diabetes, obesity, heart diseases and cancer (Asif *et al.,* 2013). Soybean has a great adaptability to different latitudes, climatic and soil conditions which enabled them to become fourth most widely grown crop across the globe after wheat, maize and rice. But one of the major problems is the presence of biotic stresses. The severity of Asian soybean rust is so explosive for the soybean crop fields that this disease was previously considered as the bioterrorism (Balardin *et al.,* 2006). The pathogen *P. pachyrhizi* can spread through the wind over a long distance and the consequences are so dangerous that it is now one of the most feared diseases of soybean field (Rosa *et al.,* 2015).

At present, three strategies have been followed widely to check the disease progression which incorporates use of different chemical fungicide, production of genetic engineered resistant soybean plant and specific cultivation techniques (Kendrick *et al.,* 2011). Chemical control using chemical fungicide belongs from the class Demethylation inhibitors (DMI) and Quinone outside inhibitors (QoI) is found to be most effective against *P. pachyrhizi* (Guicherit *et al.,* 2014). Beside this biological control using beneficial microbes and other biological organisms like fungi and essential oils from different plants have been also tested *in vitro* and exhibited promising results (Langenbach *et al.,* 2016). Genome analysis of soybean plant revealed the presence of six resistance gene which referred as *Rpp 1-6*. Further studies have shown that there are three genes present namely *GmEDS1*, *GmPAD4*, and *GmNPR1*which directly involved in the mechanism of *Rpp 2* mediated resistance in soybean plant (Pandey *et al.,* 2011). In order to draw resistance scientists have proposed another approach that is the application of recessive *R* genes. Three recessive *R* genes to *P. pachyrhizi* have been isolated and help to draw resistance in soybean plants (Langenbach *et al.,* 2016). Elimination of susceptibility gene *(S)* is another approach to draw resistance against *P. pachyrhizi* (Uppalapati *et al.,* 2012). Another effective molecular control can be made through the application of RNAi mediated gene silencing (Koch and Kogel 2014). Beside this, different biotechnological methods are also investigated like *R* gene pyramiding, introduction of engineered *R* gene, use of non-host plant, application of antimicrobial peptides and production of secondary metabolites which found to be effective against the Asian soybean rust (Tremblay *et al.,* 2009; Langenbach *et al.,* 2016).

To overcome the threat of the rust and to minimize the accruing yield loss it is become very important to know more about the disease and its eco-friendly integrated management. In

the present review an attempt has been made to compile and synthesize the important information on geographical distribution, yield losses, casual organism, disease cycle, host range, disease management, rust resistant gene and biological control, chemical control and to reveal the gaps in knowledge on various aspects of this serious disease of soybean by the pathogen *P. pachyrhizi.*

Geographical footprints of the soybean rust pathogen

The rust disease was first recorded in Japan in the year 1902 by Nakanishiki who identified the fungus as *Uredo sojae* (Bromfield *et al.,* 1980). Later, Hennings (1903) confirmed the fungus as *Uredo sojae* on leaves of wild grown soybean *G. soja* when it was collected from Tosca Province of Japan by Yoshinaga (Sharma and Gupta 2006). By 1934 the pathogen had been found in several Asian countries and as far south as Australia (Bromfield and Hartwig 1980). In the second half of the 20th century, the footprints of *P. pachyrhizi*appeared to be moving into several soybean growing countries in Africa. In 1996 the soybean rust spread in Uganda and Kenya. From these countries, the disease possibly expanded southwards to Rwanda, Zambia, and Zimbabwe in 1998 (Pretorius *et al.,* 2001; Levy 2005).

In India, the appearance of soybean rust was first reported on in 1951 (Sharma and Mehta 1996). The first authentic report of soybean rust in India was available from Pantnagar in 1970 (Sarbhoy *et al.,* 1972). Later, rust was also found in low hills of UP and Kalyani in West Bengal. Till 1974 the rust remained restricted in and around Pantnagar and subsequently disappeared from India. However, in 1980, after a lapse of almost 5 years the rust resurrected in high altitude areas of Meghalaya and later reports came from the plains of Assam in North east regions of India (Maiti *et al.,* 1981). Till 1993, the rust remained confined to this region and afterwards it spread to other soybean production areas of India (Sharma and Gupta 2006). In the following Figure 1 the worldwide occurrence of Asian soybean rust has been presented.

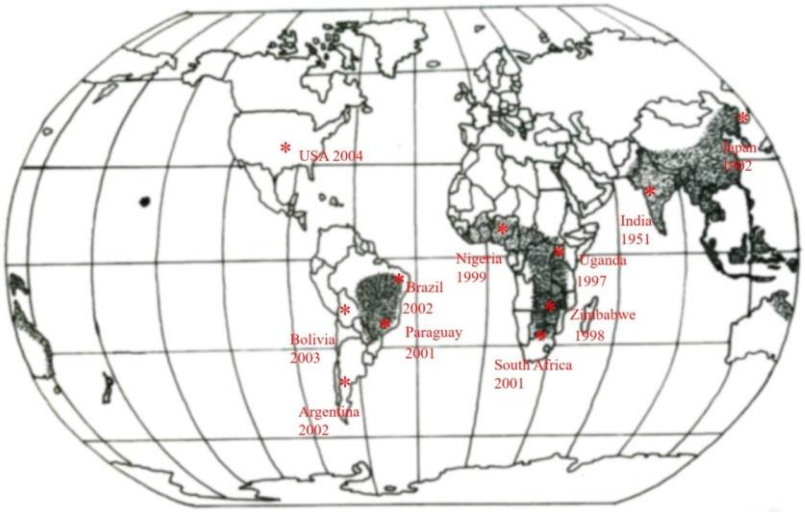

Figure 1: Distribution of Asian soybean rust and the year it was first reported for each location

The pathogen life wheel and infection process

Uredospores can be dispersed by wind and deposited on the host leaf surface which begins to germinate followed by the initiation of infection. Infection process takes place in the presence of water and an optimum temperature of 21°C to 25°C.Approximately eight days after the infection fungus begins reproduction that leads to hyphal aggregation forming the uredosorus primordium. Uredospores start producing in about three to four days after the formation of uredosorus primordium (Rosa *et al.,* 2015).

After germination of the uredospore on the leaf surface of the host plant the infection process begins. The growth of the germ tube is terminated by the formation of appressorium. Appressorium is a specialized, globose infection structure which is separated from the germ tube by the formation of a septum. The asexual cycle has been summarized in the Figure 2.

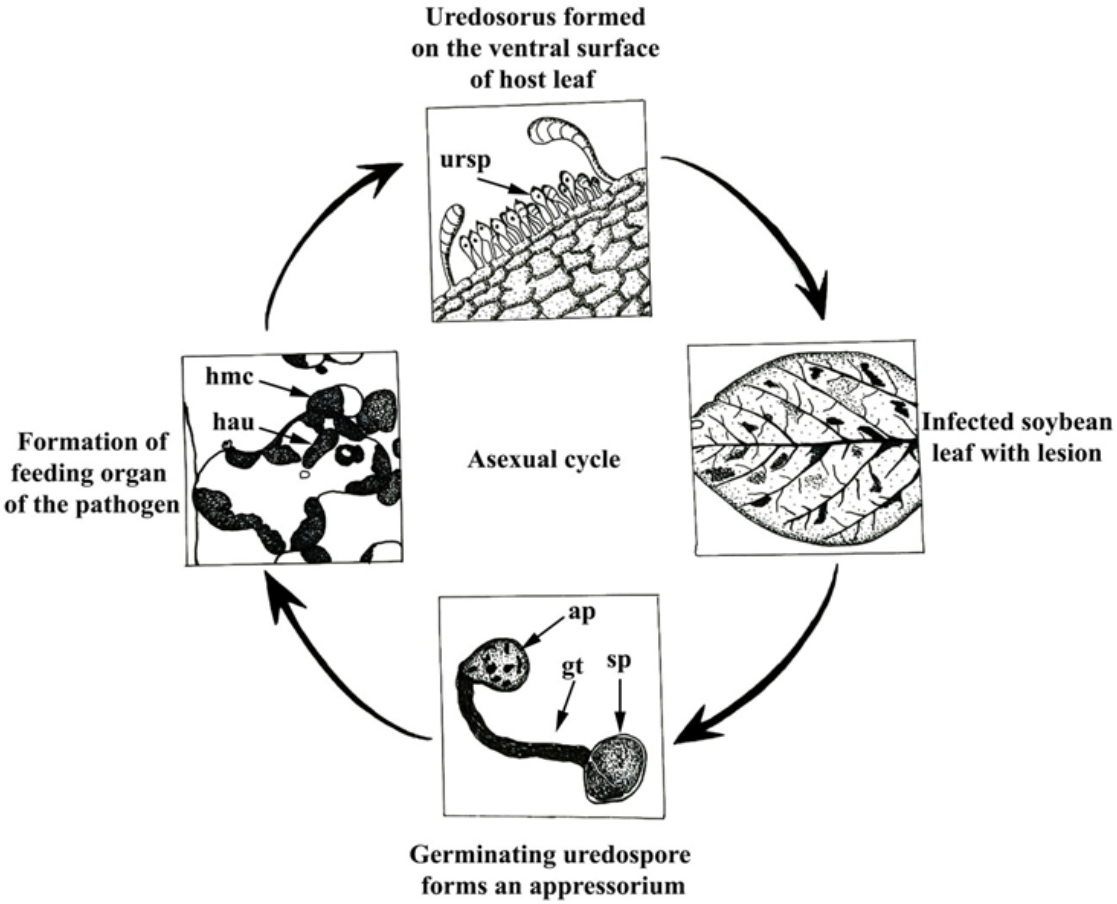

Figure 2: Life cycle of *P. pachyrhizi*. app; appressorium, sp; spores, hmc; haustorial mother cell, hau; haustoria

The fungus *P. pachyrhizi* penetrates into the host epidermal cells within the appressorium by building of an internal structure called the appressorial cone (Figure 3) which then elongates into the penetration peg (Bromfield and Hartwig 1980). The penetration of the parasite directly through the cuticle and epidermal cell wall of the host is a special characteristic feature of Asian

soybean rust that helps to differentiates *P. pachyrhizi* from other rust fungi. In contrast to *P. pachyrhizi*, majority of other rust fungi exhibited stomatal penetration (Rosa *et al.*, 2015; Chander *et al.*, 2019).

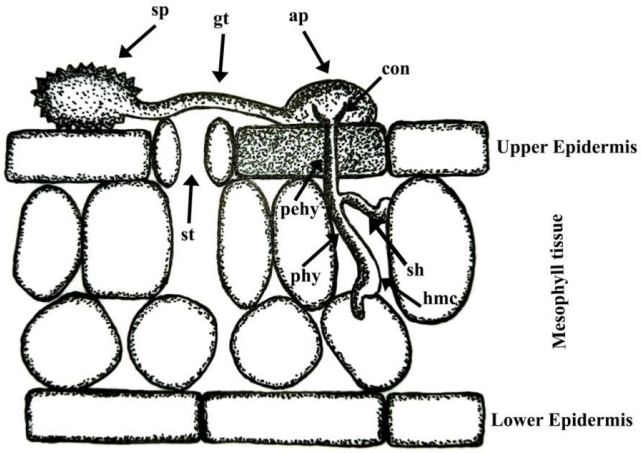

Figure 3: Initial interaction of *P. pachyrhizi* with host plant. Sp; spore, gt; germ tube, app; appressorium, penh; penetration hypha, ph; primary hypha, sh; secondary hypha, hmc; haustorial mother cell

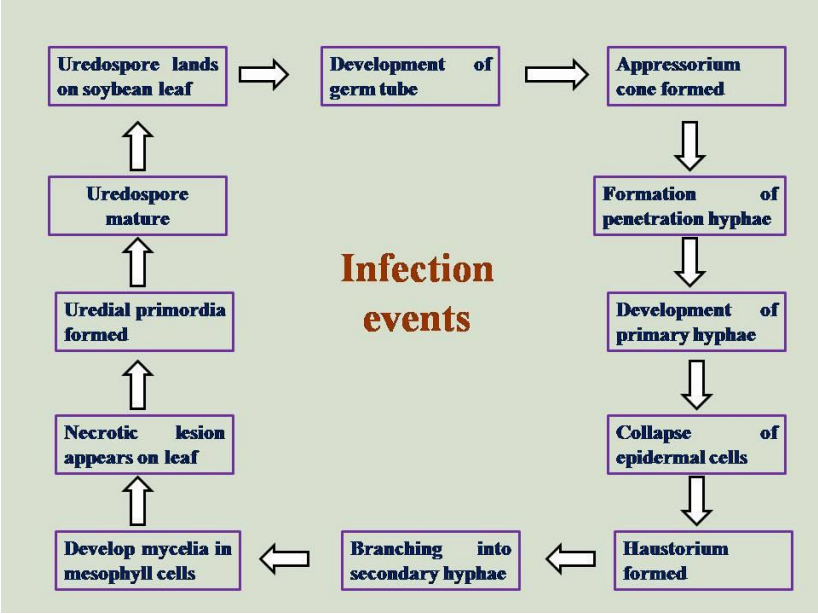

Figure 4: Different series of events that takes place during the infection

The infection process of *P. pachyrhizi* includes a sequence of events (Figure 4). The epidermal cells of the host plant undergo cell death after penetration by *P. pachyrhizi*, it is a very uncommon feature among biotrophic pathogens particularly in rust diseases (Keogh *et al.*, 1980; Hartman *et al.*, 2011). However, the cell death event does not affect the growth of the penetration hyphae, growth of the hyphae goes on and they branched after they reached the mesophyll tissue and differentiating into haustorial mother cells (Koch *et al.*, 1983). The haustorial mother cell gives rise to formation of a specialized infection structure called haustoria which is an essential

feeding organ of the pathogen. All obligate biotrophic fungal plant pathogens produce haustoria, it is a very common feature among them and failure of which is a knock-out criterion for infection (Goellner *et al.,* 2010). The fungal mycelium intensively colonizes the host tissue after the haustoria successfully established and then the production of new uredospores completes the pathogens life cycle (Koch *et al.,* 1983).

Disease epidemiology

Asian soybean rust favors the environments that are humid and warm. The spores of the pathogen can be able to germinate on the leaf of the host plant only after a continuous period of wetness, this situation will aid the growth of this disease. Temperature, rainfall and leaf wetness are some of the main factors which determines the severity of the disease (Tschanz *et al.,* 1982).

Rust epidemics are most severe when the average daily temperature is less than 28°C and presence of an extended period of leaf wetness with relative humidity of 75-80% (Hartman *et al.,* 1999). Dry conditions, excessive precipitation or daily mean temperatures greater than 30°C or less than 15°C inhibit rust development (Bromfield *et al.,* 1980). Moisture on plant surfaces is crucial for germination to occur. Hence areas where prolonged periods of leaf wetness due to dew, mist and light rain occurs provide optimum conditions for germination (Goellner *et al.,* 2010). Temperatures above 27°C for extended periods retard rust development even with adequate free moisture on the leaf surface (Hartman *et al.,* 2005). Soybean rust develops more rapidly in the areas where rainfall occurs more evenly throughout the season, as compared to the areas where rainfall occurs in an uneven pattern. Hence rust development varies according to prevailing rainfall patterns.

The uredospores are the primary inoculum of soybean rust. These are asexual, small, lightweight spores, which are released from uredosorus when the infected leaf surface gets dry. They can be able to spread from one field to another through the air current. The uredospores deposited on the leaf surface, infects the host plant and starts germinating in the presence of 21°C to 25°C temperature (Miles *et al.,* 2003). The direct penetration is a characteristic of the *P. pachyrhizi* fungus that differentiates it from other rust causing fungi (Rosa *et al.*, 2015).

Control measures

To control soybean rust different strategies has been incorporated by different researchers. In the following context some of the potential disease management techniques have been discussed.

Chemical Controls

The importance and application of fungicides in crop the field has increased significantly as their efficacy of protection has evolved drastically. In the present time the application of fungicides is the most effective means of control of soybean rust. During 1960s the first report of chemical control of soybean rust was recorded. Based on the effectiveness of lime-sulphur,

Bordeaux mixture, mercurials and zineb that are initially tested on soybean plant in Japan, scientists have showed their interest in development of fungicides to control soybean rust (Bromfield and Hartwig 1980). The most commonly used fungicides are belonged from the group triazoles, carboxamide and strobulirins.

Protective fungicides are used before the pathogen attack that ensures protective barriers against the fungal pathogens by inhibiting spore germination. Recently due to the problem of the efficacy of two most commonly used fungicide DMI and QoI, copper based multisite fungicide like dithiocarbamate and chloronitriles with combination of systemic chemicals has been tested to obtain resistance (Miles *et al.,* 2007). The group sterol biosynthesis inhibitor includes three groups of fungicides viz amines, DMI and hydroxyanilides. These compounds are so much versatile and used in various crops including soybean. Triazole is another group of fungicides with potential eradicative property and long residual effects. Triazoles such as frutriafol and tebuconazole are extensively used in the management of Asian soybean rust which gives significant resistance against *P. pachyrhizi*. There are some triazole fungicides which are commercially registered for Asian soybean rust including cyproconazole, epoxyconazole, fluquinconazole, tetraconazole, metconazole and flutriafol (Langenbach *et al.,* 2016). Strobilurins is also used in the rust disease management program. Strobilurins in combination with triazole exhibited significant resistance against the rust fungi in soybean. In the following Table 1 some of the commercially available fungicides are listed which are used to control *P. pachyrhizi.*

Table 1: Some of the major fungicides with their trade name and active ingredients used to control Asian soybean rust (After Yorinori *et al.*, 2005).

Sl. No.	Active constituents	Trade name	Dose of usage (ml/ha)
1.	Triforine	Funginex®	1500
2.	Cyproconazole	Alto®	300
3.	Flutriafol	Impact®	800
4.	Tebuconazole	Folicur®	1000
5.	Triademenol	Shavit®	500
6.	Carbendazim	Punch Xtra®	350
7.	Propiconazole	Tilt®	500
8.	Difenoconazole	Score®	300

Biological controls

Protection against Asian soybean rust using beneficial microbes and other biological organism has been obtained. The bio control of soybean rust not yet clearly found through

studies, but some macro parasites such as *Trichothecium rosae* and *Simplicillium lanosoniveum* seem to be potential biocontrol agents. These organisms colonize in the uredosori of *P. pachyrhizi*on the infected leaves which eventually reduce both sporulation and disease severity (Kumar *et al.,* 2002; Ward *et al.,* 2012). It was also found that *T. rosae* mediate the lysis of the growing uredospores by causing shrinkage and hypertrophy. In addition to this some of the *Bacillus* species were also found to be effective against *P. pachyrhizi.* The bacterium *Bacillus* is used as an active constituent of the commercially available fungicides named as Ballad® which is a potential protective agent in soybean rust disease management. A soilborne bacterium, *Xanthomonas parasitica* that are spread by rain splash, parasitizes uredia of various cereal rust fungi and causes uredospore lysis (Pon *et al.,* 1954). Beside these antagonistic microbes, it has been demonstrated that farnesyl acetate, a naturally occurring plant volatile emitted by rust infected plants, negatively affects haustorial development. Thus, this compound might be used to control soybean rust in an environmentally compatible manner (Mendgen *et al.,* 2006). These are the some evidences of biological control of soybean rust. However, more studies and trials are needed to obtain resistance through biological control.

Secondary metabolites

Accumulation of secondary metabolites in response to invading pathogens attacks is a very common defense mechanism of plants. In most of the cases these metabolites are cell wall degrading agents and antimicrobial chemicals which draw a barrier against an infection. Secondary metabolite plays an important role in the interaction of *P. pachyrhizi* and soybean plant during the disease progression. It was reported that during the infection events isoflavonoids compounds like genistein, glyceollin and daidzein is accumulated which affects the spore germination and reduces disease severity in both resistant and susceptible soybean plants (Lygin *et al.,* 2009). The role of phytoalexins is also observed in providing resistance against soybean rust. In *Glycine tomentella* an alternative host of *P. pachyrhizi*, accumulates an isoflavonoid upon infection which inhibits uredospore germination (Chung and singh 2008). Accumulation of medicarpin in *Medicago truncatula* a non-host plant of *P. pachyrhizi* supported the potential ability of phytoalexins in defeating the rust. It was reported that medicarpin negatively regulate the infection events by blocking the uredospore germination (Ishiga *et al.,* 2015). The molecular investigation on this chemical pathway could identify the specific genes which can be used to construct resistant transgenic soybean plants. Moreover these metabolites can be used as natural fungicides that could provide resistance in susceptible hosts. The importance of phenylpropanoid pathway in disease resistance has been studied by gene silencing. When the phenylalanine ammonia lyase enzyme gene gets silenced the *Rpp-2* mediated resistance in infected plants was compromised (Pandey *et al.,* 2011). Beside this, antimicrobial peptides can also provide resistance against soybean rust. However the efficacy of these peptides

is not well studied. Intragenic antimicrobial peptides from the other organisms can be used to construct transgenic plant. For instance penetratin and dermaseptin SI are two IAP which provides soybean rust resistance by inhibiting uredospore germination (Brand *et al.*, 2012).

Non-host resistance

Incorporation of non-host plant is another promising approach of soybean rust resistance. Application of non-host plant is an effective technique to identify the resistance trait. Use of these plants enables the utilization of vast genetic resources. It is a complex type of resistance strategies which shares defense mechanism with the host plant. It is very difficult to distinguish host and non-host plant since there is many intermediate resistance (Bettgenhaeuser *et al.*, 2014). Genetic analysis of these resistance traits in soybean plant may provide alternative resistance beside chemical fungicides and biological control. In terms of non-host resistance *Arabidopsis thaliana* and *M. truncatula* are best described non host plant. However the initial stage of development of *P. pachyrhizi* in both, *A. thaliana* and soybean are similar. Although there is no report of hyphal proliferation in leaf mesophyll cells of *A. thaliana*. To encounter the preinvasion resistance in *Arabidopsis* penetration mutants were used. Three mutant *pen1, pen2* and *pen3* were prepared and it was observed that hyphal proliferation occurred in these mutants. However despite of hyphal proliferation in mesophyll tissue fungus did not complete its life cycle and failed to colonize. This indicates the preinvasion resistance in this plant. The post invasion resistance was also encountered in this plant with triple mutant *pen2, pad4, sag101*. This study reveals that interspecies transfer of these genes can induce resistance against *P. pachyrhizi* (Langenbach *et al.*, 2013).

Phakopsora pachyrhizi can infect various plants but its occurrence in non-host plant is very rare. *Medicago truncatula* is the only legume non host plant in which sporulation does not occurs. The mutants in this plant were identified by forward genetic screening as the plant contains diploid genome. The mutant *M. truncatula* exhibited altered resistance to *P. pachyrhizi*. Genetic screening identified a *irg 1* (inhibitor of rust germ tube differentiation) mutant which inhibits the formation of pre-infection structure in this plant (Uppalapati *et al.*, 2012). Moreover, the interaction between *P. pachyrhizi* and *M. truncatula* induces several genes which are associated with isoflavonoids, phenylpropanoid and flavonoid pathway. These groups of chemicals block the uredospore formation which eventually slows down disease progression (Ishiga *et al.*, 2015). In addition to this the role of phytoalexins in rust resistance is also explored. These genes provide resistance in soybean plants against *P. pachyrhizi*.

Resistance genes

It is very interesting that pathogens exhibit different levels of virulence and aggressiveness in different hosts. These host specific physiologic specializations are known as pathotypes or pathogenic races (Chander *et al.*, 2019). To overcome the virulence of these

pathogens superior genetic resources are needed to achieve a long durable resistance. In plant use two types of defense against a pathogen, race specific resistance and race non-specific resistance (Rosa *et al.,* 2015). During the infection process pathogens releases effectors to establish a successful infection. In response to effectors plant induce their resistance mechanisms by activating different downstream signaling cascades. At the early stages of infection pathogens releases pathogen associated molecular pattern (PAMPs) which is identified by pathogen recognition receptors (PRR) present in plant and initiate immune responses. This type of immune response is known as PAMP triggered immunity or PTI. This plant defense response is the first line of defense and not so durable. At the later stage plant exhibit effectors trigger immunity (ETI) which is a long lasting and durable resistance. Due to ETI plant initiate different signaling cascade which results in R gene expressions (Mackey and McFall 2006; Langenbach *et al.,* 2016). Similarly different dominant R genes were also identified from different varieties of soybean plants which is presented in the following Table 2.

Table 2: List of resistance genes indentified in different soybean variety in different country

Resistance gene	Variety/ Plant line	Original name	Origin	Chromosome no.	Reference
Rpp 1	PI 200492	Komata	Japan	18 (G)	Rosa *et al.,* 2015
Rpp 1	PI 561356	Jin Yun Dou	China	18 (G)	Kim *et al.,* 2012
Rpp 1	PI 594177	Himeshirazu	Japan	18 (G)	Yamanaka *et al.,* 2015
Rpp 1	Xiao Jing Huang	Xiao Jing Huang	China	18 (G)	Yamanaka *et al.,* 2015
Rpp 1b	PI 594538A	Min Hou Bai Sha Wan Dou	China	18 (G)	Chakraborty *et al.,* 2009
Rpp 1b	PI 587886	Bai Dou	China	18 (G)	Ray *et al.,* 2009
Rpp 2	PI 230970	No. 3	Japan	16 (J)	Bromfield and hartwig 1980; Rosa *et al.,* 2015
Rpp 2	PI 197182	Raub 16.1422	Malayasia	16 (J)	Rosa *et al.,* 2015
Rpp 3	PI 462312	Ankur	India	6 (C2)	Hartwig and Bromfield 1983
Rpp 3	PI 628932	FT-2	Brazil	6 (C2)	Chander *et al.,* 2019

Rpp 3	D86-8286	D86-8286	USA	6 (C2)	Kato 2017
Rpp 4	PI 459025	Bing Nan	China	18 (G)	Hartwig 1986
Rpp 5	PI 200487	Kinoshita	Japan	3 (N)	Garcia *et al.,* 2008
Rpp 5	PI 471904	Orba	Indonesia	3 (N)	Garcia *et al.,* 2008
Rpp 6	PI 567120B	MARIF 2767	Indonesia	18 (G)	Li *et al.,* 2012; Chander *et al.,* 2019
Rpp 7	PI 605823	SAMPLE 87	Vietnam	19 (L)	Chander *et al.,* 2019

Beside the dominant resistance genes, R gene pyramiding is another potential strategy of soybean rust resistance. R Gene pyramiding is the process of combine two different R genes into a single genetic background. Several evidences supported this process as a potential technique of conferring resistance. Different researchers applied this technique and got promising result towards the Asian soybean rust resistance.

Host induced gene silencing and RNAi technique

Gene silencing by using small double stranded interfering RNA has been a potential technique in various disease management. To control soybean rust RNAi can be used to silence genes of *P. pachyrhizi* which are critical for disease development. Host induced gene silencing is another version of RNAi technique which is very effective against different fungi, virus, oomycetes, nematodes, bacteria and sucking insects (Langenbach *et al.,* 2016). Previously it was reported that gene silencing of nematodes by using siRNA in soybean plant provides protection against the pathogen. However there is no such report found about the soybean rust resistance by using this technique. Although different destructive rust fungi has been controlled in different crops by gene knockout technique which includes *Puccinia graminis, P. striiformis* and *P. triticina* (Yin *et al.,* 2010; Panwar *et al.,* 2013). These evidences support that host induced gene silencing could be used as an alternative strategy in case of soybean rust resistance. Several stage specific genes of *P. pachyrhizi* has already been identified including kinase family protein, cell wall degrading enzymes, metabolism linked genes etc. (Stone *et al.,* 2012; Link *et al.,* 2014; Langenbach *et al.,* 2016). Targeting these genes might provide resistance in soybean.

Conclusion and Future Outlook:

Asian soybean rust caused by *P. pachyrhizi* is a devastating disease of soybean field thus it is a great threat to soybean production worldwide. This virulent pathogen can spread a wide range of area since the uredospores are dispersed by wind and can initiate several infection cycle in a single growing season. It is very difficult to study the pathogen outside of its host since it is an obligate parasite. Till now majority of the researches on Asian soybean rust are mainly

targeted on the disease development, epidemiology and control measures. Though these researchers are centered on the diseased plants but it is still not clearly known whether all the soybean cultivars are resistant to *P. pachyrhizi* or not. The interaction between the host and pathogen during the infection events should be explored more thoroughly to identify the crucial elements of disease progression. More studies on the pathogen are required as there is not sufficient data present about *P. pachyrhizi*. Gene expression analysis during the infection could identify novel strategies for induced resistance against the fungus. Though researchers have already indentified some of the crucial genes in soybean but still more information is needed about the up regulation of different genes during appressorium formation and epidermal penetration to achieve a clear idea on the asexual cycle of *P. pachyrhizi*.

Chemical control is one of the effective means of controlling rust. There are many novel compounds like DMI, QoI and SDHI which holds a promising control of soybean rust in near future. But it was also found that excess and long term use of these fungicides achieve insensitivity in *P. pachyrhizi*. Since R gene mediated resistance in the cultivars variety exhibited long lasting and potential resistance it is very essential to explore more transcriptional analyses on this disease. Engineered R gene and induction of phytoalexins biosynthesis pathway is also promising way of rust resistance. Beside this exploration of non-host plant mediated resistance would provide a vast range of germplasm resources in upcoming years. More application of new biotechnological techniques like gene knockout, gene silencing and genome editing tools like CRISPR/Cas9 has to be incorporated to achieve promising resistance in soybean. It can be concluded that genetic tools along with biological control would provide a sustainable soybean production in future.

References:

1. Balardin RS, Meneghetti R, Navarini L, Debortoli MP (2006). Residual Relativo. Revista Cultivar 90:17–21
2. Bettgenhaeuser J, Gilbert B, Ayliffe M, Moscou MJ (2014). Nonhost resistance to rust pathogens– a continuation of continua. Frontiers in Plant Sciences 5:664-679
3. Brand GD, Magalhães MTQ, Tinoco MLP, Aragão FJL, Nicoli J, Kelly SM, Cooper A, Bloch jr. C (2012). Probing protein sequences as sources for encrypted antimicrobial peptides. PLoS ONE 7:e45848
4. Bromfield KR, Hartwig EE (1980). Resistance to soybean rust [*Phakopsorapachyrhizi*] and mode of inheritance. Crop Science 20:254-255
5. Bromfield KR, Melching JS, Kingslover CH (1980). Virulence and aggressiveness of *Phakopsorapachyrhizi* isolates causing soybean rust. Phytopathology 70:17-21

6. Chakraborty N, Curley J, Frederick RD, Hyten DL, Nelson RL, Hartman GL, Diers BW (2009). Mapping and confirmation of a new allele at Rpp1 from soybean PI594538A conferring RB lesion-type resistance to soybean rust. Crop Science 49:783-790
7. Chander S, Beltran AO, Bandyopadhyay R, Sheoran P, lge GO, Vasconcelos MW, Oliveira ALG (2019). Prospects for Durable Resistance Against an old Soybean Enemy: A Four-Decade Journey from *Rpp1* (Resistance to*Phakopsorapachyrhizi*). to Rpp7. Agronomy 9:348-370
8. Chung G, Singh RJ (2008). Broadening the genetic base of soybean: a multi disciplinary approach. Critical Reviews in Plant Sciences 27:295–341
9. Garcia A, Calvo ES, de Souza Kiihl RA, Harada A, Hiromoto DM, Vieira LGE (2008). Molecular mapping of soybean rust *(Phakopsorapachyrhizi*). resistance genes: Discovery of a novel locus and alleles. Theoretical and Applied Genetics 117:545–553.
10. Goellner K, Loehrer M, Langenbach C, Conratg UWE, Koch E, Schaffrath U (2010). *Phakopsorapachyrhizi*, the casual agent of Asian soybean rust. Molecular Plant Pathology 11:169-177
11. Guicherit E, Bartlett D, Dale SM, Haas HU, Scalliet G, Walter H (2014). Solatenol-the second generation benzonorbornene SDHI carboxamide with outstanding performance against key crop diseases. Sygenta Crop Protection 2014:67–72
12. Hartman GL, Chang HX, Leandro LF (2015). Research advancement and management of soybean sudden death syndrome. Crop Protection 73:60-66
13. Hartman GL, Miles MR, Frederick RD (2005). Breeding for resistance to soybean rust. Plant Disease 89:664-666
14. Hartman GL, Sinclair JB, Rupe JC (1999). Compendium of Soybean Diseases. 4th ed. American Phytopathological Society Press, St paul, MN, USA
15. Hartman GL, West ED, Theresa KH (2011). Crops that feed the world 2.Soybean-worldwide production, use, and constraints caused by pathogens and pests. Food security 3:5-17
16. Hartwig EE (1986). Identification of a fourth major gene conferring resistance to soybean rust. Crop Science 26:1135-1136
17. Hartwig EE, Bromfield KR (1983). Relationships among three genes conferring specific resistance to rust in soybeans. Crop Science 23:237-239
18. Hennings P (1903). EinigeneuejapanischeUredineen IV. HedwigiaBeiblatt 42:107-108
19. Kato M (2017). Effectiveness of Resistance Genes to the Soybean Rust Pathogen *Phakopsorapachyrhizi*. Japan Agricultural Research Quarterly 51:199 – 207

20. Kendrick MD, Harris DK, Ha BK, Hyten DL, Cregan PB, Frederick RD, Boerma HR, Pedley KF (2011). Identification of a second Asian soybean rust resistance gene in Hyuuga soybean. Phytopathology 101:535–543
21. Keogh RC, Deverall BJ, Mcleod S (1980). Comparison of histological and physiological responses to *Phakopsorapachyrhizi*in resistant and susceptible soybean. Transactions of the British Mycological Society 2:329-333
22. Killgore E, Heu R, Gardner DE (1994). First report of soybean rust in Hawaii. Plant Disease 78:1216
23. Kim KS, Unfried JR, Hyten DL, Frederick RD, Hartman GL, Nelson RL, Song Q, Diers BW (2012). Molecular mapping of soybean rust resistance in soybean accession PI 561356 and SNP haplotype analysis of the Rpp1 region in diverse germplasm. Theoretical and Applied Genetics 125:1339-1352
24. Koch A, Kogel K (2014). New wind in the sails: improving the agronomic value of crop plants through RNAi-mediated gene silencing. Plant Biotechnology Journal 12:821–831
25. Koch E, Ebrahimnesbat F, Hoppe HH (1983). Light and electron-microscopic studies on the development of soybean rust (*Phakopsorapachyrhizi* Syd). in susceptible soybean leaves. PhytopathologischeZeitschrift 106:302-320
26. Kumar S, Jha DK (2002). *Trichotheciumroseum*: A potential agent for the biological control of soybean rust. Indian Phytopathology 55:232–234
27. Langenbach C, Campe R, Schaffrath U, Goellner K, Conrath U (2013). UDP-glucosyl transferase UGT84A2/BRT1is required for *Arabidopsis* non host resistance to the Asian soybean rust pathogen *Phakopsorapachyrhizi*. New Phytologist 198:536–545
28. Langenbach C, Schultheiss H, Rosendahl M, Tresch N, Conrath U, Goellner K (2016). Interspecies gene transfer provides soybean resistance to a fungal pathogen. Plant Biotechnology Journal 14:699-708
29. Levy C (2005). Epidemiology and chemical control of soybean rust in southern Africa. Plant Disease 89: 669-674
30. Li S, Smith JR, Ray JD, Frederick RD (2012). Identification of a new soybean rust resistance gene in PI 567102B. Theoretical and Applied Genetics 125:133–142
31. Link TI, Lang P, Scheffler BE, Duke MV, Graham MA, Cooper B, Tucker ML, Van De Mortel M, Voegele RT, Mendgen K, Baum TJ, Whitham SA (2014). The haustorial transcriptomes of *Uromyces appendiculatus*and*Phakopsorapachyrhizi*and their candidate effector families. Molecular Plant Pathology 15:379–393.
32. Lygin AV, Li S, Vittal R, Widholm JM, Hartman GL, Lozovaya VV (2009). The importance of phenolic metabolism to limit the growth of *Phakopsorapachyrhizi*. Phytopathology 99:1412–1420

33. Mackey D, McFall AJ. MAMPs and MIMPs: proposed classifications for inducers of innate immunity. Molecular Microbiology 61:1365–1371
34. Maiti S, Dhar V, Verma RN (1981). Rust of soybean in India. Soybean Rust Newsletter 1: 14-16
35. Mendgen K, Wirsel SGR, Jux A, Hoffmann J, Boland W (2006). Volatiles modulate the development of plant pathogenic rust fungi. Planta 224:1353-1361
36. Miles MR, Corrales MAP, Hartman GL, Fredrick RD (2007). Differential response of common bean cultivars to *Phakopsorapachyrhizi*. Plant Disease 91:698-704
37. Miles MR, Hartman GL, Levy C, Morel W (2003). Current status of soybean rust control by fungicides. PesticideOutlook14:197-200
38. Ogot H, Okoth S, Obiero G, Mahasi J (2017). Assessment of Asian soybean rust (*Phakopsorapachyrhizi*). disease severity in selected districts of Western Kenya. IJAAR. International Journal of Agronomy and Agricultural Research 11:50-53
39. Pandey AK, Yang C, Zhang C, Graham M, Horstman HD, Lee Y, Zabotina O, Hill JH, Pedley KF, Whitham SA (2011). Functional Analysis of the Asian Soybean Rust Resistance Pathway Mediated by Rpp2. Molecular Plant Microbe Interactions 24:194-206
40. Panwar V, McCallum B, Bakkeren G (2013). Endogenous silencing of *Puccinia triticina*pathogenicity genes through inplanta-expressed sequences leads to the suppression of rust diseases on wheat. The Plant Journal 73:521–532
41. Pon DS, Townsend CE, Wessman GE, Schmitt CG, Kingsclover CH (1954). A *Xanthomonas parasitic* on uredia of cereal rusts. Phytopathology 44:707-710
42. Pretorius ZA, Kloppers FJ, Frederick RD (2001). First Report of Soybean Rust in South Africa. Plant Disease 85:1288
43. Ray JD, Morel W, Smith JR, Frederick RD, Miles MR (2009). Genetics and mapping of adult plant rust resistance in soybean PI 587886 and PI 587880A. Theoretical and Applied Genetics 119: 271-280
44. Rosa CRE, Spehar CR, Liu JQ (2015). Asian Soybean Rust Resistance: An Overview. Journal of Plant Pathology and Microbiology 6:307-313
45. Sarbhoy A, Thapliyal PN, Payak MM (1972). *Phakopsorapachyrhizi* on soybean in India. Science and Culture 4:198
46. Sharma ND, Mehta SK (1996). Soybean rust in Madhya Pradesh. TVIS Newsletter 2: 19-20
47. Sharma SK, Gupta GK (2006). Current Status of Soybean Rust *(Phakopsorapachyrhizi).* – A Review. Agricultural Review 27: 91-102

48. Stone CL, McMahon MB, Fortis LL, Nuñez A, Smythers GW, Luster DG, Frederick RD (2012). Gene expression and proteomic analysis of the formation of *Phakopsorapachyrhizi*appressoria. BMC Genomics 13:269-290.
49. Tremblay A, Hosseini P, Li S, Scheffler BE Matthews BF (2009). Laser capture microdissection and expressed sequence tag analysis of uredinia formed by *Phakopsorapachyrhizi*, the causal agent of Asian soybean rust. Physiological and Molecular Plant Pathology 73:163–174
50. Tschanz AT, Tsai BY (1982). Effect of maturity on soybean rust development. Soybean rust Newsletter 5:39-41
51. Uppalapati SR, Ishiga Y, Doraiswamy V, Bedair M, Mittal S, Chen J, Nakashima J, Tang Y, Tadege M, Ratet P, Chen R, Schultheiss H, Mysore KS (2012). Loss of abaxial leaf epicuticular waxin*Medicago truncatula*irg1/palm1 mutants results in reduced spore differentiation of anthracnose and non host rust pathogens. Plant Cell 24:353–370
52. Ward NA, Robertson CL, Chanda AK, Schneider RW (2012). Effects of *Simplicilliumlanosoniveum*on *Phakopsorapachyrhizi*, the soybean rust pathogen, and its use as a biological control agent. Phytopathology 102:749–760
53. Yamanaka N, Hossain MM, Yamaoka Y (2015). Molecular mapping of Asian soybean rust resistance in Chinese and Japanese soybean lines, Xiao Jing Huang, Himeshirazu, and Iyodaizu B. Euphytica 205:311–324
54. Yin C, Jurgenson JE, Hulbert SH (2010). Development of a host- induced RNAi system in the wheat stripe rust fungus *Puccinia striiformis*f. *sp.tritici*. Molecular Plant Microbe Interaction 24:554–561
55. Yorinori JT, Paiva WM, Frederick RD, Costamilan LM, Bertagnolli PF, Hartman GE, Godoy CV, Nunes JJ (2005). Epidemics of soybean rust (*Phakopsorapachyrhizi*). in Brazil and Paraguay. Plant Disease 89:675–677

INSECT BIODIVERSITY: PINPOINTING THEIR BENEFICIAL ROLE

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Abstract:

Insects' world is diverse from different perspectives. Taxonomically they are the most diversified; functionally they have been reported to be involved in numerous phenomena and their dominance at all ecosystems is largely established. Statistically they account for more than fifty percentages of the reported species. This wider distribution is largely associated with the various adaptability in morphological, functional and genetic features that have enabled them to cope up with the diverse habitats. They largely influence human & animal health, agriculture and natural resources. They are rigorously referred as disease carriers affecting health and agricultural practices. Conversely, they are the prime agent that brings about important beneficial consequences like scavenging, pollination, yielding essential products, serving important informative models, rendering forensic related important information and others. There are factors that severely impacts insects population and diversity. Altered environmental conditions, increasing anthropogenic activities and changing agricultural practices have brought about marked changes in insect richness and biodiversity. Various categories of plant protection chemicals are targeting different systems and developmental stages of insects differentially. In the aspect of Anthropocene era, recent findings have conclusively shown dwindling diversity with reduction in terrestrial, aquatic and flying lineages of insect species. Contrary, the increasing herbivory have instigated diversification of various insect clades. There are diverse points relating to and emerging from insect biodiversity. This article is an attempt to unravel the beneficial insects and their detailed overview.

Keywords: Insects, Diversity, Beneficial, Environment, Plants, Richness

Introduction:

Insects are important components of the various ecosystems and are intricately linked to distinctive ecological functioning and services. They dominate all the major ecosystems as the predominant component except the coldest and most saline one. They are variously sized and inhabit all terrestrial and freshwater habitats (Stork *et al.,* 2015). The name Insects originate from Latin, *inseco*, from *in*, "to cut up"; as insects can be cut into 3 major parts – Head, thorax and abdomen. Insects have always been featured in taxonomy by various scientists. Aristotle in his "*Scala Naturae*" distinctly placed insects as a separate group just above the sponges and worms but below the marine shells. Carl Linnaeus in his "*Systema Naturae*", 1758 divided animal kingdom into six major classes including "Class Insecta". Jean Baptiste *de* Lamarck in his "*Philosophie Zoologique"* considered insects as one of the major nine invertebrate phyla.

Modern taxonomic classification based on morphology-based systematics and various phylogenetic data have placed insects as a major class under sub-phylum Uniramia of Phylum Arthropoda. Approximately insects constitute 66% of all animal species and 82% of the arthropods (Redak, 2023).

They are reported to evolve during Devonian period and as per records, their oldest fossil dates back to Early Devonian period which was of a primitive wingless insect. The oldest flying insects howsoever date back to mid-carboniferous. They subsequently diversified and majorly these four large-scale radiations of insects were considered – beetles, flies, moths and wasps. The insects are characterized for their interconnected three-part body - head, thorax and abdomen. The head supports a pair of sensory structures – the antennae, simple eyes (0 to 3), compound eyes (1 pair) and small appendages in its modified form to make the mouthparts. The thorax carries legs (3 pairs) &up to 2 pairs of wings. The abdomen harbours major systems – digestive, excretory, reproductive etc. Besides being a deleterious pests and parasite, they are effective pollinators and yields useful substances for diverse use like honey, silk, wax, lacquer etc (Redak, 2023). The article gradually will cover different role of the insects with major emphasis on the beneficial aspects.

Beneficial role of insects

1. Pollination:

This is the process by which flowering plants reproduce and it is integral for their survival. Pollens, the repertoire of genetic information are needed to travel from anther, the male reproductive part to stigma, the female reproductive part. The natural phenomenon like rain and wind often executes this; however in many different plant species pollination is specifically accomplished by agents like insects. Insects as a pollinators dates back to Cretaceous period. The tumbling flower beetle trapped in amber has been reported by researchers. *Cretoparacucujus cycadophilus* was the earliest beetle as per fossil record that was retrieved carrying the pollen of cycads. Of the many popular insect pollinators, few worth mentioning are Bumblebees, Hoverflies, Solitary bees, Wasps, Moths, Butterflies, Beetles, Ants etc. To elaborate the vivid relationship, it is important to discuss a few. The lepidopterans – butterflies and moths serve an important role in pollination in both wild ecosystems as well as managed ones. Bees are general visitors and generally pollinate a variety of crops and vegetables. The insect pollinators get the floral reward by getting access to nectar, heat sources, materials for nesting and glimpses of sites for mating, brooding and sleeping on their journey from one to another. There are a series of effective steps involved in this process of communication between flower and insect pollinators. Generally olfactory and visual cues stimulate nectar feeding responses in the pollinators. The sensory responses of the insects are important to perceive different floral traits like floral size, colouration pattern, organised positioning, helping the insects in understanding pre-existing biases, proper landing, subsequent feeding and detachment. Technical advancement and data from different projects like “1000 Plant Transcriptome Project” and “5000 Insects Genome

Project" have delineated the involvement of several genes shaping the plant-pollinators relationship and subsequent evolutionary trend.

Table 1: important floral characteristics and subsequent preferences and patterns of readily involved insect visitors (Wojcik 2021)

Floral Trait	Colour	Shape	Nectar Guides	Odour	Pollen	Nectar	Bloom
Canatharophily (beetle)	pale/dull, white, green	large, bowl-shaped	none	strong fruity or foul	abundant	accessible nectaries	day
Melittophily (bees, pollen wasps)	yellow, blue, purple, ultraviolet	complex, disc, or tubula	present, obvious	fragrant, pleasant	abundant	abundant	day
Psychophily (butterflies)	red, pink, purple, bright	disc shaped, landing pad	present	strong and fragrant	limited	Abundant, deep	day
Phalaenophily (moths)	pale, cream, white, yellow	tubular, with and without landing pad	none	strong and fragrant	limited	Abundant, deeep	day and night
Myophily (flies)	yellow, white	disc shaped	present	strong and fragrant	limited	abundant	day and night
Sapromyophily (carrion flies)	marron, green, dull	funnel or trap, small	present	strong and putrid	limited	absent	day and night
Myrmacophily (ants)	varied	open, small	present	none	varied	abundant, extrafloral nectaries	day

A cascade of gene has been implicated in floral development that often shows impact to co-ordinate pollinators' oriented floral attributes. Conversely, the visiting insects have specific physical adaptations like presence of hairs or scales for adhering the pollens. Bees are specialised in harbouring "scopa", dense aggregation of hairs on the underside of the abdomen or on their hind limbs. Few are even more specialised in having structures like "corbicula" that facilitates carrying a tightly packed ball. Flies are eventually covered by hairs throughout their body rendering passive uptake of pollens. Butterflies and moths have scales on face, thorax, wings,

abdomen and hind limbs. Pollens gets transported along these scales variously located in the body. Beetles feeds on pollens, hence the mouthparts itself or at times the rows of dense hairs or pollen broom on the maxilla and labium mediates the transportation of pollen (Wojcik, 2021).

Precisely the cumulative approaches of molecular developmental studies, population genetic approaches and detailed structural dynamics have rendered significant information on key floral traits and insects' capabilities rendering successful pollination generations after generations (Fattorini and Glover, 2020).

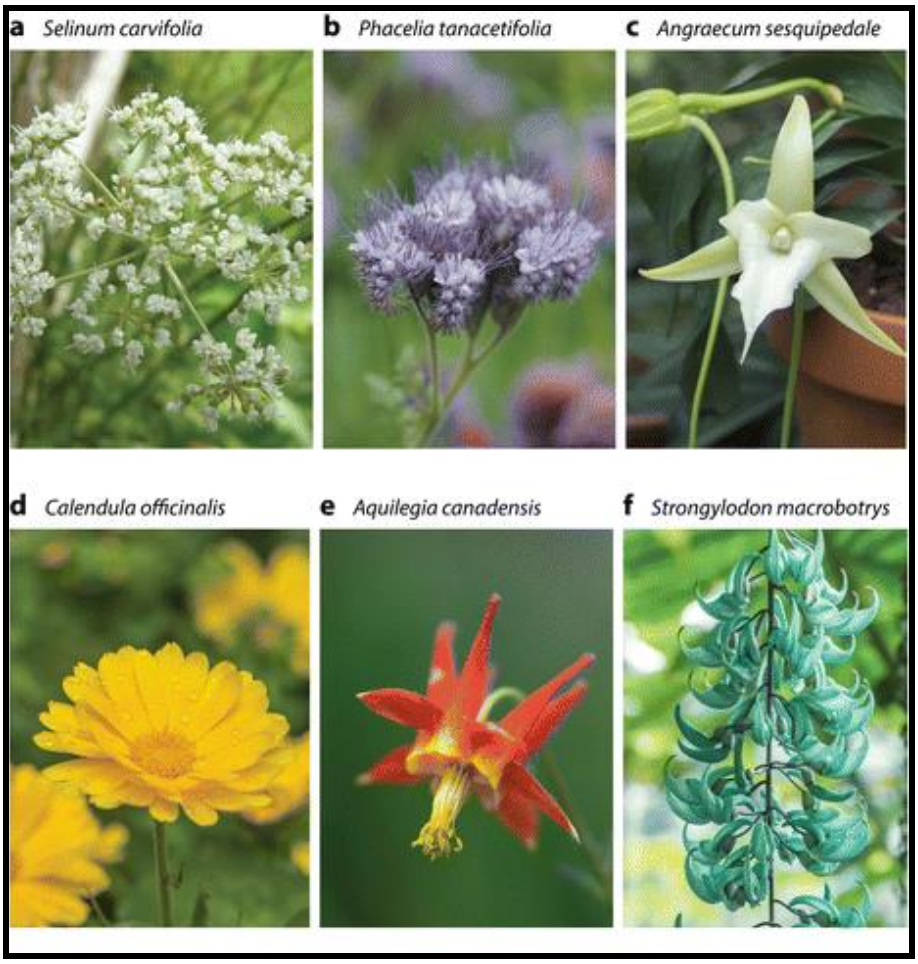

Figure 1: Pictures of different flowers pollinated by insects. (a) Fly-pollinated *Selinum carvifolia*. (b) Bee-pollinated *Phacelia tanacetifolia*. (c) Moth-pollinated *Angraecum sesquipedale*. (d) Butterfly-pollinated *Calendula officinalis*. (e) Bird-pollinated *Aquilegia canadensis*. (f). Bat-pollinated *Strongylodon macrobotrys (*Fattorini and Glover, 2020)

2. Efficient predators and parasitoids:

Predator insects often prey upon harmful organisms like ladybird beetles, ground beetles, lace wings, yellow jacket wasps, hover flies, mantids, dragonflies, damseflies etc. Usually the insect predators are characterized for having chewing mouth parts that enables them to chew and swallow up as found in ladybugs, preying mantis etc. Some of the assassin bugs, larvae of lacewings have piercing and sucking mouthparts. They stick their mouthparts into the prey, immobilize them using powerful toxins & digestive juices and then suck out the body content.

Few predating insects are slow runners and wait for the prey to fall to them. Others are efficient flyers or runners that aids in catching even the fast flying prey. Many insects can camouflage themselves well with the background facilitating easy ambush of the prey (Winterton, 2009).

- Family Coccinellidae – Insects like lady bug belong to this. They are active and voracious feeder of aphidsthat abundantly target pine, willow, several vegetable crops like potatoes etc.
- Family Carsbidae – Ground beetles and tiger beetles attacks aphids and other larvae of beetles & flies.
- Family Reduviidae –Assassin bugs kill the prey even of larger body size than themselves. They have strong sucking mouthparts allowing them to insert their proboscis and inject its digestive enzymes leading to oozing out of the body fluid.

  Ambush bug crypt itself to hide behind floral attributes as they wait for the prey. As the prey approaches, the raptorial front legs specialised in grabbing prey catch it firmly. Many small flies, beetles, bees, wasps that visit flowers are foraged by ambush bugs.
- Family Chrysopidae –Insects like green lacewings characterised for lacy looking wings belong to this family. They generally prey upon aphids, small caterpillars and beetles' larvae.
- Family Syrphidae –Syrphids or Hoverflies are named for their nature of hovering around flowers. Their larvae are the voracious feeder of scales, aphids, thrips and even smaller caterpillars. The adult hoverfly often lay eggs near or among the aphid colony as a strategy to ensure eating up of aphids.
- Family Asilidae –The representatives of this family efficiently hunt down the prey in the mid-air. They inject neurotoxin present in the saliva that rapidly immobilizes the prey, which is then carried back by themselves to the perch for feeding. Ex- Robberflies prey mostly on flying insects such as butterflies, bees, true bugs etc.
- Family Libellulidae – Dragonflies are characterized for their agile flying, strength and sharp eyesight. They are also efficient insect catcher that can hold an insect even in the middle of air. Mainly they target mosquitoes, butterflies, midges, damselfies.
- Family Vespidae–Wasps are the eusocial insects. They are opportunistic feeders as well feeding on caterpillars, leaf miners, spiders, aphids etc.

Parasitoids are the insects that parasitize oninsect species. Basically, they survive in or on the body of another insect (host), which is usually a parasite. They derive nutrition and enjoy protection therein. However, parasitoids execute it's affected in one of its immature stages and as they develop, they destroy its host eventually. The larvae of wasps, beetles and flies often act as parasitoids. The cotton bollworm, *Helicoverpa armigera* is a polyphagous species that affects important crop species like cotton, tomato, chickpea, rice, legumes, various fruits and flowering plants as well. The flies and waspscan parasitize *Helicoverpa* sp. The adult females often target the different developmental stages of *Helicoverpa* sp. by laying eggs either inside or on it. As the

eggs hatch, they start feeding. The parasitoid larva gradually spins its cocoon and pupates to emerge into adult. Depending upon the life stage of the host they attack, the entomologists have devised nomenclature. The wasp, *Trichogramma* sp., parasitizes the eggs of *Helicoverpa* sp.; henceit is referred as egg parasitoid. *Microplitis* attacks *Helicoverpa* caterpillars, hence referred to as larval parasitoid. Parasitoids are important considering their natural ability of pest management without any financial investment (Conti and Colazza, 2012).

Figure 2: *Trichogramma* sp sitting on the eggs of different agricultural pest (Parra and Zucchi, 2004)

3. Insects as scavengers and weed killers:

There are insects like Rove beetles, carrion beetles, midges, sand fliesetc. that feed on dead and decaying materials like animal dungs, vegetables' refuse, rotten substances etc. In an experiment by Ilardi *et al.*, a burying beetle, *Nicrophorus vespilloides* was shown to have accelerated decomposition of soil carrying mouse carcasses. These scavenging beetles also enrich the organic matter and nitrify the soil (Ilardi *et al.,* 2021).

Weeds are the plants that grow undesirably at a wrong place at the cost of native cultivation. They interfere with the natural yield and severely harm livestock, wildlife and even human beings. Insects can directly destroy weeds and serve as important biological control. Ex-water hyacinth, *Eichhornia crassipes* was effectively controlled in the southern part of India by the weevil *Neochetina* sp. & mite *Orthogalumna terebrantis*. There are several other examples worldwide and this process of biological control is relatively inexpensive (Jimanez and Balandra, 2007).

4. Insects in forensic science:

The forensic or medico-legal science is the investigative science that examines the site of crime and the associated evidences. The insects' species and developmental stages associated with the corpse can render lot of information. This is the time that has elapsed since death,

shifting of the body from site of crime or any other disturbance to the body. It's first implications were reported from China in the 13th century for investigating the death of a poor farmer. Forensic entomology primarily estimates "post mortem interval". This is the time that has elapsed after the death of the individual. It is determined by the evaluation of the insects or its succession pattern present at the crime spot and on the body itself by thorough scientific investigations. Francesco Redi, the Italian physician, discarded the theory of spontaneous generations in 1668. This theory brought huge revolution and gradually spurred analysing insects' life cycle and presence in corpses' respect, thus gradually paving the way for forensic entomology.

Hermann Reinhard, a Germany based doctor is associated to contribute significantly to this field. Dr. Louis Francois E Bergeret, French physician of 19th century, for the first time used forensic entomology and determined the post mortem interval for a case. The succession of insects on the buried and exposed corpse was studied. His theories have significantly contributed to the field of forensic entomology and have laid the foundation of it. Some of the books that he authored are *Faune des Tombeaux* and *La Faune des Cadavres*; they form the basics of forensic entomology (Benecke, 2001).

The readily investigated insects for the said purpose are as follows (Joseph *et al.,* 2011):

- Flies: These are the first to arrive and attach to the dead bodies and their maggots specialized to feed upon moistened remains. Blow flies can smell dead decaying flesh from up to 16 km. Flesh flies thrive on decaying garbage, corpse, dung and other remains; though a few of the fire flies sp. lay eggs in the open wounds as well.
- Beetles: They arrive generally after flies and are the residents of the corpses at its later stages of decomposition. The hide or skin beetles, precisely known as Dermestid beetles infest a decaying corpse after soft tissues are eaten up by other organisms. Generally, they propagate on hairs and skin of the cadaver and are amongst the most readily collected insects by entomologists. Similar are the conditions implicated with Bone beetles. Carrion beetles relish the maggots whereas the larvae of the carrion beetles propagate chiefly on carcasses. Scarab beetles feed on fungi and decaying flesh. Another important organism from this group are Sap beetles that feed on infested remains and are crucial in the investigation purpose.
- Mites and Moths: *Macrocheles* mites feed on carcasses and are spotted at the earlier stages of decomposition whereas *Tyroglyphidae* & *Oribatidae* thrives on skin and hence considered to join the later stages of decomposition. Moths' larvae are primarily active during twilight and feed the hair of corpses. These are amongst the last animals joining the body for decomposition.

The application of this particular investigative science is employed in several other cases as well in the determination of food infestation by looking at the debris, analysing the presence of drugs in the faeces, bodies and dead skin of insects feeding on corpse or extraction of DNA

from blood consuming insects. The application of entomology for investigating the crime is in rapid progress worldwide. In India, dedicated IFF Lab (Incognito Forensic Foundation), a private enterprise is present with its centres at Bangalore and Chennai. Howsoever, this technique is not much given importance in India yet. Even there are some outstanding instances, majorly the consideration of insects at the site of crime are not much in practice. There are lack of experts and infrastructure as well dedicated for this study and analysis (Amendt *et al.*, 2011).

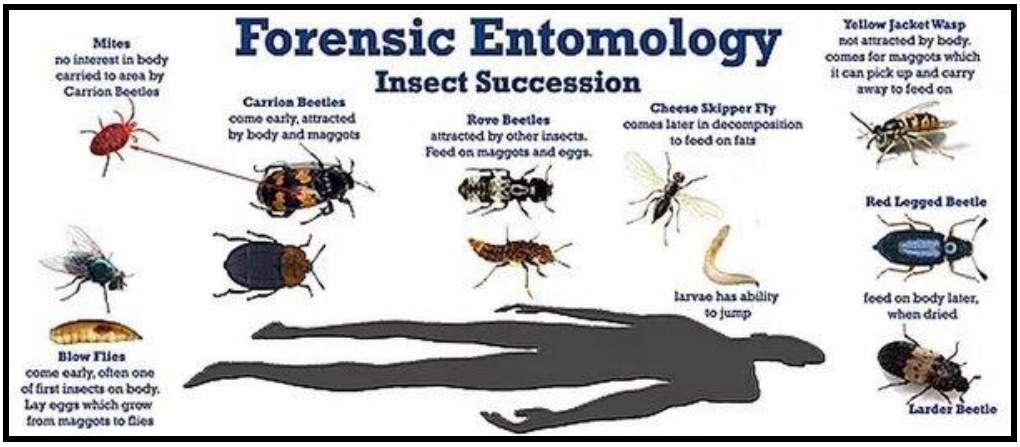

Figure 3: Different insects of forensic entomology (https://qr.ae/psI2b8**)**

Conclusion:

Insects, the distinctly segmented arthropods are widely distributed in the universe. Their anatomy and adaptability make them successful. They are harmful causing losses to vegetation, resources etc. But there is huge list of insects that brings about considerable benefits to mankind and ecosystem. This article is an attempt to describe some of the important beneficial aspects of insects. Theypromote soil aeration, fill the top layer of soil with nutrients for being excellent decomposer, acts as natural pest control, acts as scavengers by feeding on dead decaying matter, channelize water by digging the soil, bring about pollination in 75% of global crops, helps in building nation's economy by making several important medicinal & commercial products, immensely helpful to pharmaceutical industries and are important tool for investigating science.Threats to insects decline are immense ranging from deforestation, urbanization, habitat destruction, introduction of invasive species and several others. The meta analysis data suggest decline in insect population by 9% per decade with more threats to terrestrial insects than aquatic ones. It is important that we understand the several positive attributes of insects and make efforts to preserve them. Without insects, earth will be less attractive withecological imbalances owing to disturbance in food web and disruption in ecosystem.

References:

1. Stork N E., McBroom J G., Gely C *et al.*, New approaches narrow global species estimates for beetles, insects and terrestrial arthropods. Proceedings of the National Academy of Sciences of USA (2015). 112, 7519-7523. https://doi.org/10.1073/pnas.1502408112.

2. Redak R (2023). Introduction to and importance of insects. In: D. Allison, J., Paine, T.D., Slippers, B. Wingfield, M.J. (eds) Forest Entomology and Pathology. Springer, Cham. https://doi.org/10.1007/978-3-031-11553-0_1.
3. Wojcik V. Pollinators: Their evolution, ecology, management and conservation. Arthropods - Are they beneficial for mankind? IntechOpen; 2021. https://dx.doi.org/10.5722/IntechOpen.97153.
4. Fattorini R., and Glover B.J. Molecular mechanisms of pollination biology. Annual Review of Plant Biology 2020 71, 487-515.
5. Shaun L. Winterton, Chapter 229- Scales and Setae. Editors: Vincent H. Resh, Ring T. Card. Encyclopedia of Insects (Second Edition), Academic Press, 2009, 901-904. ISBN 9780123741448. https://doi.org/10.1016/B978-0-12-374144-8.00238-1.
6. Conti E., and Colazza S. Chemical ecology of egg parasitoids associated with true bugs. Psyche: A Journal of Entomology. https://doi.org/10.1155/2012/651015.
7. Parra, J.R., and Zucchi, R.A. (2004). Trichogramma in Brazil: feasibility of use after twenty years of research. Neotropical Entomology, 33, 271-281.
8. Ilardi M. O., Cotter S. C, Hammer E. C., *et al.*, Scavenging beetles control the temporal response of soil communities to carrion decomposition. 2021. https://doi.org/10.1111/1365-2435.13849.
9. Jimanez M. M, Balandra M. A. G. Integrated control of Eichhornia crassipes by using insects and plant pathogens in Mexico. Crop Protection (2007). 26, 1234-1238. https://doi.org/10.1016/j.cropro.2006.10.028.
10. Benecke M. A brief history of forensic entomology. Forensic Science International 120, 2-14, 2001.
11. Joseph I., Mathew D. G., Sathyan P., *et al.*, The use of insects in forensic investigations: An overview on the scope of forensic entomology. Journal of Forensic Dental Sciences 3 (2), 89, 2011.
12. Amendt J., Richards C. S., Campobasso C. P., *et al.*, Forensic entomology: applications and limitations. Forensic Science, Medicine and Pathology 7, 379-392, 2011.

Environment, Development and Sustainability
(ISBN: 978-93-95847-87-2)

THE ROLE OF ECOTOURISM IN BIODIVERSITY CONSERVATION EFFORTS IN TRIPURA, INDIA

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Abstract:

Tripura is a hilly North-Eastern state of India blessed with rich flora and faunal biodiversity. It has a variety of ecosystems and moderate climate throughout the year, all of which supports a multitude of wildlife species and thus considered the state Tripura has immense scope for ecotourism. It involves participation of local communities in overall economic development of area along with learning environment friendly way of life and support biodiversity conservation efforts while observing nature and wildlife. This study highlights how biodiversity conservation efforts have been made based on holistic approach of ecotourism development in the state of Tripura. It further looks at the other factors that play a role in successfully conserving biodiversity through ecotourism activities in the state of Tripura, a part of Indo-Burma biodiversity hotspot region of India.

Keywords: Ecotourism**;** Biodiversity Conservation; Community-Based Ecotourism; Overexploitation; Sustainable Ecotourism; Tripura

Introduction:

Ecotourism development and biodiversity conservation efforts have worked in tandem since the early twentieth century (1). Biodiversity conservation and sustainably utilizing natural resources improve the benefits of ecotourism development (2, 4). The International Union for Conservation of Nature suggested that biodiversity and ecotourism are mutually related (6). The International Ecotourism Society offers the following definition: “responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education” (3). Nature-based tourism considering environmental sustainability reduces the impact on native species of a specific habitat and there is a strong correlation exists between biodiversity conservation and growth of ecotourism businesses (5,7, 8).It has been proven fact that nature-based tourism should be coupled with biodiversity conservation efforts throughout the globe. Several studies recommend that positive impact has been found regarding biodiversity conservation with the help of a “coexistence model”, i.e., community-based ecotourism (CBET). Further, by gathering proper knowledge regarding carrying capacity of

ecotourism sites, information about local biodiversity register, providing vocational training and awareness to the local peoples will increase the ecotourism growth.

Implication of sustainable ecotourism approach become a promising driver to support the livelihood of local communities which play a key role behind achieving biodiversity conservation goals (9). On the other hand, ecotourism threats to biodiversity values such as over exploitation sometimes create negative impact on biodiversity in worldwide in many hotspot region including Eastern Himalayan region of India (10,11).

Ecotourism in the state of Tripura gaining its momentum in the last five years with raising global interest as it is listed under two mega biodiversity hotspots of India. As per Tripura Forest Department record (TFD,2016), the state Tripura is home to 1545 plant species with highest numbers of species belonging to Angiosperms followed by Dicotyledons, Monocotyledons, Pteridophyta and Gymnosperms. Several variety of wild animals belonging to different groups are found in Tripura and host of over 90 species of mammals and few of them are under rare, endangered and endemic species of IUCN category and home to a large numbers of bird species. The recorded bird species were 342 and there is also 47 fish species recorded in the state. Besides these, 55 herpeto fauna were recorded and several category of invertebrates animals like odonata, butterflies etc. (14). An empirical analysis of biodiversity conservation goals and ecotourism development in Tripura is of vital importance. Therefore, this study attempted to assess current biodiversity conservation efforts and ecotourism development scenario in the state of Tripura, a North Eastern part of India.

Methodology:

This study is based on mainly secondary sources like published research article, review work, book, electronic data bases etc. and in few cases also used primary information related with ecotourism and biodiversity conservation efforts in Tripura and elsewhere. The literature searched with keywords such as ecotourism, biodiversity, sustainable development, man wildlife conflict etc.

Identified trust area of Tripura Tourism Policy 2020-2025 related to ecotourism development

Tripura Tourism Policy 2020-2025 has been identified few thrust area related to ecotourism development in Tripura. Some of the important initiatives are development of bird watching sites, development of different wetlands, nature walk sites and Eco Park, development of some area for eco friendly recreation, identification of sacred grooves etc.

From the literature review it has been found that the biodiversity conservation effort throughout the state have been taken only by means of establishment of eco park, sanctuary, protected area etc. and these sites are the potent destination for local as well as foreign visitors.

Some important Ecotourism sites in Tripura with key biodiversity aspects

Jampui Hill

Jampui hills are well-known for its attractive landscape. Tourists visit this place to see green forests, beautiful orange garden and soul inspiring sun rise. It is fall under the subdivision of Kanchanpur, district North Tripura and share its boundary with neighboring state Mizoram. In this area so many undisturbed vegetation are found and due to its peculiar characteristic different types of wildlife particularly wild boar, cat, snakes and avian fauna are easily encountered. It is a heaven place for ornithologist and butterfly lover.

Dumboor Lake

It is the largest important wetland in the state of Tripura located in Gandacheerra which is 120 km away from state capital city Agartala and covers an area of 41 sq. km. with an unending spell of luxuriant green vegetation and rich bio diverse wetland area. Migratory birds and traditional fishing gears are additional attraction. Various species of migratory birds are noticed in the winter and it has rich reservoir of natural fishes. The lake is the confluence of rivers Raima and Sarma. The most important Gomati River is originating from these reservoirs. So many indigenous fish species are found in this lake.

Sepahijala Wildlife Sanctuary

It is an area of 18.53 square kilometers and situated in Bishalgarh subdivision of Sepahijala district. It has a perennial different tree locally known as sal, segun, karai etc. and large sized water body which attract so many bird species including migratory bird particularly in the winter seasons. Also, one well managed botanical garden and zoo are the main components of this sanctuary. The habitat is primarily deciduous in nature but little evergreen vegetation is also seen throughout the year. Different types of bamboo are one of the significant natural resources of this sanctuary as it supports so many wild animals in many ways. Core area of this sanctuary is designated as National Park particularly for Clouded Leopard enclosures. Several local resident birds along with some migratory birds with about 150 species. Four species of primate, the rhesus macaque, pig tailed macaque, capped langur and dusky langur is found. It is rich in countless medical and therapeutically botanical species of plants. The sanctuary has been developed both as a wildlife sanctuary and as an academic and research centre. Also butterfly beauty can see in this sanctuary.

Rowa Wildlife Sanctuary

The Rowa Wildlife Sanctuary is located in the Panisagar subdivision of north district of Tripura. This Sanctuary in Tripura is a small wildlife sanctuary covering an area of 0.86 square kilometer. From conservation point of view, Rowa Wildlife Sanctuary is an important destination for wildlife biologist. Despite its small size has over the years gained a great deal of popularity, because of its natural beauty, restored with the active cooperation of the local community.

Several species of butterflies, birds, herpatofauna are easily encountered. The key habitats in the sanctuary are small size wetland, botanical garden, regenerated secondary forest and bamboo bush. Fifty-three butterfly species has been recorded from this sanctuary (12). 20 species of Amphibia and 33 species of Reptilia also were recorded from this site. Interestingly one of the amphibian species *Hoplobatrachus litoralis* is the first record from this site in India (13). To protect the plants including several species of medicinal plants as well as animal native biodiversity is important as these serves a so many ecosystem services to the local communities.

Gomati Wildlife Sanctuary

It covers an area of about 389.54 square kilometers and located in south part of the state. It is considered largest sanctuary in the state. Most of the forest types are deciduous in nature but some semi evergreen type is also visible in this sanctuary. It is a significant habitat of several types of wild life animals like macaque, Rhesus, Capped langur, pigtailed macaque and spectacled langur. A large numbers of bird's species including migratory and non migratory birds are seen here. The significant encounter of large body size mega herbivores Asian elephant *Elephas maximus* which is an endangered animal as per Schedule-I of the Indian Wildlife Protection Act (1972) in this sanctuary.

Trishna Wildlife Sanctuary

It has an area of 194.708 square kilometers and is situated in South district of Tripura and most of the area is undisturbed forests which support rich in vegetation and wildlife. The Indian Gaur (Bison), birds like Pheasant tailed Jacana, White breasted King Fisher, Red Jungle Fowl, and Hornbill etc are the important wildlife in the sanctuary. This sanctuary has a number of different types of wetlands and grass land which support different types of fish species and birds. Different species of migratory birds are visit during the winter period. The first butterfly park of the state of Tripura was established near to this sanctuary and now become a important tourist destination for local as well as foreigner to get an experience on conservation biology. Several types of butterfly are found in this park. It is also the habitat of Hoolock Gibbon and primates like Capped Langur, Golden Langur, *Maccaca mullata*, Spectacle monkey etc.

Unakoti Eco Park

It is situated in Kailashahar sub division of Unakoti district of Tripura. It is famous because of presence of sculpture emblem and ancient shiva that hosts rock carvings, figures and images of gods and goddesses. It is not just a place to see rock reliefs of Shiva, but also an important tourist destination due to its scenic beauty while trekking. The trek starts from the Unakoti Eco Park and goes through an undisturbed forest area. So many perennial streams are available in the vicinity of park. Many types of endemic flora and fauna is found in the park and its adjoining area. A great number of butterfly species has been explored in this site. This is

becoming famous place for nature walk among students, wildlife saver and common peoples of Tripura and its neighboring states Assam and Mizoram.

Hathaikotor (Baramura) Park

This park is located in Baramura Hill Range under Khowai district of Tripura. The habitat is characterized by deciduous forest with a small perennial stream flowing through it. This part is famous for its undulating greenery habitat and also great number of wildlife like butterflies, birds, rhesus monkey, spectacle monkey etc. One of the important bird species Oriental pied hornbills *Anthracoceros albirostris* found in this eco park. Every year with the initiative of Forest Department, Government of Tripura Hornbill festival has been organized at the premises of Hathaikotor (Baramura) Eco Park aiming to conserve the striking forest bird Hornbill. The Hornbill festival began on 8th February 2020.Now a days it is a most attractive place to visit by eco-lover.

Rudrasagar

The Rudrasagar wetland is located in the Melaghar under Sonamura sub-division of Sephahijala district. The Government of India's Ministry of Environment, Forest and Climate Change has recognized it as an important wetland from conservation point of view considering the parameters like biodiversity of it and ecosystem services render to the local peoples etc. The secretary general of the Ramsar Convention has declared Rudrasagar Lake as a wetland of international importance. It harbours atleast 55 numbers of freshwater fish species such as *Sperata aor*, *Wallago attu*, *Heteropneustus fossilis*, *Anabus testudineus*, *Nandus nandus*, *Chitala chitala* etc. The state fish *Ompok pabda* are also found to be in this important wetland. So many ecologically important bird species can be seen in this wetland throughout the year like Grey headed fish eagle, Cotton pygmy goose, Coppersmith barbet, Painted snipe etc. It is a potential Important Bird Area (IBA) in the state of Tripura and attracts a large number of waterfowl particularly in the winter season.

Kalapania Nature Park

Kalapania Nature Park situated in Sabroom subdivision of South district. It was established in 2004 covering 21 hectares of deserted land into natures paradise set amidst charming ambience of natural beauty. A perennial water body is found in the park. The park has so many host plants for butterflies. Avian diversity is also available throughout the year. It is one of the important managed Eco Park in the state.

Tepania Eco Park

Tepania Eco-Park was established in 1995 under the control of Forest Department, Government of Tripura in Udaipur which is known as Lake City of the state. With time Eco Park ambience of natural beauty has been upgraded some extent considering different environmental issues as well as eco tourism angle. The most important appeal of Tepania Eco Park are a only

one of its kind of medicinal plant resources and a number of wooden made watch tower for viewing the wild life spectacle in a perfect and panoramic habitat. Large number of bird species, butterfly color beauty, dragonfly and spider are common encounter. Among the mammals rhesus monkey are seen common. It is an ideal place for educational tour for environmental studies. The state bird Green Imperial Pigeon *Ducula aenea* can seen in this park.

Khumulwng Eco Park

The Khumulwng Eco Park is within the Tripura Tribal Areas Autonomous District Council, Head Quarter Khumulwng, West district of Tripura. Thet total area of the park is 14.5 hectre only although due to its heterogenous habitat it harborus so many flora and faunal diversity. Different types of colourful insects like moth, butterfly, odonata species are easily encounter. A perennial water body is found here which support different types of fish species. Some kind of amphibian fauna can also be seen. A good number of flowering plantations is also maintained in this park.

Lembucheera Eco Park

It is situated in West district of Tripura and is near to state capital Agartala city. It is a beautiful place for urban biodiversity conservation point of view. It is an ideal place for butterfly watching as well as bird watching. The state insect *Apis cerana* can be seen in this place.

Oxygen Park

It is established in Salbagan near to Agartala city of west district. Undisturbed forest is found in the park. Different types of wildlife like Squirrel, rhesus monkey, jungle fowl, bird watching can easily available. To visiting this park one can, get experience true beauty of Sal forest, an important tree plant in deciduous type forest. Different types of bamboo bushes are also can seen. In the periphery of the park by the initiative of Forest Department, Government of Tripura is establishing the largest Orchidarium in the State as the state is the home for varieties of orchids. In near future it becomes one of the exceptional tourist destinations of the state for peoples across the state as well as other parts of the country.

Forest City Park

It was established in the kumarghat subdivision of Unakoti district near Kumarghat-Kailashahar road. So many woody plants along with natural vegetation are present here and it helps to mitigate wildlife human conflict in nearby area by proving them home support. This place is support so many butterflies as it is rich of fodder and nectar sources of so many butterfly species and also home to many types of bird species. Different types of big tree species are found here.

Conclusion:

Ecotourism is often viewed as an effective strategy for promoting the conservation of endangered species and habitats as it plays an important role in raising awareness of sustainable

development, motivating people to save biodiversity and teaching the importance of biodiversity conservation for human livelihood. It provides economic, social, and cultural incentives for the local people while staying on the environmentally friendly way in conserving high biodiversity value. At this early growing phase of ecotourism development in Tripura some degree of conflicts in terms of habitat degradation and over exploitation has occurred. Increasing awareness among all the stakeholders of the society and developing integrated management strategies are the only promising resolutions for successful ecotourism development and biodiversity conservation in the state of Tripura.

Recommendations:

1. Focus should be necessary on identification of sacred groove of Tripura considering biodiversity rich area for both flaora and fauna.
2. Identification and proper management of many more significant wetlands across the state for conservation aspects.
3. Capacity building on biodiversity conservation approach and its linking with ecotourism industry among the relevant stakeholders should need to be done properly.
4. Proper implementation of Tripura Tourism Policy 2020-2025 for ecotourism development and biodiversity conservation approach should be followed.
5. Priority should be given on community based ecotourism development.
6. Before starting of any developmental work in the eco sensitive zone Environmental Impact Assessment need to be carried out properly.

Acknowledgements:

The authors wish to gratefully acknowledge the support of the authority of Ramkrishna Mahavidyalaya, Kailashahar, Tripura and Rammohan College, Kolkata, West Bengal.

Conflicts of Interest:

The author declares no conflicts of interest regarding the publication of this work.

References:

1. Sellars, R. W. (1997). *Preserving Nature in the National Parks: A History*. Yale University Press.
2. Stronza, A. L., Hunt, C. A., & Fitzgerald, L. A. (2019). Ecotourism for conservation? *Annual Review of Environment and Resources, 44*, 229–253.
3. The International Ecotourism Society (TIES). (2018). *What is Ecotourism?* Retrieved from http://www.ecotourism.org/what-is-ecotourism
4. Noriega, J. A., Zapata-Prisco, C., García, H., Hernández, E., Hernández, J., Martínez, R., Santos-Santos, J. H., Pablo-Cea, J. D., & Calatayud, J. (2020). Does ecotourism impact biodiversity? An assessment using dung beetles (Coleoptera: Scarabaeinae) as

bioindicators in a tropical dry forest natural park. *Ecological Indicators, 117*(February), 106580. https://doi.org/10.1016/j.ecolind.2020.106580

5. Jurkus, E., Povilanskas, R., & Taminskas, J. (2022). Current trends and issues in research on biodiversity conservation and tourism sustainability. *Sustainability (Switzerland), 14*(6). https://doi.org/10.3390/su14063342
6. De Zoysa, M. (2022). Ecotourism development and biodiversity conservation in Sri Lanka: Objectives, conflicts, and resolutions. *Open Journal of Ecology, 12*, 638-666. https://doi.org/10.4236/oje.2022.1210037
7. International Union for Conservation of Nature and Natural Resources (IUCN). (2012). *Integrating Business Skills into Ecotourism Operations*. Retrieved from https://portals.iucn.org/library/efiles/documents/2012-032.pdf
8. World Tourism Organization (WTO). (2013). *Sustainable Tourism for Development Guidebook.*
9. Bashar, M. A. (2018). Vision on biodiversity: Ecotourism and biodiversity conservation in Bangladesh. *Journal of Biodiversity Conservation and Bio-Resource Management, 4*, 1-10. https://doi.org/10.3329/jbcbm.v4i1.37871
10. Higgins-Desbiolles, F. (2011). Death by a thousand cuts: Governance and environmental trade-offs in ecotourism development at Kangaroo Island, South Australia. *Journal of Sustainable Tourism, 19*, 553-570. https://doi.org/10.1080/09669582.2011.560942
11. Brandt, J. S., Radeloff, V., Allendorf, T., Butsic, V., & Roopsind, A. (2019). Effects of ecotourism on forest loss in the Himalayan biodiversity hotspot based on counterfactual analyses. *Conservation Biology, 33*, 1318-1328. https://doi.org/10.1111/cobi.13341
12. Lodh, R., & Agarwala, B. K. (2016). Rapid assessment of diversity and conservation of butterflies in Rowa Wildlife Sanctuary: A Indo-Burmese hotspot-Tripura, N.E India. *Tropical Ecology, 57*(2), 231-242.
13. Purkayastha, J., Khan, N., & Roychoudhury, S. (2021). A preliminary checklist of Herpetofauna occurring in Rowa Wildlife Sanctuary, Tripura, India. In N. Roy, et al. (Eds.), *Socio-economic and Eco-biological Dimensions in Resource use and Conservation, Environmental Science and Engineering*. https://doi.org/10.1007/978-3030-32463-6_10
14. Tripura Forest Department (TFD). (2016). *Forest and wildlife resources of Tripura*. Retrieved from http://forest.tripura.gov.in/forest-and-wildlife-resurces-of-tripura.

IMPACT OF FOOD SAFETY AND FOOD CONTAMINATION ON COMMUNITY HEALTH

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Abstract:

Food is considered as safe and hygienic for intake when there is no dangerous substance present in it that may be injurious for human health. Foods and drinks can be sometimes contaminated, and due to that it's becoming inappropriate for human consumption. Food contamination is a pervasive issue with far-reaching implications for public health. Food contamination mainly happens when bacteria or other germs get into food, which can eventually cause food-borne illness. While most food contaminations are accidental, there has been some evidence of intentional food contamination. This abstract mainly explores the sources, types, and consequences of food contamination. It delves into microbial, chemical, and physical contaminants, emphasizing their potential to cause foodborne illnesses. The abstract also highlights preventive measures and regulatory efforts aimed at ensuring food safety, emphasizing the critical role of education and awareness in mitigating the risks associated with food contamination.

Keywords: Food Contamination, Food Safety, Food-Borne Illness, Microbial Contamination, Environmental Contaminants.

Introduction:

Food contamination refers to the presence of harmful substances or microorganisms in food, compromising its safety and quality (1). Contaminants can include bacteria, viruses, parasites, chemicals, or foreign objects (2). Contamination can occur at various stages, from production and processing to distribution and preparation (3). It poses serious health risks, leading to foodborne illnesses. Common sources of contamination include improper handling, inadequate storage, and contaminated water or raw ingredients (4). Effective food safety measures, such as proper hygiene, sanitation, and quality control, are crucial to prevent and mitigate the risks of food contamination (5,6).

Concept of food contamination

- **Biological food contamination:** It involves the presence of living microorganisms such as bacteria, viruses, parasites, or fungi in food, posing a risk to human health. These contaminants can multiply rapidly under favorable conditions, leading to foodborne illnesses (7). Common sources include-raw or undercooked meat, unpasteurized dairy

products, contaminated water, and improperly handled fruits and vegetables. Proper food handling, cooking, and hygiene practices are essential to prevent and control biological contamination. Additionally, maintaining a clean and sanitary environment during food processing and production is crucial to mitigate the risk of introducing harmful microorganisms into the food supply (8).

- **Chemical food contamination:** It occurs when harmful substances, either naturally occurring or introduced during food processing, handling, or storage, contaminate food. These substances can include pesticides, food additives, preservatives, heavy metals, and environmental pollutants. Chemical contamination may result from the use of pesticides in agriculture, improper use of food additives, contamination during food processing, or the leaching of chemicals from packaging materials. Adverse health effects can range from acute poisoning to long-term health issues. Rigorous monitoring, adherence to safety regulations, and proper handling of chemicals throughout the food supply chain are essential to minimize the risk of chemical contamination in food (9).
- **Physical food contamination:** It involves the presence of foreign objects or substances in food that can cause harm if consumed such as glass, metal, wood, plastic, or other materials inadvertently introduced during the production, processing, packaging, or handling of food. Physical contaminants can lead to injuries such as cuts, choking, or internal damage. Prevention measures include strict quality control, proper handling practices, and the use of appropriate materials in food processing and packaging. Regular inspection and adherence to safety protocols help minimize the risk of physical contamination in the food supply chain, ensuring consumer safety and product integrity (10).

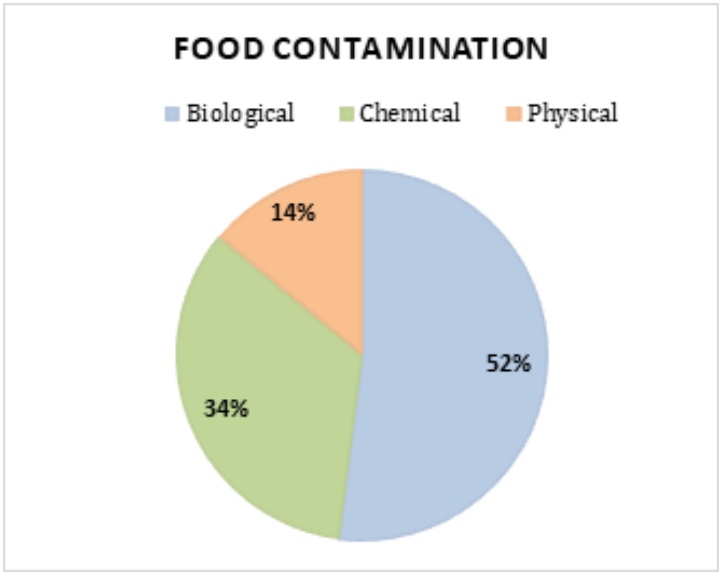

Figure 1: Common types of food contamination

Common sources of food contamination in fridge

- **Raw ingredients:** Contaminated raw materials, such as fruits, vegetables, and meats, can introduce harmful microorganisms into the food supply.
- **Cross-Contamination:** Transfer of contaminants from one surface or food item to another, typically during food preparation, if proper hygiene practices are not followed.
- **Storage:** Improper storage conditions, such as incorrect temperatures or exposure to contaminants, can lead to food spoilage and contamination.
- **Transportation:** Contamination may occur during transportation if proper handling and storage procedures are not followed.
- **Water and air quality:** Water used in food production and air quality in food processing areas can be sources of contamination (11).
- **Personnel:** Poor personal hygiene of food handlers can introduce harmful microorganisms during food preparation and handling.
- **Packaging Materials:** Materials used in packaging, if not food-safe, may transfer harmful substances to the food (12).

Contamination during the food production, processing, storage, and preparation phases

Contamination risks exist at various stages of the food production and consumption process.

- **Food Production:** During agricultural practices use of pesticides and fertilizers can leave residues on crops (13). Livestock farming involve application of antibiotics and hormones to animals and thus facilitate their transfer into meat and dairy products (14).
- **Food Processing:** Cross contamination may occur through shared equipment and surfaces and lead to the transfer of pathogens between different food products. Improper use or contamination of additives and preservatives can impose health risks (15).
- **Storage:** Inadequate refrigeration can promote bacterial growth, especially in perishable foods. Packaging Materials: Contaminants from packaging materials may leach into the food (16).
- **Preparation:** Poor personal hygiene practices by food handlers can introduce pathogens.

Cross-Contamination

Using the same cutting board or utensils for raw and cooked foods can lead to contamination (17). Addressing contamination at each phase involves implementing proper hygiene practices, adhering to safety standards, regular testing, and educating both producers and consumers about safe food handling practices (18-19). Environmental influences can contribute to food contamination in several ways (Figure 2).

- **Water Contamination:** Polluted water sources used in irrigation or processing can introduce harmful microorganisms, chemicals, or heavy metals to crops and seafood (20).

- **Airborne Contaminants:** Dust, pollutants, or contaminants in the air can settle on crops or food during outdoor storage, posing a risk to food safety (21).
- **Soil Contamination:** Contaminated soil may transfer pollutants or heavy metals to crops, affecting the safety of the harvested food (22).
- **Climate Change:** Altered weather patterns can impact the spread of pests, pathogens, and mycotoxins, influencing the safety of agricultural products (23-28).

Figure 2: Contamination in the food production and processing

Chemical contaminants in drinking water

Chemical contaminants in drinking water can include various substances, posing potential health risks. Some common examples are:

- **Heavy Metals:** Lead, arsenic, mercury, and cadmium can leach into water sources from natural deposits or industrial activities, leading to long-term health issues (29).
- **Disinfection Byproducts:** Chlorine or other disinfectants used in water treatment can react with organic matter, forming byproducts such as trihalomethanes, which may have health implications (30).
- **Pesticides and Herbicides:** Agricultural runoff can introduce pesticides and herbicides into water sources, impacting drinking water quality (31).

- **Industrial Chemicals:** Effluents from industrial activities may contain various chemicals, including solvents, heavy metals, and persistent organic pollutants, which can contaminate water (32-35).

Cross contamination of food products

To avoid cross-contamination in food preparation, segregate raw meats from ready-to-eat items, utilizing separate cutting boards and utensils for each. Hands should be washed thoroughly after handling raw meat and before touching other foods. Colour-coded or labeled tools need to be employed to distinguish between different types of ingredients. Surfaces, countertops, and equipment are to be cleaned and sanitized regularly, particularly after working with raw meats. Raw and cooked foods should be stored separately in the refrigerator, ensuring raw meats are at the bottom to prevent drips onto other items. Adhering to these practices minimizes the risk of harmful bacteria spreading and enhances overall food safety (36).

Naturally occurring contaminants in food

Mycotoxins produced by certain molds, mycotoxins can contaminate crops like grains, nuts, and fruits. Mycotoxin such as aflatoxins can be carcinogenic (37). Biogenic Amines are formed during the decay of proteins in certain foods. Biogenic amines like histamine and tyramine can be found in aged cheeses, fermented products, and some fish. While not contaminants in the traditional sense, allergens naturally present in foods can cause adverse reactions in sensitive individuals. Common allergens include peanuts, tree nuts, shellfish, and gluten (38). Certain foods can contain naturally occurring heavy metals such as mercury, lead, and cadmium due to environmental factors Fish for instance, may accumulate mercury from water sources (39).

Types of bacteria in refrigerated food

Refrigeration slows down bacterial growth but doesn't eliminate it entirely. Several types of bacteria can still persist in refrigerated food.

Psychrotrophs: These bacteria can grow at colder temperatures, including those found in refrigerators such as *Listeria monocytogenes* and *Yersinia enterocolitica*.

Spoilage Bacteria: While not necessarily harmful, spoilage bacteria can affect the taste, texture, and appearance of food such as *Pseudomonas* and *Bacillus species.*

Pathogenic Bacteria: Some pathogenic bacteria can survive in refrigerated conditions, albeit at a slower rate such as *Salmonella, Escherichia coli* (*E. coli*) etc.

Fecal coliforms, *S. aureus*, *Enterobacteriaceae* are also some of the food contamination pathogens in the fridge. *Campylobacter sp, Yersinia enterocolitica* and *Staphylococcus aureus* are also reported.

Overall reason for food contamination

Food contamination can result from various factors. Microbial pathogens like bacteria, viruses, and parasites are common causes of foodborne illnesses. Improper handling, storage, or

cooking can lead to the proliferation of these pathogens (40). Cross-contamination causes transfer of harmful microorganisms from one surface of a food item to another can occur during food preparation, often through shared utensils or inadequate cleaning practices (41). Poor hygiene practices like lack of proper handwashing, sanitation, and personal hygiene by food handlers can introduce harmful bacteria into the food. Contaminated water and raw ingredients used in food preparation and raw ingredients may carry contaminants. Agricultural practices, such as pesticide use, can also contribute to contamination (42). Improper storage and temperature control can promote the growth of bacteria, making food unsafe for consumption (43-44).

Effects of food contamination

Food contamination can have various adverse effects on individuals and public health. Consuming contaminated food can lead to foodborne diseases, causing symptoms like nausea, vomiting, diarrhea, abdominal pain, and, in severe cases, hospitalization or death. Certain contaminants, such as heavy metals or mycotoxins, may have cumulative effects over time, leading to chronic health issues like organ damage, neurological disorders, or cancer. Outbreaks of foodborne illnesses can result in significant economic losses due to medical expenses, reduced productivity, and damage to the food industry's reputation. Food contamination incidents can erode public trust in food safety systems and the reliability of certain food products or brands. Preventing food contamination through robust food safety measures, education, and effective regulation is crucial to safeguard public health and maintain the integrity of the food supply chain (45).

Global implication of food contamination

Foodborne illnesses resulting from contamination can lead to widespread health issues, affecting individuals, communities, and healthcare systems globally. The severity ranges from mild illnesses to severe cases and even fatalities. Foodborne diseases result in significant economic burdens due to medical expenses, lost productivity, and costs associated with managing outbreaks. Additionally, contamination events can lead to the destruction of large quantities of food, causing financial losses for both producers and distributors. High-profile cases of food contamination can erode consumer confidence in the safety of food products. This loss of trust can affect consumer behavior, leading to changes in purchasing habits and preferences. Contamination can pose a threat to food security by reducing the availability of safe and nutritious food. This is particularly critical in regions where access to a diverse and secure food supply is already a challenge (46).

Ineffective refrigeration and food borne illness at home

Ineffective refrigeration at home can contribute to foodborne illnesses due to temperature fluctuations, overcrowding, inadequate sealing, poor organization and delayed consumption.

Inconsistent temperature maintenance can lead to bacterial growth. A refrigerator set above 40°F (4°C) may not adequately slow down bacteria, increasing the risk of contamination. Overloading the refrigerator restricts airflow, causing uneven cooling. Certain areas may not reach the necessary temperature, allowing bacteria to thrive in warmer zones. Damaged gaskets or seals can result in air leaks, affecting the refrigerator's efficiency. This comprises the applicant's ability to maintain a consistently low temperature, promoting bacterial proliferation. Improper storage and organization can lead to cross-contamination. Raw meats, seafood, or poultry stored above ready-to-eat foods can transfer harmful bacteria, posing a health risk. Failing to consume perishable items before their expiration dates increases the likelihood of consuming spoiled or contaminated food.

To prevent foodborne illnesses, it's crucial to maintain proper refrigeration conditions, practice good hygiene, and adhere to safe food storage practices at home. Regular cleaning, temperature monitoring, and awareness of food expiration dates are essential components of food safety (47).

Factors that affect food safety

- Poor personal hygiene of food handlers, inadequate handwashing, and unsanitary conditions in food preparation areas can introduce contaminants.
- Inadequate refrigeration or cooking temperatures can promote the growth of bacteria and other pathogens in food.
- Water used in food preparation and the quality of raw ingredients, including produce and meats, can introduce contaminants.
- As food production becomes more globalized, complex supply chains increase the risk of contamination during transportation, storage, and distribution.
- Cross-Contamination: Improper handling of raw and cooked foods, as well as using the same utensils or surfaces for both, can lead to the transfer of harmful microorganisms.
- Technology and Processing Methods: Innovations in food processing, packaging, and preservation methods can introduce new challenges or risks if not implemented correctly (48).

Importance of food safety for community health

Foodborne infections affect millions of people annually, leading to significant morbidity and mortality. The World Health Organization (WHO) estimates that approximately 600 million individuals worldwide experience foodborne illnesses each year. Out of this staggering number, around 420,000 people succumb to these infections. Various factors contribute to foodborne infections, including bacteria (*e.g. Salmonella, Campylobacter*), viruses (*e.g.* Norovirus, Hepatitis A), parasites (*e.g. Giardia, Cryptosporidium*), and toxins produced by certain microorganisms. Contaminated food, inadequate hygiene practices during food preparation, and improper storage conditions are common causes. The impact of foodborne illnesses extends

beyond immediate health effects. Economic costs related to medical treatment, loss of productivity, and food recalls pose additional burdens on societies and industries. Preventive measures such as stringent food safety regulations, proper hygiene education, and robust surveillance systems are essential to reduce the incidence of foodborne infections and their associated fatalities. Public awareness and adherence to safe food handling practices also play a crucial role in minimizing the global burden of foodborne diseases (49). Ensuring safe food practices helps prevent the spread of foodborne illnesses, which can lead to severe health consequences. Contaminated food can harbor bacteria, viruses, parasites, and toxins, causing infections and diseases.

Proper food safety measures reduce the risk of foodborne diseases, minimizing the number of individuals falling ill and requiring medical attention. Children, elderly individuals, pregnant women, and those with compromised immune systems are more susceptible to severe consequences of foodborne infections. Food safety measures safeguard these vulnerable groups Reducing Fewer cases of foodborne illnesses mean less strain on healthcare systems, decreasing hospitalizations, medical expenses, and the demand for healthcare resources.

Foodborne outbreaks can lead to economic losses due to medical costs, lost productivity, and damage to the reputation of food producers and distributors. Ensuring food safety helps maintain a robust and trustworthy food industry. Strict adherence to food safety standards fosters trust among consumers. When people have confidence in the safety of their food supply, they are more likely to make healthy food choices and support local food industries. Chronic health issues can result from repeated exposure to low levels of contaminants in food. Adhering to food safety practices promotes long-term community health and reduces the risk of chronic diseases related to food consumption. Overall, prioritizing food safety is essential for maintaining a healthy community, preventing the spread of diseases (50)

Safe handling and storage of food in the refrigerator

The refrigerator temperature is kept at or below 40°F (4°C) to slow down bacterial growth. A refrigerator thermometer is used to monitor and maintain the proper temperature. Separation of raw and ready-to-eat foods done during storage like raw meats on the bottom shelf to prevent cross-contamination and to be kept in leak-proof containers or sealed plastic bags. The ready-to-eat foods, like fruits and leftovers, are to be kept on higher shelves. Proper Storage Containers are used for different food items. Use of airtight containers or wrap foods tightly in plastic wrap or aluminum foil prevent odors from spreading and to maintain freshness. Labeling and Dating must be done. Containers with the early date need timely consumption. Regular Cleaning are to be ensured. Any spills should be cleaned promptly to prevent the growth of bacteria and the transfer of odors. Shelves and drawers are wiped down regularly. Frequent checks on expiration dates on packaged foods need to be monitored and discard items that have passed their use-by dates. Inspect fruits and vegetables for signs of spoilage and discard if

necessary. By following these precautions, one can minimize the risk of foodborne illness and maintain food quality (51).

Discussion:

A 2006 study revealed that in India a notable reason behind most of the foodborne illnesses is pathogenic contamination of stored, prepared and even preserved food. Some studies found that refrigerators can cause wider spectrum cross contamination of food if not used properly. A study in Scotland said that maximum cases of household food poisoning occur because of mishandling of food. *Salmonella* is the most widely known pathogen for refrigerator food contamination in Australia. Almost every house keeps raw foods and cooked foods side by side on the same fridge shelves. In some houses, covering the food containers was not done properly. In a few cases, raw fish were stored in the fridge for several days. Even sometimes raw meat and cold food like ice cream were stored in the same place in the fridge without proper covering. Maximum houses don't even clean the fridge on a regular basis, and remain uncleaned for a long time. A study in the USA showed — only 6% people clean refrigerators weekly and 80% people clean it monthly once or less. Sometimes a water bottle is kept even without a cap in the fridge. It is reported from many houses that they are unaware of the knob for temperature setting or regulating the fridge. Lack of knowledge and awareness that food contamination can happen even in refrigerators, among people. A study says that 50% of people in the survey were unaware of 'cross contamination' due to their poor education level. Even they were unaware of microbial growth in food stored in the fridge due to uncleanliness (52). Apparently, the survey showed that younger than 25 years respondents were more aware about the correct temperature for refrigeration. Urban respondents have more general knowledge of pathogens which causes food contamination than rural respondents (53). Preventing food contamination involves implementing a combination of good practices at various stages of the food supply chain. Enforce strict hygiene practices among food handlers, including regular handwashing, proper use of gloves, and maintaining a clean working environment. Follow safe food handling practices, including separate storage for raw and cooked foods, avoiding cross-contamination, and using clean utensils and surfaces. Ensure that food is cooked thoroughly to kill harmful microorganisms, and maintain proper temperatures during storage and transportation to prevent bacterial growth. Implement rigorous quality control measures during food processing, manufacturing, and packaging to detect and eliminate contaminants. Ensure the quality and safety of water used in food production and maintain clean air in food processing areas to prevent contamination (54). Implement effective pest control measures to prevent insects or rodents from contaminating food storage and processing areas. Provide ongoing training for personnel involved in food handling to keep them informed about proper practices and the importance of food safety. Use food-safe packaging materials and ensure proper sealing to prevent physical and chemical contamination (14).

Conclusion:

Food contamination is a critical concern that poses serious risks to public health and safety. Whether biological, chemical, or physical, contaminants can enter the food supply chain at various stages, from production to distribution and preparation. Preventing contamination requires a comprehensive approach, including stringent hygiene practices, proper food handling, quality control measures, and compliance with regulatory standards. Ongoing education and training, along with the use of safe packaging materials, contribute to maintaining the integrity of the food supply. Vigilance across the entire food industry is essential to identify and address potential sources of contamination, ultimately safeguarding consumers and ensuring the delivery of safe and high-quality food products.

Acknowledgement:

The authors acknowledge their departments and Institute. This review received no external funding.

References:

1. Robertson L., Sprong H., Ortega Y., van der Giessen J., Fayer R. (2014). Impacts of globalisation on foodborne parasites. *Trends Parasitol.* 30, 37–52. https://doi.org/10.1016/j.pt.2013.09.005
2. Salter S. (2014). The food-borne identity. *Nat. Rev. Microbiol*. 12, 533–533. https://doi.org/10.1038/nrmicro3313
3. Callejón R., Rodríguez-Naranjo M., Ubeda C., Hornedo-Ortega R., Garcia-Parrilla M., Troncoso A. (2015). Reported foodborne outbreaks due to fresh produce in the United States and European Union: trends and causes. *Foodborne Pathog. Dis.* 12, 32–38. https://doi.org/10.1089/fpd.2014
4. CDC (2013). Surveillance for Foodborne Disease Outbreaks—United States, (2009-2010). *Ann. Emerg. Med.* 62, 91–93. https://doi.org/10.1016/j.annemergmed.2013.04.001
5. Song Q., Zheng Y. J., Xue Y., Sheng W. G., Zhao M. R. (2017). An evolutionary deep neural network for predicting morbidity of gastrointestinal infections by food contamination. Neurocomputing 226, 16–22. https://doi.org/10.1016/j.neucom.2016.11.018
6. Rather IA, Koh WY, Paek WK, Lim J. (2017). The Sources of Chemical Contaminants in Food and Their Health Implications. *Front Pharmacol.* 17;8:830. https://doi.org/10.3389/fphar.2017.00830
7. Wilcock A., Pun M., Khanona J., Aung M. (2004). Consumer attitudes, knowledge and behaviour: a review of food safety issues. *Trends Food Sci. Technol*. 15, 56–66. https://doi.org/10.1016/j.tifs.2003.08.004
8. Ingelfinger J. (2008). Melamine and the global implications of food contamination. N. Engl. J. Med. 359, 2745–2748. https://doi.org/10.1056/NEJMp0808410

9. Mastovska K. (2013). *Modern Analysis of Chemical Contaminants in Food. Food Safety Magazine*. Available online at: http://www.foodsafetymagazine.com/magazine-archive1/februarymarch-2013/modern-analysis-of-chemical-contaminants-in-food/
10. chrenk D. (2004). Chemical food contaminants. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 47, 841–877. https://doi.org/10.1007/s00103-004-0892-6
11. Hussain MA. (2016) Food Contamination: Major Challenges of the Future. *Foods*, 5(2):21. https://doi.org/10.3390/foods5020021
12. Stefano V. D. & Avellone, G. (2014) "Food contaminants," Journal of Food Studies, 3,(1),88-103. https://doi.org/10.5296/jfs.v3i1.6192
13. Sadiku, M., Ashaolu, T.J. & Sarhan. M. (2020). Food Contamination: A Primer. International Journal of Advances in Scientific Research and Engineering. 06. 01-07. https://doi.org/10.31695/IJASRE.2020.33736
14. Nerín, C., Margarita, A., & Carrizo, D. (2015). Food contamination during food process. Trends in Food Science & Technology. 48. https://doi.org/10.1016/j.tifs.2015.12.004
15. Villanueva, C. M., Gracia-Lavedan, E., Julvez, J., Santa-Marina, L., Lertxundi, N., Ibarluzea, J., Llop, S., Ballester, F., Fernández-Somoano, A., Tardón, A., Vrijheid, M., Guxens, M., & Sunyer, J. (2018). Drinking water disinfection by-products during pregnancy and child neuropsychological development in the INMA Spanish cohort study. *Environment international*, *110*, 113–122. https://doi.org/10.1016/j.envint.2017.10.017
16. Wang, R. Y., & Needham, L. L. (2007). Environmental chemicals: from the environment to food, to breast milk, to the infant. *Journal of toxicology and environmental health. Part B, Critical reviews*, *10*(8), 597–609. https://doi.org/10.1080/10937400701389891
17. Ingelfinger J. R. (2008). Melamine and the global implications of food contamination. *The New England journal of medicine*, *359*(26), 2745–2748. https://doi.org/10.1056/NEJMp0808410
18. Yiğit, V. & Duran, T. 1997. Institutional Nutrition Technology I (in Turkish). Ekin Publishing, Istanbul, Turkey.
19. WHO, 2012. Five keys to growing safer fruits and vegetables: promoting health by decreasing microbial contamination, Geneva.
20. WHO, 2003. Assuring food safety and quality: guidelines for strengthening national food control systems. Food and Agriculture Organization of the United Nations.
21. United States Department of Health and Human Services. Healthy People 2020: Food Safety; United States Department of Health and Human Service, Office of Disease Prevention and Health Promotion: Washington, DC, USA, 2010.

22. WHO 2004 Surveillance programme for control of food borne infections and toxications in Europe 8th report. Journal Infec.43, 80-84.
23. Calderon, R. (2000). The epidemiology of chemical contaminants of drinking water. *Food Chem. Toxicol*. 38, S13–S20. https://doi,org/10.1016/S0278-6915(99)00133-7
24. Bai, Y., Lin, X. H., Zhu, J. H., Cui, S. H., Guo, L. X., Yan, S. F., Wang, W., Xu, J., & Li, F. Q. (2021). Quantification of Cross-Contamination of Campylobacter jejuni during Food Preparation in a Model Kitchen in China. *Journal of food protection*, *84*(5), 850–856. https://doi.org/10.4315/JFP-20-280
25. Osaili, T. M., Obaid, R. S., Alowais, K., Almahmood, R., Almansoori, M., Alayadhi, N., Alowais, N., Waheed, K., Dhanasekaran, D. K., Al-Nabulsi, A. A., Ayyash, M., & Forsythe, S. J. (2020). Microbiological quality of kitchens sponges used in university student dormitories. *BMC public health*, *20*(1), 1322. https://doi.org/10.1186/s12889-020-09452-4
26. Sinha, A., & Dutta, S. (2019). Waterborne & foodborne viral hepatitis: A public health perspective. *The Indian journal of medical research*, *150*(5), 432–435. https://doi.org/10.4103/ijmr.IJMR_1430_18
27. Pal, M, Ayele, Y. (2020). Emerging Role of Foodborne Viruses in Public Health. 5. 1-04.
28. Pal, M. & Hofmeister, M. (2021). Food Contamination Poses a Threat to Food Safety. 3: 1-4.
29. Pal, M & Jadhav, V. (2013). Microbial Contamination of various Indian Milk Products. Beverage and Food World. 39. 43-44.
30. Gibb, H. J., Barchowsky, A., Bellinger, D., Bolger, P. M., Carrington, C., Havelaar, A. H., Oberoi, S., Zang, Y., O'Leary, K., & Devleesschauwer, B. (2019). Estimates of the 2015 global and regional disease burden from four foodborne metals - arsenic, cadmium, lead and methylmercury. *Environmental research*, *174*, 188–194. https://doi.org/10.1016/j.envres.2018.12.062
31. Gleason, K., Shine, J. P., Shobnam, N., Rokoff, L. B., Suchanda, H. S., Ibne Hasan, M. O., Mostofa, G., Amarasiriwardena, C., Quamruzzaman, Q., Rahman, M., Kile, M. L., Bellinger, D. C., Christiani, D. C., Wright, R. O., & Mazumdar, M. (2014). Contaminated turmeric is a potential source of lead exposure for children in rural Bangladesh. *Journal of environmental and public health*, *2014*, 730636. https://doi.org/10.1155/2014/730636
32. Naujokas, M. F., Anderson, B., Ahsan, H., Aposhian, H. V., Graziano, J. H., Thompson, C., & Suk, W. A. (2013). The broad scope of health effects from chronic arsenic exposure: update on a worldwide public health problem. *Environmental health perspectives*, *121*(3), 295–302. https://doi.org/10.1289/ehp.1205875

33. Currie, J., Zivin, J. G., Meckel, K., Neidell, M., & Schlenker, W. (2013). Something in the water: contaminated drinking water and infant health. *The Canadian journal of economics. Revue canadienne d'economique*, *46*(3), 791–810. https://doi.org/10.1111/caje.12039
34. Gibb, H., Devleesschauwer, B., Bolger, P. M., Wu, F., Ezendam, J., Cliff, J., Zeilmaker, M., Verger, P., Pitt, J., Baines, J., Adegoke, G., Afshari, R., Liu, Y., Bokkers, B., van Loveren, H., Mengelers, M., Brandon, E., Havelaar, A. H., & Bellinger, D. (2015). World Health Organization estimates of the global and regional disease burden of four foodborne chemical toxins, 2010: a data synthesis. *F1000Research*, *4*, 1393. https://doi.org/10.12688/f1000research.7340.1
35. Muir, D. C., & Howard, P. H. (2006). Are there other persistent organic pollutants? A challenge for environmental chemists. *Environmental science & technology*, *40*(23), 7157–7166. https://doi.org/10.1021/es061677a
36. Ruzzin J. (2012). Public health concern behind the exposure to persistent organic pollutants and the risk of metabolic diseases. *BMC public health*, *12*, 298. https://doi.org/10.1186/1471-2458-12-298
37. Marriott, N.G. & Gravani, R.B. (2006) Principles of Food Sanitation, New York, NY: Springer,5th Edition.
38. Isara, A. R., Isah, E. C., Lofor, P. V., & Ojide, C. K. (2010). Food contamination in fast food restaurants in Benin City, Edo State, Nigeria: Implications for food hygiene and safety. *Public health*, *124*(8), 467–471. https://doi.org/10.1016/j.puhe.2010.03.028
39. Maftoonazad, N., & Badii, F. (2009). Use of edible films and coatings to extend the shelf life of food products. *Recent patents on food, nutrition & agriculture*, *1*(2), 162–170. https://doi.org/10.2174/2212798410901020162
40. Wang RY, Needham LL. Environmental chemicals: from the environment to food, to breast milk, to the infant. J Toxicol Environ Health B Crit Rev. 2007 Dec;10(8):597-609. https://doi.org/10.1080/10937400701389891
41. Olaimat, A. N., Taybeh, A. O., Al-Nabulsi, A., Al-Holy, M., Hatmal, M. M., Alzyoud, J., Aolymat, I., Abughoush, M. H., Shahbaz, H., Alzyoud, A., Osaili, T., Ayyash, M., Coombs, K. M., & Holley, R. (2024). Common and Potential Emerging Foodborne Viruses: A Comprehensive Review. *Life (Basel, Switzerland)*, *14*(2), 190. https://doi.org/10.3390/life14020190
42. Hamidiyan, N., Salehi-Abargouei, A., Rezaei, Z., Dehghani-12. Tafti, R., Akrami-Mohajeri, F. The prevalence of Listeria spp. food contamination in Iran: A systematic review and meta-analysis. Food Research International, 107, 437-450.2018.
43. Troeger, C., Khalil, I.A., Rao, P.C, Cao, S., Blacker, B.F., 13. Ahmed, T., Armah, G., Bines, J.E., Brewer, T.G., Colombara, D.V., Kang, G., Kirkpatrick, B.D., Kirkwood, C.D., Mwenda, J.M., Parashar, U.D., Petri, W.A. Jr., Riddle, M.S., Steele, A.D., Thompson,

R.L., Walson, J.L., Sanders, J.W., Mokdad, A.H., Murray, C.J.L., Hay, S.I., Reiner, R.C.Jr. Rotavirus vaccination and the global burden of rotavirus diarrhea among children younger than 5 years. Journal of American Medical Association Pediatrics, 172, 958-965.2018.

44. Sospedra, I., Rubert, J. V., Soler, C., Soriano, J. M., & Mañes, J. (2009). Microbial contamination of milk and dairy products from restaurants in Spain. *Foodborne pathogens and disease*, *6*(10), 1269–1272. https://doi.org/10.1089/fpd.2009.0337
45. Fung, F., Wang, H. S., & Menon, S. (2018). Food safety in the 21st century. *Biomedical journal*, *41*(2), 88–95. https://doi.org/10.1016/j.bj.2018.03.003
46. Fung, F., Wang, H. S., & Menon, S. (2018). Food safety in the 21st century. *Biomedical journal*, *41*(2), 88–95. https://doi.org/10.1016/j.bj.2018.03.003
47. Uyttendaele M, Franz E, Schlüter O. Food safety, a global challenge. *Int J Environ Res Public Health.* 2016;13(1):67. https://doi.org/10.3390/ijerph13010067
48. Pal, M., Selamawit, M., Muluken, T., Suneeta, P. & Jashbhai, P. (2016). Bacterial Contamination of Dairy Products. Beverage and Food World. 43. 40-43.
49. Scott, E., Bloomfield, S. F., & Barlow, C. G. (1982). An investigation of microbial contamination in the home. *The Journal of hygiene*, *89*(2), 279–293. https://doi.org/10.1017/s0022172400070819
50. Towns, R. E., Cullen, R. W., Memken, J. A., & Nnakwe, N. E. (2006). Food safety-related refrigeration and freezer practices and attitudes of consumers in Peoria and surrounding counties. *Journal of food protection*, *69*(7), 1640–1645. https://doi.org/10.4315/0362-028x-69.7.1640
51. Gettings, M. A., & Kiernan, N. E. (2001). Practices and perceptions of food safety among seniors who prepare meals at home. *Journal of nutrition education*, *33*(3), 148–154. https://doi.org/10.1016/s1499-4046(06)60184-x
52. Obande, D. and Young, L., Safe food refrigeration knowledge, attitudes, and practices of university students. Br. Food J., 2020, 122(4), 1085-1098. https://doi.org/10.1108/BFJ-05-2019-0327
53. Yella, R., Ramachandrappa, N.K.,Vemula, S., Balakrishna, N. & Gavaravarapu, S. (2016). Food Safety in Domestic Refrigerators - A Mixed Methods Study to Identify Key Messages for Promoting Safe Storage Practices among Households. The Indian journal of nutrition and dietetics. 53. 1-14. https://doi.org/10.21048/ijnd.2016.53.1.3871
54. Kennedy, J., Jackson, V., Blair, I. S., McDowell, D. A., Cowan, C., & Bolton, D. J. (2005). Food safety knowledge of consumers and the microbiological and temperature status of their refrigerators. *Journal of food protection*, *68*(7), 1421–1430. https://doi.org/10.4315/0362-028x-68.7.1421

DIRECTING HUMAN FOOD HABITS TOWARD GLOBAL SUSTAINABILITY

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Abstract:

It's important to note that the world population is expected to exceed 9 billion by 2050, and there are growing concerns about the sustainability of livestock farming. Red meat in particular has a larger environmental footprint. Modest meat consumption has been recommended not only to avoid deficiencies in essential nutrients but also to reduce the development of chronic diseases and have a significant positive impact on global food security. Studies have shown that vegetarian and vegan diets are the most affordable, while pescatarian diets are the most expensive. Sustainable diets that address health and environmental concerns associated with food production and consumption can be pursued by replacing animal-based foods with plant-based foods. Such diets are particularly effective in high-income countries, improving nutritional content, reducing premature mortality, and reducing some environmental impacts. Regulated public health strategies that focus on improving energy balance need to be implemented by governments.

Introduction and background:

Providing adequate human nutrition within the carrying capacity of ecosystems is a key element of the global challenge of environmental sustainability. The 2030 Agenda for Sustainable Development is a vision that was launched by the United Nations in 2015. The agenda's primary objective is to promote a healthy and progressive future for all people on the planet. The agenda aims to stop climate change and prevent its most devastating effects to protect and restore the planet's environment and natural resources. The world population, which currently stands at 7.3 billion, is expected to exceed 9 billion by 2050. The Food and Agriculture Organization (FAO) has predicted that by 2050, 70% more food will be needed to meet the needs of the growing population, which is a major challenge due to limited resources and arable land (Silva, 2012). Although meat consumption is declining in developed countries, it is increasing worldwide as consumers are generally unwilling to limit their meat consumption (Turnes, A., Pereira, P., Cid, H., & Valente, A., 2023). This is particularly true for developing countries such as China, India, and Russia, as these populations are increasingly middle class and demand more luxury products such as meat or other animal products (e.g. cheese, and dairy products) (Chen, C., Chaudhary, A., & Mathys, A., 2019).

The adoption of healthy and sustainable diets could be critical to protecting the Earth's natural resources and reducing diet-related mortality, but their adoption could be hindered if such diets prove more expensive and unaffordable for some populations. Demand-side interventions, such as change in food habits, can significantly contribute towards the achievement of 2030 national sustainable development goals at the global level.

Environmental impact of current eating habits

Our current eating habits, especially our meat and dairy consumption, have a high environmental impact. Meat is an important source of high-quality dietary protein and a wide range of micronutrients, including iron, zinc, selenium, vitamin D, and vitamin B12, for a large proportion of the world's population. While these nutrients can be obtained in sufficient quantities by consumption of a range of fruits and vegetables, access to meat often protects against malnutrition and improves cognitive development in children in many developing countries where the availability of such foods may be limited. However, excessive consumption of meat and meat products, particularly in developed countries, is often associated with excessive energy and fat consumption, leading to overweight, obesity, and an increased risk of chronic diseases such as cardiovascular disease and type 2 diabetes, as well as cancer, particularly colorectal cancer (Salter A. M., 2018). Because of population growth and global warming, there is growing concern about the sustainability of livestock farming. Recently, environmental concerns have also grown, with greenhouse gas emissions being 57% higher for beef when compared with tofu and four times higher for poultry (Millward, D. J., & Garnett, T., 2010). Red meat, in particular, has a larger environmental footprint. Despite the environmental concerns, studies have shown that meat consumers are often unwilling to change their eating habits for environmental reasons. While modest meat consumption is essential to avoid nutrient deficiencies, limiting meat consumption can help reduce the development of chronic diseases and significantly boost global food security. Consumers need to consider the impact of their dietary choices on the environment.

Sustainable diets: concept, benefits and challenges

The vegetarian and vegan diets are most commonly used in terms of the different dietary change scenarios. While the vegan diet excludes all animal foods, the vegetarian diet may include dairy products. The pescatarian diet excludes meat but may include fish. Another variant like the ovo-lacto-vegetarian diet may include both eggs and dairy products. The flexitarian or semi-vegetarian diet is a predominantly plant-based diet that occasionally includes meat or fish. In the face of population growth and global warming, there is growing concern about the sustainability of agricultural animal production. Modest meat consumption is an important strategy not only to avoid deficiencies in essential nutrients but also can reduce the development of several chronic diseases and could have a significant positive impact on global food security.

Meat alternatives are products that are similar to meat in taste and texture but are made from protein sources that are not derived from animals. Plant-based proteins are the most commonly used ingredients in the preparation of meat alternatives. Soy, wheat gluten, and mushrooms are the most important ingredients in this context. Soy is used for its high nutritional value in producing protein-rich products such as tofu, which is obtained by curdling and pressing soy curd into a compact block. Soy flour is the least processed soy product used for the production of texturized vegetable soy protein as well as soy protein concentrate (70% protein) and isolate (90% protein). Soy meat alternatives, such as texturized vegetable protein, are usually produced by an extrusion process that allows for different shapes and sizes of the product. Wheat gluten, also known as seitan, is obtained by isolating starch from wheat flour and is used for its binding, dough-forming, and leavening properties. Its cohesive and chewy quality gives products made with wheat gluten a meat-like texture. Mushrooms are sometimes added to make the dish more palatable (Kumar, P.; Chatli, M.K.; Mehta, N.; Singh, P.; Malav, O.P.; Verma, A.K., 2017) (Malav, O.P.; Talukder, S.; Gokulakrishnan, P.; Chand, S., 2015). Legume proteins from peas, lentils, lupins, or chickpeas are also used to make meat alternatives. Research shows that pea-based protein is indeed one of the most promising alternatives to animal-based protein. It has a high nutritional value, is rich in essential amino acids, and is easily digestible. Pea protein is also sustainable and environmentally friendly as it requires less water and land to produce compared to animal-based protein sources. In addition, it is a good option for people with dietary restrictions such as lactose intolerance, as it is dairy-free. When heated, oilseed proteins from rapeseed and canola can be used as structuring agents, promoting a meat-like texture (Kyriakopoulou, K.; Dekkers, B.; van der Goot, A.J., 2019).

Mycoprotein is a protein-rich product that is obtained from the mycelium of the fungus Fusarium venenatum during fermentation and can be processed for human consumption. When mixed with a small amount of egg albumin, some roasted barley malt extract and water or a natural flavoring is added instead of malt to mycoprotein to obtain a savory character (Finnigan, 2011). The thread-like structure of mycoprotein also gives texture to this product like meat.

Plant-based milk alternatives are extracts from legumes (chickpeas, soybeans), cereals (oats, rice), pseudo-cereals (quinoa, teff, amaranth), nuts (almonds, cashew nuts, hazelnuts, walnuts, coconut) or seeds (sesame, sunflower) that are consumed as a substitute for cow's milk. These plant-based milk alternatives are made by breaking down (size reduction) plant material (cereals, pseudo-cereals, legumes, oilseeds, nuts) in water and further homogenizing the fluids to resemble cow’s milk in appearance and consistency. The main reasons for consuming these milk alternatives are adopting a vegetarian or vegan diet and health reasons such as lactose intolerance or cow’s milk protein allergy.

Cultured meat is produced by growing cells from farm animals using a culture medium to replicate the complex structure of animal muscle tissue. Although the use of animals to obtain animal cells is technically necessary, only a few animals are needed to produce large quantities of meat due to cell proliferation (Chriki, S., & Hocquette, J. F., 2020).

Microalgae, the tiny organisms living in aquatic environments, have gained increasing attention in recent years due to their immense nutritional value. These microorganisms are a rich source of proteins, carbohydrates, lipids, and various bioactive compounds. Microalgae proteins have a complete essential amino acid profile, making them an excellent dietary option. Moreover, their protein content surpasses that of traditional sources like meat, poultry, and dairy. Unlike most plant-based protein sources that lack certain essential amino acids, microalgae proteins contain the complete essential amino acid profile. This makes microalgae an excellent choice for those seeking alternative, sustainable, and complete protein sources and a promising option in addressing global food security challenges. With the growing global population and increasing demand for protein-rich foods, alternative and sustainable sources like microalgae can play a significant role in meeting nutritional needs. Due to their exceptional nutritional composition, microalgae and their derived compounds have gained recognition as dietary supplements and potential food sources. Various forms of microalgae, such as spirulina and chlorella, are available in the market as supplements and are often regarded as superfoods. These supplements are rich in nutrients, easily digestible, and offer numerous health benefits. In addition to their nutritional benefits, microalgae have also been acknowledged for their potential positive impact on the environment. The National Academies of Sciences and Medicine, comprising 130 academies worldwide, have recognized microalgae as one of the innovative foods that could benefit both health and the climate. The cultivation of microalgae requires fewer resources, such as land, water, and fertilizers, compared to traditional livestock farming. Furthermore, microalgae can sequester carbon dioxide and produce oxygen through photosynthesis, contributing to mitigating climate change (Alcorta, A., Porta, A., Tárrega, A., Alvarez, M. D., & Vaquero, M. P., 2021).

A comparative analysis of sustainable diets and the present diet, focusing on their nutritional and environmental impact

The consumption of meat and dairy products has long been associated with a variety of health and environmental concerns. In recent years, there has been a growing interest in plant-based alternatives to these products. A model study was conducted with adult Dutch subjects to investigate the effects of a diet with less or no meat and dairy products on nutrient intake and to assess the adequacy of nutrient intake when these products are replaced with plant-based alternatives. The study examined the nutrient intake of adults who partially (30%) or completely (100%) replaced meat and dairy products with plant-based alternatives. The results of the study

revealed that partial replacement did not significantly change the percentages below the nutrient spectrum when compared to the reference intake. This suggests that individuals who choose to partially replace meat and dairy products with plant-based alternatives can maintain similar levels of nutrient intake. Furthermore, the study found that greenhouse gas emissions and land use were both reduced by approximately 14% when individuals partially replaced meat and dairy products with plant-based alternatives. This demonstrates the potential environmental benefits of adopting a diet with fewer animal products.

However, the study also found that full replacement of meat and dairy products with plant-based alternatives was insufficient in terms of certain nutrient intake. Specifically, vitamin A, thiamine, vitamin B12, and zinc intake were found to be inadequate in individuals following a 100% plant-based diet. These nutrients are typically found in higher quantities in animal products, and their absence in a fully plant-based diet can lead to nutrient deficiencies

It is important to highlight that while the study focused on the nutrient intake of Dutch adults, the findings may be applicable to other populations as well. The results suggest that individuals who choose to completely replace meat and dairy products with plant-based alternatives should pay special attention to ensuring adequate intake of the nutrients mentioned earlier. This can be achieved through careful meal planning and the inclusion of fortified plant-based alternatives. Thus, this model study conducted on adult Dutch subjects provides valuable insights into the nutrient intake of individuals who partially or completely replace meat and dairy products with plant-based alternatives. (Seves, 2017).

The cost of healthy and sustainable diets: their affordability and future projections

A handful of global and regional studies have been conducted by pairing a comparative risk assessment of dietary risks with cost to estimate the costs of healthy and sustainable dietary patterns and the costs of climate change by combining dietary scenarios with greenhouse gas emissions footprints and estimating the social cost of carbon.

Results of those studies suggest that in high-income and upper-middle-income countries, dietary change interventions that incentivize the adoption of healthy and sustainable diets can help consumers in those countries not only reduce costs but also at the same time, contribute to fulfilling national climate change commitments and reduce public health spending. Currently, in lower-middle-income to low-income countries, conventional healthy and sustainable diets are moderately more expensive. However, reducing food waste, a favorable socioeconomic development scenario and a more comprehensive cost accounting that incorporates the diet-related costs of climate change and health care into the cost of diets increased the affordability of sustainable dietary patterns in our future projections. When these measures were combined, healthy and sustainable dietary patterns in low-income to lower-middle-income countries were up to 25-29% and on average up to 37% more affordable than in 2050. In general, vegetarian and

vegan diets were found to be the most affordable, while pescatarian diets were the most expensive (Springmann, M., Wiebe, K., Mason-D'Croz, D., Sulser, T. B., Rayner, M., & Scarborough, P., 2018).

Environmental and health analysis of sustainable diets

Sustainable diets aim to address the increasing health and environmental concerns associated with food production and consumption. A joint environmental and health analysis of different sustainable diets based on three different approaches to sustainable diets motivated by environmental, food security, and public health objectives, conducted at the regional level using an integrated health and environmental model across more than 150 countries, shows that pursuing environmental goals by replacing animal-based foods with plant-based foods was particularly effective in high-income countries in terms of improving nutritional content, reducing premature mortality (up to 12% reduction) and reducing some environmental impacts, particularly greenhouse gas emissions (up to 84% reduction). However, more freshwater was also consumed (an increase of up to 16%) and the effectiveness in countries with low or moderate consumption of food of animal origin was low. Pursuing food security goals by reducing underweight and obesity resulted in a similar reduction in premature mortality (up to 10% reduction) and a moderate improvement in nutritional content. The adoption of an energy-balanced, low-meat diet is also expected to meet public health goals, which are consistent with available evidence that a healthy diet leads to an adequate supply of most nutrients and a large reduction in premature mortality (19% reduction in flexitarian diets and 22% reduction in vegan diets).

The outcome of another global modeling analysis with country-level details showed a significant reduction in global environmental pollution (54-87% reduction in greenhouse gas emissions, 23-25% reduction in nitrogen deposition, 18-21% reduction in phosphorus deposition, 8-11% reduction in cropland use and 2-11% reduction in freshwater use) and in low-income countries in most regions, except for some environmental domains like cropland use, freshwater use, and phosphorus deposition (Springmann, M., Clark, M. A., Rayner, M., Scarborough, P., & Webb, P., 2021).

Conclusion:

The current findings emphasize the need for further research and education on balanced plant-based diets to ensure optimal nutrient intake while reducing environmental impacts. While some studies have been conducted to assess the environmental impact of food production value chains and identify potential improvement strategies, there is still a lack of integration between environmental, nutritional, economic, and health indicators when assessing the consequences of dietary change. To address this gap, more case studies should be conducted in different countries to identify sustainability indicators for various dietary transition scenarios. These studies can

help explore potential synergies and trade-offs between different indicators, allowing for a more comprehensive understanding of the impacts of dietary choices. By accounting for not only health and environmental factors but also economic costs, a more accurate assessment of the true costs of different diets can be made. To promote healthy and sustainable diets, governments must implement regulated public health strategies that focus on improving energy balance and advocating for predominantly plant-based diets. Updating national dietary guidelines to reflect the latest evidence on healthy eating should be prioritized not only for improving health outcomes but also for reducing environmental impacts and meeting broader sustainability criteria. Overall, further research, education, and policy changes are necessary to ensure that balanced plant-based diets become the norm. By integrating different indicators and considering the costs of diets, a healthy and sustainable diet can be the most cost-effective option in most countries in the future. We must continue to explore the environmental, nutritional, economic, and health implications of dietary choices to ensure a sustainable and prosperous future for all.

References:

1. Silva, J. G. (2012, June). *Feeding the World Sustainably*. Retrieved February 10, 2024, from United Nation, Peace, dignity and equality: https://www.un.org/en/chronicle/article/feeding-world-sustainably
2. Turnes, A., Pereira, P., Cid, H., & Valente, A. (2023). Meat Consumption and Availability for Its Reduction by Health and Environmental Concerns: A Pilot Study. *Nutrients*, 15(14), 3080. https://doi.org/10.3390/nu15143080.
3. Chen, C., Chaudhary, A., & Mathys, A. (2019). Dietary Change Scenarios and Implications for Environmental, Nutrition, Human Health and Economic Dimensions of Food Sustainability. *Nutrients, 11(4)* , 856. https://doi.org/10.3390/nu11040856.
4. Salter A. M. (2018). The effects of meat consumption on global health. *Revue scientifique et technique (International Office of Epizootics)*, 37(1), 47–55. https://doi.org/10.20506/rst.37.1.2739.
5. Millward, D. J., & Garnett, T. (2010). Plenary Lecture 3: Food and the planet: nutritional dilemmas of greenhouse gas emission reductions through reduced intakes of meat and dairy foods. *The Proceedings of the Nutrition Society, 69(1),* , 103–118. https://doi.org/10.1017/S0029665109991868.
6. Kumar, P.; Chatli, M.K.; Mehta, N.; Singh, P.; Malav, O.P.; Verma, A.K. (2017). Meat Analogues: Health Promising Sustainable Meat Substitutes. *Crit. Rev. Food Sci. Nutr.* , 57, 923–932.
7. Malav, O.P.; Talukder, S.; Gokulakrishnan, P.; Chand, S. (2015). Meat Analog: A Review. Crit. Rev. *Food Sci. Nutr.* , 55, 1241–1245.

8. Kyriakopoulou, K.; Dekkers, B.; van der Goot, A.J. (2019). Plant-Based Meat Analogues. In Sustainable Meat Production and Processing. *Elsevier: Amsterdam, The Netherlands, 2019* , pp. 103–126; ISBN 978-0-12-814874-7.
9. Finnigan, T. (2011). Mycoprotein: Origins, production and properties. In Handbook of Food Proteins. *Elsevier: Amsterdam, The Netherlands* , pp. 335–352; ISBN 978-1-84569-758-7.
10. Chriki, S., & Hocquette, J. F. (2020). The Myth of Cultured Meat: A Review. *Frontiers in nutrition* , 7, 7. https://doi.org/10.3389/fnut.2020.00007.
11. Alcorta, A., Porta, A., Tárrega, A., Alvarez, M. D., & Vaquero, M. P. (2021). Foods for Plant-Based Diets: Challenges and Innovations. *Foods (Basel, Switzerland), 10(2)* , 293. https://doi.org/10.3390/foods10020293.
12. Seves, S. M.-K. (2017). Are more environmentally sustainable diets with less meat and dairy nutritionally adequate?. *Public health nutrition, 20(11)*, 2050–2062. https://doi.org/10.1017/S136898001700.
13. Springmann, M., Wiebe, K., Mason-D'Croz, D., Sulser, T. B., Rayner, M., & Scarborough, P. (2018). Health and nutritional aspects of sustainable diet strategies and their association with environmental impacts: a global modelling analysis with country--level detail. *The Lancet. Planetary health, 2(10)*, e451–e461. https://doi.org/10.1016/S2542-5196(18)30206-7.
14. Springmann, M., Clark, M. A., Rayner, M., Scarborough, P., & Webb, P. (2021). The global and regional costs of healthy and sustainable dietary patterns: a modelling study. *The Lancet. Planetary health* , 5(11), e797–e807. https://doi.org/10.1016/S2542-5.

A REVIEW ON ARSENIC: A DUAL PLAYER CYTOTOXIC AND CYTOPROTECTIVE

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Abstract:

A well-known hazardous element that is present across the earth, arsenic has gained international attention. The majority of our groundwater is heavily contaminated with arsenic, and a large number of people drink the water, which could cause a variety of abnormalities. Surveys in arsenic-affected states assessed over 100,000 persons for symptoms of arsenicosis; 9.7% of these individuals had skin lesions related to arsenic. It can be used to treat cancer even though it damages DNA by producing reactive oxygen species (ROS), which causes cytotoxicity. Arsenic-produced free radicals can elevate oxidative stress in cancer cells to the point where the cells decide to undergo apoptosis in order to escape the burden of oxidative stress. This chemical change allows it to also operate as a cytoprotective agent.

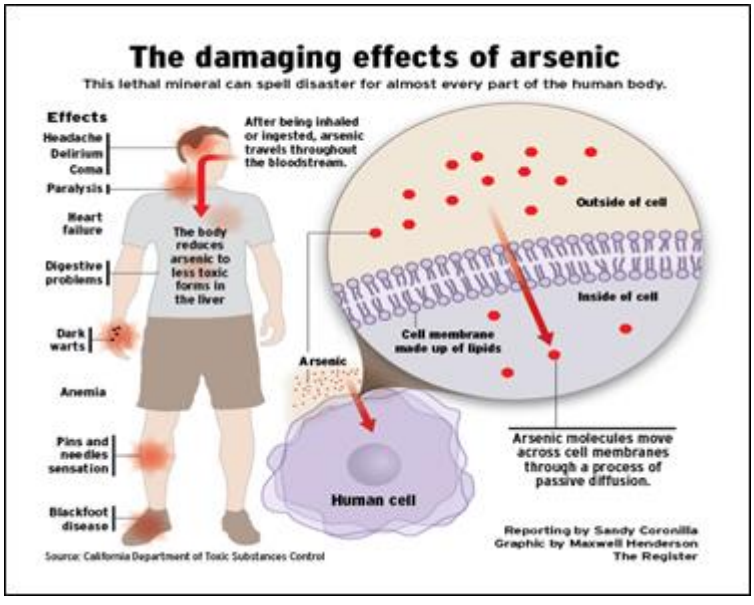
Keywords: Arsenic, Arsenicosis, ROS, Cytotoxicity, Cytoprotective Function

Worldwide scenario of arsenic contamination

Arsenic contamination of groundwater is a global issue. People who rely entirely on deep tube wells or manual pumps for drinking water are at high risk from arsenic contamination. In India, there are several prominent locations that are on the verge of disaster owing to arsenic toxicity. Crops produced in hazardous areas contribute to further contamination of groundwater. In India, around 80% of the rural population and 50% of the urban population use groundwater for residential reasons. Over 33% of the country's groundwater is deemed unsafe for consumption. Arsenic contamination in groundwater in South Asia is primarily found in floodplains of rivers that originate in the Himalayan Mountains. The first groundwater arsenic event and health repercussions in India were recorded in 1976 in the Indian Union Territory of Chandigarh (Datta 1976). This first report suggests the probability of widespread groundwater arsenic pollution, notably in the Ganga River Basin. Groundwater contamination and its impact on individuals have been highlighted in Bihar (2002), Uttar Pradesh (2003), Jharkhand (2004), and the Upper Ganga Plain in Uttar Pradesh (2009) (Chakraborti *et al.*, 2009). Between 2004 and 2006, arsenic contamination was observed across the Brahmaputra Plain, including Assam and Manipur. In six states, groundwater arsenic pollution has affected 35 districts with a population of 70.4 million people. Over 100,000 people were evaluated for arsenicosis symptoms during

surveys in arsenic-affected states, and 9.7% of them had arsenical skin lesions (Chakraborti *et al.,* 2009). Groundwater arsenic contamination in the Allahabad-Kanpur Track of the Upper Ganga Plain has also been discovered (Chakraborti *et al.,* 2009). It has been observed that arsenic concentration decrease with increasing depth of tube wells (Roy Chowdhury *et al.,* 1999). Not only Asian countries but also China, Mongolia, Nepal, Cambodia, Myanmar, Afghanistan, DPR Korea, and Pakistan faced arsenic intoxication due to ground water contamination. There are reports of arsenic contamination from Kurdistan province of Western Iran and Vietnam, where several million people may have a considerable risk of chronic arsenic poisoning (Mukherjee *et al.,* 2006). A high arsenic content in drinking water is the leading cause of arsenicosis worldwide (Mukherjee *et al.,* 2006). Groundwater poisoning with arsenic was first documented in the western USA and Alaska in the mid-20th century. However, it was not completely recognised in Oklahoma, Texas, and Arkansas, as well as the Midwest and northeastern regions, until the 1980s (AWWA, 1999). Recently, groundwater carrying arsenic levels higher than the USA Federal and State MCLs was discovered in sections of the Atlantic Coast Plain. Arsenic contamination of groundwater in Canada dates back to the 1970s in New Brunswick and Nova Scotia, and the 1960s and 1980s in Western Canada (Budinova *et al.,* 2009). Groundwater contamination with arsenic has also been observed in Chile, Argentina, Vietnam, Hungary, Laos, and Cambodia (Mukherjee *et al.,* 2006). In Europe, the findings of arsenic pollution of groundwater happened over a duration of approximately 100 years.

Health effects of arsenic



Arsenicosis is a chronic condition caused by consuming water with high arsenic levels over an extended period. It is frequently referred to as arsenic poisoning. Arseniasis refers to chronic arsenical poisoning, while arsenicism is a disease characterised by gradual arsenic poisoning (Kapaj *et al.,* 2006). Recent reviews have not provided a comprehensive summary of arsenic's effects on human health. Studies in Bangladesh and West Bengal (India) found that chronic arsenic exposure might produce respiratory system consequences, including chronic cough and bronchitis (Guha Mazumder, 2003; Milton *et al.,* 2002). It is found that patients with chronic arsenic exposure experience skin manifestations such as weakness, conjunctival congestion, redness of the eyes,

persistent cough, and chronic bronchitis (respiratory tract inflammation). Long-term exposure to arsenic has been shown to harm the respiratory system (Milton *et al.,* 2002; Milton *et al.,* 2003). Not only that, it has been reported that arsenic consumption damages platelets. Platelets are important components in cardiovascular disease. Arsenite, a trivalent form of arsenic, has been linked to increased platelet aggregation when combined with thrombin. It is claimed that arsenic in drinking water causes arterial thrombus development in rats. Long-term exposure to arsenic in drinking water has been linked to an increase in platelet aggregation, which contributes to cardiovascular disease. Arsenic neuropathy is a known consequence of arsenic exposure. Chronic arsenic exposure leads to peripheral neuropathy, a degenerative condition of the peripheral nerves. This is a common nervous system issue. Neuropathy typically affects sensations and develops gradually. Patients may have chronic pain, hypersensitivity to stimuli, muscular weakness, or atrophy (Guha Mazumder 2003; Mukherjee *et al.,* 2003). In this case, sensory and sensorimotor (sensation and muscles) neuropathy have also been documented (Rahman *et al.,* 2003). Additionally, a number of studies revealed an adverse relationship between verbal IQ and long-term memory and arsenic levels (Kapaj *et al.,* 2004). Furthermore, it was discovered that exposure to arsenic in individuals with chronic malnutrition may have an impact on long-term memory, attention, and speech comprehension (Calderon *et al.,* 2001). Additionally, several studies have demonstrated that elevated arsenic exposure in children can impair their intellectual ability.

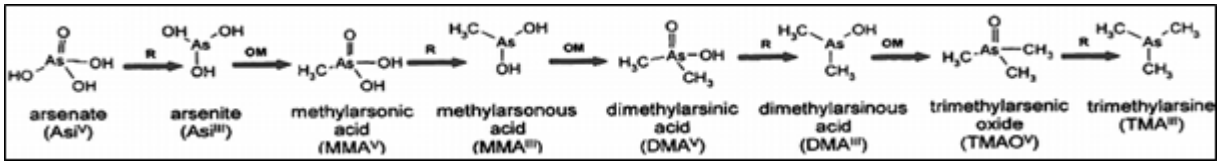
Hepatic abnormalities were documented in people who had lived in places contaminated with arsenic for an extended period of time. According to Santra *et al.,* (2007), there is a linear correlation between the occurrence of hepatomegaly and the amount of arsenic present in drinking water. Numerous negative health effects have been linked to long-term arsenic exposure. Patients who used drinking water tainted with arsenic for an extended period of time experienced a number of inflammatory clinical disorders, such as hypertrophy of the liver and spleen (Mazumder 2005). These conditions finally led to liver cirrhosis and ultimately drove the patient's body towards cancer. It has been suggest that inorganic arsenic serves as a diabetogenic agent in humans, but little is known about pathophysiological mechanisms. The underline fact is that people exposed to arsenic suffer from type two-diabetes.

According to Centeno *et al.,* (2006), arsenic is a special kind of carcinogen. The only known human carcinogen for which there is sufficient proof of a carcinogenic risk through both ingesting and inhalation is arsenic. Since 1980, arsenic has been recognised as a human carcinogen by the International Agency for Research on Cancer (IARC) (IARC, 2005). The possible health risk that arsenic in drinking water poses to people has been highlighted by numerous researchers. Many nations have established a link between arsenic exposure and cancer, including the USA, Taiwan, Bangladesh, India, Argentina, and Chile, to mention a few.

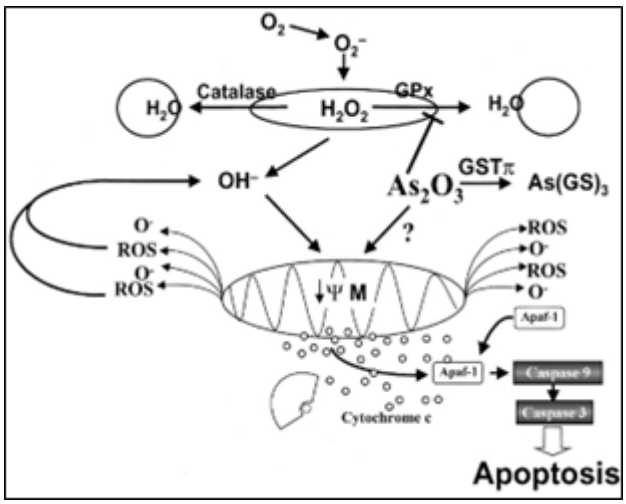
Patients in West Bengal who were exposed to arsenic experienced severe skin lesions. The exact number of people with cancer remained unknown since they were unable to pay for the necessary tests. In addition to the skin, arsenic exposure also caused cancer in the lung, liver, kidney, and bladder.

How arsenic leads to cytotoxicity and cytoprotective function

Arsenic actually damages DNA by acting as an uncoupler to produce reactive oxygen species. It also damages tissue, which can result in diseases. It is clear from this that arsenic harms biological systems in a number of ways, one of which is the production of an excessive amount of reactive oxygen species (ROS) (Barchowsky *et al.*, 1999). According to experimental research, arsenic causes a rise in the generation of reactive oxygen species, including hydroxyl radicals (Wang *et al.*, 1996), hydrogen peroxide (Barchowsky *et al.*, 1999; Chen *et al.*, 1998), and others (Barc**howsky *et al.*, 1999). The byproduct of cellular metabolism, reactive oxygen species (ROS) are essential for activating different signalling pathways in both plants and animals.**



Arsenic in different oxidation states



Arsenic in producing free radicals

Hydroxyl radicals, superoxides, and hydroperoxides are the three main classes of reactive oxygen species (ROS) that can be generated. Each class has unique properties related to its half-life, reactivity, target specificity, localization, and most significantly, consequences on biology and pathology. Currently, a variety of nitrogen-containing substances, also known as RNS (Reactive Nitrogen Species), such as nitric oxide (NO), nitroxyl anion (NO−), and peroxynitrite (ONOO−), can be classified as ROS. Inducible nitric oxide synthase (iNOS) generates NO, which combines with superoxide to form the other reactive nitrogen specie s(RNS). Other

acronyms for ROS include ROI (Reactive Oxygen Intermediates) and RNI (Reactive Nitrous Intermediate). Typical byproducts of the biological reduction of molecular oxygen include superoxide anion ($O_2^{\cdot}$), hydrogen peroxide (H_2O_2), hydroxyl radical ($OH^{\cdot}$), and organic peroxides. As arsenic sequentially reduces from its trivalent to pentavalent form, it interferes with vital enzyme's functional groups and impairs crucial biochemical events, both of which contribute to the production of reactive oxygen species (ROS) (Bashir *et al.,* 2006). Prolonged and sustained ROS can result in somatic mutations, neoplastic transformation, and severe harm to cell structure and function. ROS have been linked to a broad range of illnesses, such as chronic inflammation, which can eventually cause the start and spread of several types of cancer (Droge 2002). As a result, inflammation and oxidative stress may coexist. The relationship between oxidants and inflammation has been the subject of numerous investigations, yet it is still mostly unclear. The majority of the research concluded that oxidative stress and inflammation are two distinct phenomena that work together negatively to affect the physiological system. The activation of signalling pathways mediated by ROS is initiated by an inflammatory trigger. ROS functions as an inflammatory mediator as well as a signalling molecule. For example, superoxide has a high affinity for reactive nitrogen species (RNS), which raises the cell's proinflammatory burden and causes nitrosative stress. Thus, the physiological system experiences an additional oxidative burden from both inflammation and oxidative stress at the same time. However, despite numerous reports from early studies indicated that arsenic has immunomodulatory, or more precisely immunosuppressive effects, the effect of arsenic on the immune system is still unknown (Choudhury *et al.,* 2016). It is also known that arsenic can combat with leukemia. The anti-leukemic properties of arsenic were initially documented in the late 1800s. Up until radiation therapy took its place, As_2O_3 was used as the main anti-leukemic medication. However the hematologic use of arsenic experienced a re-emergence in popularity in the 1930s when its efficacy was reported in patients with chronic myelogenous leukemia (CML) (Forkner *et al.,* 1931). Arsenic trioxide has been reported to induce both clinical and hematologic responses in patients with recurrent acute promyelocytic leukaemia (APL) in recent Chinese publications (Zhang *et al.,* 1996; Shen *et al.,* 1997). The way that arsenic trioxide functions in APL patients are a significant observation, since 20% to 30% of individuals with this kind of acute myelogenous leukaemia relapse even after receiving combination chemotherapy and all-trans retinoic acid treatment. Arsenic trioxide showed positive clinical responses in nine out of ten patients with recurrent APL, according to a Chinese investigation (Shen *et al.,* 1997). The process by which arsenic has an anti-leukemic impact reveals that it promotes significant cellular changes, such as the induction of apoptosis, the inhibition of proliferation, the encouragement of differentiation, and the inhibition of angiogenesis (Snow 1992). Critical cell proteins may react with closely related cysteine residues in response to arsenic, which primarily takes the trivalent

forms of arsenite and arsenic trioxide, to cause biological consequences. Most proteins that have a lot of cysteine and readily accessible thiol groups are likely to interact with arsenic. Some recent evidences showed that arsenic is also act against breast cancer (Skoczynska *et al.,* 2022).

Conclusion:

From the discussion above, we deduced that arsenic, a well-known poisonous element, acts both as a harmful agent and has a beneficial therapeutic effect on cancer. We propose that arsenic functions as both a cytotoxic and a cytoptrotective agent, depending on the amount and degree of exposure. Arsenic-induced changes in membrane transport, cellular signalling pathways, and organelle function such as mitochondria, endoplasmatic reticulum, and nucleus all contribute to carcinogenic or anticancer effects of arsenic. The baseline activity of membrane receptors, cytokines, transcription factors, pro- and antiapoptotic enzymes, and the cell cycle all influence cellular responsiveness to arsenic. The final cell response to arsenic is determined by the genome's overall stability, changes in gene expression, and DNA repair capabilities. Arsenic may have beneficial benefits due to considerable metabolic variations between cancer and healthy cells.

References:

1. AWWA (1999). Water Quality and Treatment: a handbook of community water supplies. McGraw- Hill, New York.
2. Barchowsky A, Klei L R, Dudek E J, Swartz H M & James P E, Stimulation of reactive oxygen, but not reactive nitrogen species, in vascular endothelial cells exposed to low levels of arsenite, *Free Radic Biol Med*, 27 (1999). 1405.
3. Bashir S, Sharma Y, Irshad M, Gupta S D & Dogra T D, Arsenic-induced cell death in liver and brain of experimental rats, *Basic Clin Pharmacol Toxicol*, 98(2006). 38-43.
4. Budinova T, Savova D, Tsyntsarski B, Ania CO & Cabal B, Parra J B & Petrov N, Biomass waste-derived activated carbon for the removal of arsenic and manganese ions from aqueous solutions, *Applied Surface Science*, 255 (2009). 4650-4657.
5. Calderon J, Navarro M E, Jimenez-Capdeville M E, Santos-Diaz M A, Golden A, RodriguezLeyva I, Borja-Aburto V & Diaz-Barriga F, Exposure to arsenic and lead and neuropsychological development in Mexican children, *Environ. Res*, 85 (2001). 69–76.
6. Centeno J A, Tchounwou P B, Patlolla A K, Mullick F G, Murakata L, Meza E, Gibb H, Long fellow D & Yedjou C G, Environmental Pathology and Health Effects of Arsenic Poisoning: A Critical Review, In Managing Arsenic in the Environment: From Soil to Human Health, Naidu R, Smith E, Owens G, Bhattacharya P, Nadebaum, Eds.; CSIRO Publishing: Melbourne, Australia, (2006). 311–327.

7. Chakraborti D, Ghorai S K, Das B, Pal A, Nayak B & Shah B A, Arsenic exposure through groundwater to the rural and urban population in the Allahabad-Kanpur track in the upper Ganga plain, *J. Environ. Monit*, 11(2009). 1455–1459.
8. Chen Y C, Lin-Shiau S Y & Lin J K, Involvement of reactive oxygen species and caspase 3 activation in arsenite-induced apoptosis, *J Cell Physiol*, 177 (1998). 324.
9. Choudhury S, Gupta P, Ghosh S, Mukherjee S, Chakraborty P, Chatterji U & Chattopadhyay S, Arsenic-induced dose-dependent modulation of the NF-kB/IL-6 axis in thymocytes triggers differential immune responses, *Toxicol*, 357 (2016). 85–96.
10. Droge W, Free radicals in the physiological control of cell function, *Physiol Rev*, 82 (2002). 47-95.
11. Forkner C E & Scott T F M, Arsenic as a therapeutic agent in chronic myelogenous leukemia, *JAMA*, 97(1931). 3-5.
12. Guha Mazumder D N, Chronic arsenic toxicity: clinical features, epidemiology, and treatment: experience in West Bengal, *J. Environ Sci Health*, A38 (2003).141– 163.
13. International Agency for Research on Cancer. Arsenic and arsenic compounds. 1980 Vol. 23, 39p.
14. Kapaj S, Peterson H, Liber K, & Bhattacharya P, Human Health Effects From Chronic Arsenic Poisoning– A Review, *J. Environ. Sci. Health*, A41 (2006). 2399–2428.
15. Mazumder D N, Effect of chronic intake of arsenic-contaminated water on liver, *Toxicol Appl Pharmacol*, 206 (2005). 169-175.
16. Milton A H & Rahman M, Respiratory effects and arsenic contaminated well water in Bangladesh, *Int. J. Environ. Health. Res*, 12 (2002). 175–179.
17. Milton A H, Hasan Z, Rahman A & Rahman M, Non-cancer effects of chronic arsenicosis in Bangladesh: preliminary results, *J. Environ. Sci. Health*, A38 (2003). 301– 305.
18. Mukherjee S C, Rahman M M, Chowdhury U K, Sengupta M K, Lodh D, Chanda C R, Saha KC & Chakraborti D, Neuropathy in arsenic toxicity from groundwater arsenic contamination in West Bengal, India, *J. Environ. Sci. Health*, A38 (2003). 165–183.
19. Mukherjee A, *et al.*, Arsenic contamination in groundwater: a global perspective with emphasis on the Asian scenario, *J Health Popul Nutr*, 24 (2006).142-163.
20. Rahman M M, Mandal B K, Chowdhury T R, Sengupta M K, Chowdhury U K, Lodh D, Chanda C R, Basu G K, Mukherjee S C, Saha K C & Chakraborti D, Arsenic groundwater contamination and sufferings of people in North 24-Parganas, one of the nine arsenic affected districts of West Bengal, India, *J. Environ. Sci. Health*, A38 (2003). 25–59.
21. Roy Chowdhury T, Basu G K, Mandal B K, Biswas B K, Chowdhury U K, Chanda C R, Lodh D, Roy S L, Saha K C, Roy S, Kabir S, Zaman Q Q & Chakraborti D, Arsenic poisoning in the Ganga delta, *Nature*, 401(1999).545–546.

22. Santra A, Chowdhury A, Ghatak S, Biswas A & Dhali G.K, Arsenic induces apoptosis in mouse liver is mitochondria dependent and is abrogated by N-acetylcysteine, *Toxicol Appl Pharm*,220 (2007).146-155.
23. Shen Z-X, Chen G-Q & Ni J-H,Li X-S, Xiong S-M, Qiu Q-Y , Zhu J, Tang W, Sun G-L, Yang K-Q, Chen Y, Zhou L, Fang Z-W, Wang Y-T, Ma J, Zhang P, Zhang T-D, Chen S-J, Chen Z & Wang Z-Y, Use of arsenic trioxide (As2O3). in the treatment of acute promyelocytic leukemia (APL).:II. Clinical efficacy and pharmacokinetics in relapsed patients, *Blood*, 89 (1997). 3354-3360.
24. Shen S, Lee J, Weinfeld M & Le C S, Attenuation of DNA damage-induced p53 expression by arsenic: A possible mechanism for arsenic co-carcinogenesis, *Mol Carcinog*, 47(7). (2008). 508-18.
25. Snow E T, Metal carcinogenesis: mechanistic implications, *Pharmacol Ther*, 53(1992). 31-65.
26. Sun H D, Ma L & Hu X-C *et al.,* Ai-Lin 1 treated 32 cases of acute promyelocytic leukemia, *Chin J Integrat Chin Western Med*, 12 (1992).170-172.
27. Skoczynska A, Skoczynska M, Breast Cancer and Arsenic Anticancer Effects: Systematic Review of the Experimental Data from In Vitro Studies, BioMed Research International, 2022 (2022). 16.
28. Wang T S, Kuo C F, Jan K Y & Huang H, Arsenite induces apoptosis in Chinese hamster ovary cells by generation of reactive oxygen species, *J Cell Physiol*, 169 (1996). 256.
29. Zhang P, Wang SY & Hu XH, Arsenic trioxide treated 72 cases of acute promyelocytic leukemia, *Chin J Hematol*, 17 (1996). 58-62.

SUSTAINABLE DEVELOPMENT OF RIVER FRONT GHATS OF VARANASI, UTTAR PRADESH

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Abstract:

India's ancient and historical cities have a unique built and cultural heritage that attracts tourists which become one of the major economic activities of that area. but! all these historical cities and heritage sites are deteriorating with time. Due to the rapid growth of modern urbanization, the quality of the traditional buildings, living environment and infrastructure of the city has also declined. As a result, a sustainable development of today's fast-growing modern cities has become a very important issue that integrates cultural heritage and aspirations for the future. Through sustainable development, cultural heritage, urban development planning and local economic development are linked together to meet the needs of the present generation and preserve things for future generations. The city of Varanasi has beautifully nurtured the natural, architectural, artistic and religious expressions of traditional Indian culture, the holy Ganga riverside Ghats, numerous temples and holy water bodies are part of the city's heritage and glory as well as major tourist attractions of the city. This article mainly points out the heritage of river front historical sites and monuments of the city and focuses on the importance of sustainable development for the conservation and development of it.

Keywords: River Front, Sustainability, Conservation, Development, Cultural Landscape, Heritage.

Introduction:

The tangible heritage of the city includes the riverside Ghats, sacred ponds, magnificent buildings, religious structures and archaeological sites, while intangible heritage such as tradition, performing arts, food, rites and rituals etc. form the backbone of Varanasi's traditional culture. The riverfront Ghats are an integral part of local culture as well as a place of tourist attractions. The Ghats of Varanasi on the west bank of the river are especially sacred for all Hindu rituals. The integration of the Ganges with the religious, traditional and cultural milieu has had an important impact on the economic and social life of the city. In the 2nd century AD, the Ghats were first described. Later, during the Gupta period, from the 3rd to 6th century AD, the Ghats became an economic and cultural center. The riverfront landscape (Ghats) became prominent in the overall landscape of Varanasi under the patronage of the Marathas in the 18th – 19th centuries. Palaces, buildings, temples and pilgrims' rest houses were built along the Ghats.

Even during the 19th-20th centuries, many Ghats were rebuilt, renamed and reshaped. From the 1950s, the state government of Uttar Pradesh proceeded to build stone steps on the Ghats and repair them. The riverfront is a complex ecosystem emerging from the practice of spatial rituals, cultural and natural phenomena that respond to its cycles that reflect the Hindu understanding of cosmic order. Overuse and exploitation of rivers have increased pollution levels that have put pressure on ecosystems, disrupting the purity of rivers and the continuity of spatial practices. Varanasi's riverfront landscape has developed as a complex ecosystem where culture and nature exist in a reciprocal relationship (Ramakrishnan 2003). But the city's uncontrolled growth, poor governance and lack of awareness have resulted in neglect and degradation of historical and cultural sites. Unscientific maintenance of the river front, illegal encroachment, management of solid and liquid wastes and increasing pressure due to three million visitors annually are endangering the heritage of this cultural city (Sinha 2017, pp158). With over 3,500 heritage footprints, Varanasi has perhaps the largest collection of built stock of any living city in the world. But over time the primitive temples, mythical Ghats, old riverside palaces, and colonial buildings have fallen into disrepair and are completely dilapidated. We have to be conscious and active to preserve the wonderful glory and cultural structure of Varanasi, India's cultural capital (Praharaj. S. 2014, pp 167-174).

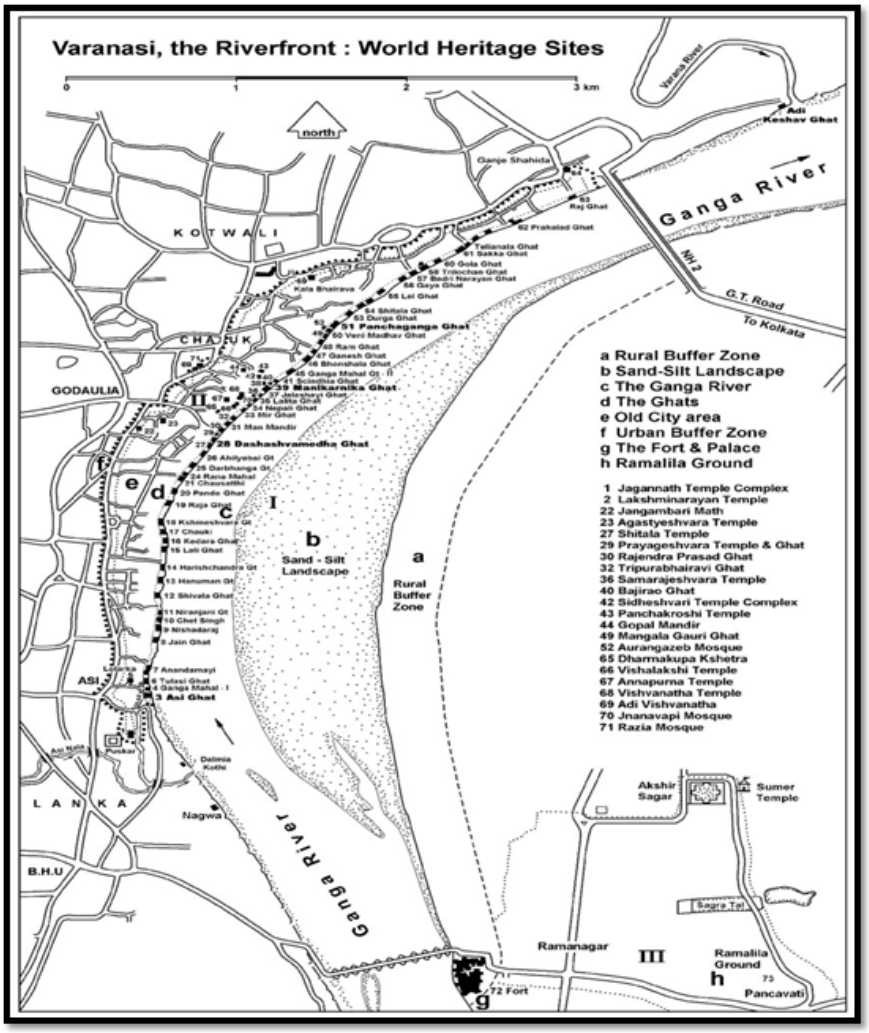
Literature Review:

Rana P.B. Singh (2018), It is beautifully described that the geological structure of Varanasi provided the basis for the growth of a crescent-shaped city, symbolically described as the crescent moon on Lord Shiva's forehead. He also considered this characteristic in the context of river ecology as a unique aspect of energy quantum and direction of energy flow. Sirima and Backman (2013) state that the main focus when discussing sustainable tourism is economic and environmental sustainability. As tourism growth does not always ensure the development of local communities, he also points out the importance of social sustainability and calls for giving equal importance to the issue. Xing *et al.,* (2013). Sustainable tourism development policy and local environment protection are emphasized on these two issues. Engel and Engel (1990:20): The spirit of sustainability defines development depending upon the emergence of holistic understanding and action in every segment of society (cf.) Praharaj. S, (2014): He discussed local economic development through the rehabilitation of historical areas, development of infrastructure and the preservation of cultural heritage by developing a tourism system. That is to say, an integrated approach is both sustainable preservation of heritage, development of the local economy and propagation of native culture. Sherring states that (1868: 9): For beauty and majesty, no scene on earth can better surpass that of Vararanasi, seen from the river Ganges. Singh, Rana P.B. (2004): Here he records his views on the debates on traditional issues under the special scheme of the government. He states that heritage conservation has not been recognized

as part of inclusive development because religious concepts play an important role there and can be managed in terms of the 'religio-politics interface'. Feizabadi, T. N. (2015): Elucidated on the emergence of the concept of sustainable development and its impact on tourism and the government's approach to tourism development. According to him, with the increase in the population and tourists, there has been a proportional increase in environmental problems and the resulting pressure on natural resources. He drew attention to how tourism, the environment, society and the economy can have a positive impact using sustainable development.

Objectives of the study:

The main objective of this research paper is to create awareness among the public about the sustainable development of the beautiful Ghats of Varanasi city and to highlight our traditional heritage, culture and history



Source: Varanasi Riverfront (Singh, 2009)

Location of the study area:

The Ganga River and the riverfront Heritage Zone of Varanasi spread between 25º 17.350’ to 25º 19.678’ North and 83º 00.340’ to 83º 02.374’east and it covers an area of 374ha area. Asi river in the south and varna river is the northern limit of this river front zone which

covers a length of 7 k.m along the river bank of Ganga. The western edge of this rive front heritage zone is marked by an ancient road connecting Asi-Godaulia-Chowk-Maydagin Matyodari-Raj Ghat (Singh, Rana P.B. 2004, pp 25).

Heritage zone of Varanasi city:

According to the VDA Zoning Plan, five heritage zones were identified in the previous master plan of Varanasi (1991–2011) and the same has been retained in the current plan (2011–2031) (Singh and Pal 2012). These are the heritage areas Riverfront Ghats, Durgakund-Sankatmochan hanuman temple area, Kamachcha-Bhelupura Area, Kabir Math (Lahartara) Area, and Sarnath. Among these heritages, riverfront heritage is discussed in this research paper.

The Ganges is always regarded by Hindus as the "mother" and is worshiped as an essential power in life-force. The riverfront landscape should be viewed not as an isolated element, but as a holistic subject of meaningful relationships where life and experience are intertwined with the everyday world. The Ganga riverfront is the nexus of major rituals and festivals in the holy city of Varanasi. Any festival, any ritual and religious circumambulation begins with a holy bath in the Ganges and ends with the Ganges.

The geological structure affects the flow of the Ganga from south to north in a semicircular shape near Varanasi. The Ganga River adjacent to Varanasi is an example of natural heritage. The multiculturalism of India is observed along the Ganga Ghats of Varanasi as people from different parts of India have settled in the Ghats adjoining the city of Varanasi since ancient period.

A symbol of great cultural heritage:

There are 84 important Ghats and 96 holy shrines from Ganga-Varna confluence north of Varanasi to Asi- Ganga confluence in the south. These 84 Ghats have been compared with 84 lakh organic species (yoni) according to Hindu mythology. It is believed that each Ghats frees man from the pains of being born in one million organic species (yoni) and helps in salvation by washing away the sins of the people. Therefore, to get rid of 84 lakh organic species, to purify the soul and to be free from the cycle of rebirth, it is necessary to take a bath in every Ghats of Varanasi city (84Ghats x 10, 00000 organic species or yoni = 84,000000 organic speies). Further 12 months / 12 Zodiac x 7 layers of atmosphere is equal to 84 in this way one can complete the annual cycle of cosmic journey by bathing all 84 Ghats and can attain salvation by being completely free from the bondage of birth and death. On the other hand, 96 holy water-shrines near the Ghats have been explained 12x 8 = 96, (12 is division of time/Zodiac and 8 is direction) so it is also representing manifestive transcendental dimension of Varanasi (Singh Rana, 2009). According to The Kashikhanda (KKh 84.107-10, 114) among all the 84 Ghats, five Ghats have been given more importance in terms of spirituality. To the north of these Ghats are "Adikeshab, then gradually to the south are Panch Ganga Ghats, Manikarnika Ghats, Dashaswamedh Ghats

and Asi Ghats respectively. These most sacred five Ghats are called ―Panch tirthas‖. It is believed that by bathing in these five Ghats, one attains the same virtue of bathing in all the Ghats and one is freed from the cycle of life and death and attains salvation.

Although Varanasi has improved urban civic infrastructure such as sanitation, solid waste management, water supply etc. and has been improved and measures have been taken to reduce pollution of the Ganges through the schemes launched by the government, it has so far failed to fully address the issues yet so far it has failed to fully resolve the issues. Modern engineering and construction styles are not compatible with or sensitive to the city's ancient cultural heritage, myths, legends and local ecology.

Heritage risk and challenges:

Heritage zones, areas and properties are being irreversibly altered or even destroyed due to the massive pressures of tourism, economic development and population pressure, which are now under threat. The integrity of the cultural landscape and atmosphere and urban skylines in the region are collectively at risk. The growing population is having a severe impact on the environment and the carrying capacity of river ecosystems and unplanned mass tourism. In many cases, old heritage buildings and structures are altered or demolished in the name of development, especially those with multi-ownership or ownership legal complications or those that are too expensive to renovate. The buffer zone and the skyline of the old city, the status quo of which is currently preserved, are also threatened by encroachment and rising building heights. (Singh, 2004). Cultural practices and rituals at the Ganga Ghats are generating waste that contributes to local pollution, resulting in a disconnect between ideals and reality and a mismatch between perceptions of the Ganga as pure and clean (Conaway 2015). The Ganga in Varanasi, far from nourishing health and life, is a source of water-borne enteric diseases for those who bathe in it and drink its waters (Sinha.A 2018). Ghat priests believe that the Ganga will always remain pure even if it is not cleaned, thereby pointing to a lack of religious solidarity in the state's efforts to clean the Ganga. (Alley 1998). River Ganges flows past Varanasi as a holy blessing that purifies the city and gives it unique shape and prosperity. But now the Ganges is considered as a dumping ground for city waste water and flowers. Today in Varanasi Ganga is only a symbol of religious frenzy with no respect and no effort to revive the holy river and lack of awareness and conservation initiatives is observed. Due to neglect and inadequate efforts, the living environment of the heritage precincts of Ghat areas has deteriorated considerably. Most of the traditional areas are surrounded by slums and the location of these densely populated settlements is indicative of past degradation of local environmental services. Most of the traditional areas are surrounded by slums and the location of these densely populated settlements indicates the deterioration of local environmental and civic services. As Varanasi is mainly a city of temple and religious importance, the production of flower waste (4.2MT/day) is high.

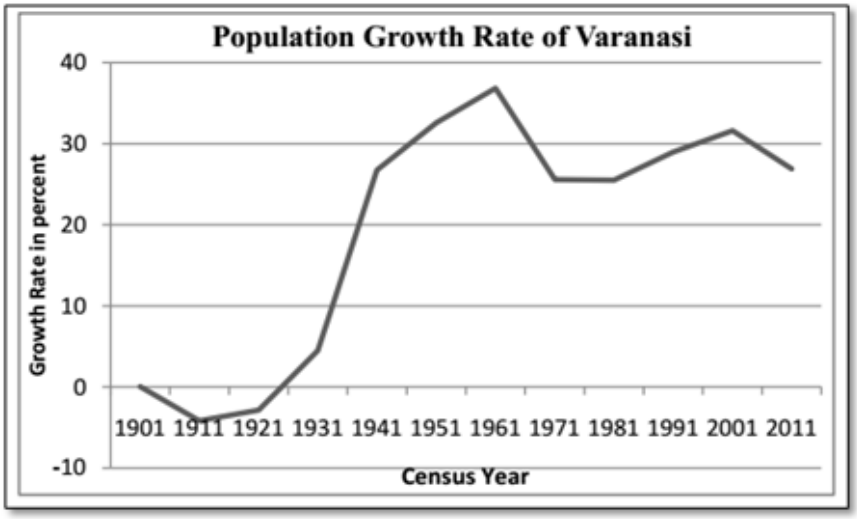
Varanasi also has 84 Ghats where a large number of pilgrims and tourists perform various religious rituals at these Ghats thereby generating various types of waste almost every day.

Development and population pressure:

Like most urban areas in India, Varanasi has to deal with intense development pressures. Every inch of the old city center and riverbanks are built up, with a population density of around 400 to 500 people/per 0.01sq km).

Table 1: Development and population pressure of Varanasi city

Year	Population	Increasing/ Decreasing	Decadal Growth Rate
1901	226105	-	-
1911	217012	-9093	-4.20
1921	210745	-6269	-2.89
1931	220143	+9398	+4.46
1941	278955	58812	+26.72
1951	369799	90844	+32.57
1961	505952	136153	+36.82
1971	635175	129223	+25.54
1981	797162	161987	+25.50
1991	1027819	230657	+28.93
2001	1211749	183930	+17.89
2011	1435113	223364	+18.43



Population growth of Varanasi city (1901-2011)

The graph shows that the growth rate has decreased significantly after 1991 suggesting that residential preference in the core urban area may have shifted to the peripheries of the city. This indicates probably the urban renewal may be needed this city. The Varanasi urban area is

also promoted to million cities in 1991. The situation changed in 2001 the population growth rate had slightly decrease 17.89%. The situation has changed in the year 2011, the population growth rate has increased 18.433% and it is estimated that it will reach at 20.03 % by the year 2021. The current estimate population of Varanasi city in 2024 is 1,701,000. Additionally, an estimated 30,000 daily floating population is recorded in the city. This huge population pressure is causing traffic congestion during peak and normal times. The result is noise pollution and smog. Therefore, the built heritage of the city is seriously threatened today due to population pressure.

Tourist and pilgrimage pressure:

Around lakhs of pilgrims visit the city every year, six months, October to March, being the main season for tourists. Among important tourist attractions Dasaswamedh Ghat area attracts maximum tourists visiting Varanasi. This tourism often affects the heritage of the place socially, ecologically and culturally.

Table 2: Increasing trend in tourist flow in Varanasi city (Source: Year-wise-Tourist-Statistics, UP)

Year	Domestics	Foreign	Total
2017	5947355	334708	6282063
2018	6095890	348970	6444860
2019	6447775	350000	6797775
2020	876303	106189	982492
2021	3075913	2566	3078479
2022	71147310	83741	71231051

Tourism obviously has economic benefits, but uncontrolled tourism also has negative effects on the environment. Tourism is a threat to tourism and can be a huge burden on resources. Resource depletion, social pollution, environmental pollution and tourism are the three main negative impacts. This does not mean that only tourism is creating environmental problems in Varanasi, there are already many environmental problems and tourism is greatly exacerbating those problems.

Environmental pressure:

Low level of sanitation infrastructure coupled with increase in floating population has led to increased rate of defecation in Ghats and river banks or exposed areas. As a result these valuable sacred heritages which are attractive to these tourists are gradually losing their traditional value and are turning into highly polluted and unhealthy areas The river's eco-system is facing increasing pressure from the population of the Riverfront Heritage Zone and other parts of the city whose sewage flows directly into the river. It also faces the pressure of polluting agricultural run-off from villages surrounding the city. However, about 80% of the pollution in

Varanasi's river Ganges is urban waste. About 60% of the total pollution is concentrated in the riverfront and the Old City Heritage Zone near Varanasi. Waterborne diseases are occurring in this area due to polluted water (singh2004).

One of the most important aspects of heritage conservation and urban renewal is efficient and effective governance, Varanasi has recently seen a strong and efficient institution dedicated to heritage, which is still in its infancy. But many critics feel that VUDA- in the name of heritage management only adds a new chapter on heritage in the master plan document, but it does nothing. Municipal corporations, VUDA (Varanasi urban development authority) and INTACH (The Indian National Trust for Art and Cultural Heritage) all have separate lists of heritage structures and monuments but have never shown interest in making a single comprehensive list. There is a lack of linkages between various institutions and technical expertise in matters related to heritage conservation and management.

Main findings and suggestion:

The bio-centric approach to the urban development of Partick Geddes in the early 20th century is particularly important in this regard. He believed that the heritage of cities could be preserved by planning for individual and social development, by linking cultural perspectives with ecological niches. Decentralization, civic responsibility, heritage preservation, cooperative and alternative and complementary planning are of particular importance (Tyrwhitt 1947). The current ongoing development which does not take proper care of the old city and its heritage buildings, is facing criticism for maintaining the continuity and cleanliness of the river Ganga and preserving the river banks. It has been argued that most of these plans rely on the theoretical ideals of outsiders, which do not fit the local environment. For the sustainable development of the Ganga and its Ghat areas and to ensure a healthy and resilient river course, planning and management strategies need to integrate the spiritual and phenomenal aspects of nature. The divinity of the Ganga and its material properties should be bridged in such a way that its transcendental powers are inherent in its earthly flow (Amita Sinha, 2018).

The city of Varanasi is in a precarious position with the pressure of increasing urbanization, the struggle for modernization and the precious heritage and antiquities. Even as the level of economic activity in Varanasi continues to increase, the city suffers from the threat of losing its distinct ancient heritage character, making the city seem a little less vibrant. This is not only a concern for Varanasi and India's culture-loving intellectuals, but also for all residents of the local community, so we all need to adopt new innovative tools to bring back the unique heritage and glory of Varanasi.

Heritage conservation and management are often people's awareness. A man's own heritage depends on his level of respect for wealth and culture. Both the above-mentioned aspects are clearly lacking in the case of Varanasi. Washing clothes, throwing waste, open defecation in holy

rivers, Ghats and holy pools is a routine for the people of Varanasi. If Varanasi is to become a world heritage city, these things need to be stopped

1. For sustainable conservation of Ghats, the design of a healthy and resilient cultural landscape must be ensured. Reform and management strategies should be based on a systematic approach.
2. Documentation, preservation and revival of tangible and intangible heritage of Varanasi should be given priority. In this case, local people and organizations involved in the promotion business can be taken along.
3. Investments should be allocated for the development of the heritage assets that Varanasi has (such as the tourism industry) these historical and cultural assets, which distinguish Varanasi from other cities.
4. Protecting and maintaining heritage and its protection shall be continuously monitored, evaluated and prioritized where necessary
5. It is imperative to have the support of local residents, stakeholders and local politicians in developing heritage protection programs for heritage protection and development.
6. Urban development planning should follow specific guidelines, planning support systems for traditional areas.
7. To promote heritage to bring sustainable economic benefits to the local people and above all to create awareness among the citizens and promote their active participation through information and cultural programs on heritage issues through government channels.
8. Modernity should be avoided if heritage is in danger.

Concluding remarks:

Moral and ethical pollution caused by materialism and consumerism is replacing the old sense of values that supported sustainability. Over the past eight hundred years of foreign rule and cultural domination, beginning with the entry of Islam and ending with the British, the ancient Hindu value system has lost much of its essence. However, a massive awakening of old cultural values and awareness will promote a new consciousness of sustainability.

References:

1. Ramakrishnan, P. S. (2003). The sacred Ganga river-based cultural landscape. Museum International, 55(2), 7-17.
2. Pati, A., & Husain, M. (2023). People's perspectives on heritage conservation and tourism development: a case study of Varanasi. Built Heritage, 7(1), 17.
3. Singh, Rana P.B. 2004 g. The Ganga Riverfront in Varanasi, a Heritage Zone in Contestation. Context: Built, Living and Natural, vol. 1 (1), September: pp. 25-30.
4. Singh, Rana P.B. (2018), The Gaṅgā Ghāṭs, Varanasi(Kashi):The Riverfront Landscape, Varanasi.pp.1-77

5. Singh, R. P., & Rana, P. S. (2016). Riverfront Varanasi, India: Interfacing Contestation in Heritage Making. Contemporary Geographer, 1(1), 49-65.
6. Sinha, A. 2017.Ghats on The Ganga In Varanasi, India: A Sustainable Approach To Heritage Conservation, Landscape Research Record No. 6.pp158.
7. Praharaj, S. (2014). Conservation and Urban Renewal as a base for Sustainable Development in Historic Cities: A Case of Varanasi. Sustain. Constr. Tradit. visà-vis Mod. Archit., sayı April, 167-174
8. Feizabadi, T. N. (2015). A Critical Review of the Sustainability of Tourism in Varanasi. Department of Geography, Banaras Hindu University.
9. Eck, D. L. (1983) Banaras. The City of Light. New Delhi: Penguin India.
10. Shyju, P. J., Bhat, I. A., Myers, K, & Tanwar, N. (2020). Local stakeholders' perspectives on religious heritage and tourism development in Varanasi. International Journal of Tourism Cities, 6(3), 529-544.
11. Singh, Rana P.B. and Pal, Neelam 2012. Varanasi: Master Plans and Perspectives of
12. Heritagescapes. Radha Publications, New Delhi: pp. 97-115.
13. Maurya, R., Pandey, B. W., & Negi, V. S. (2017). Sustainable Urban Development Through Ghats: A Case Study of Varanasi, Uttar Pradesh. Sustainable Smart Cities in India: Challenges and Future Perspectives, 637-654.
14. https://uptourism.gov.in/en/post/Year-wise-Tourist-Statistics.

Environment, Development and Sustainability
(ISBN: 978-93-95847-87-2)

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ISBN 978-93-95847-87-2
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