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RESEARCH TRENDS IN SCIENCE AND TECHNOLOGY VOLUME V

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PREFACE

Welcome to the ever-expanding universe of "Research Trends in Science and Technology." In an era where innovation is the heartbeat of progress, this compilation serves as a compass, guiding us through the exciting terrain of cutting-edge discoveries and transformative advancements.

As we stand on the precipice of a new era, characterized by rapid technological evolution and groundbreaking scientific inquiry, this book encapsulates the zeitgeist of our quest for knowledge and mastery over the forces that shape our world. The preface, like a prologue to an epic tale, invites you to embark on a journey through the corridors of laboratories, the circuits of innovation, and the frontiers of the unknown.

The canvas upon which our exploration unfolds is vast and diverse, spanning disciplines from physics to computer science, from engineering marvels to the intricate tapestry of biological systems. In each chapter, you will encounter the tireless efforts of researchers and visionaries who push the boundaries of what is possible, challenging the status quo and reshaping the contours of our technological landscape.

This compendium is more than a collection of academic pursuits; it is a testament to the human spirit's insatiable curiosity and its relentless pursuit of understanding. From artificial intelligence to renewable energy, from nanotechnology to space exploration, the pages within are imbued with the spirit of inquiry that propels us forward into uncharted territories.

As you delve into the diverse realms of science and technology, we invite you to be a fellow traveler, a curious mind ready to explore the uncharted and embrace the unfolding future. "Research Trends in Science and Technology" beckons you to be a part of the ongoing narrative of human ingenuity, where every discovery is a beacon lighting the way to a brighter, more connected, and technologically advanced future. Join us as we navigate the currents of progress, where the synergy of science and technology shapes the destiny of generations to come.

Editors

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ADAPTING HOTEL RESERVATION SYSTEM TO THE PANDEMIC SCENARIO

Saptarshi Paul

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Abstract:

Hotel reservation systems have come a long way from lager books to digital systems. The digital reservation systems are available in both offline and online modes. While offline systems are good enough for small establishments, hotel chains and hospitality business rely on online systems that can reach out to anyone with access to the World Wide Web. The Covid-19 pandemic made its impact felt on all business, organized and stand-alone alike. One of the worst hit was the tourism and travel industry. Starting with the use of hotels as mandatory paid isolation centers to fully opening up to pre-covid standards, the reservation softwares had to go through lot of changes. In addition to considering full details and identification of guests, airlines and hotels were now needed to keep track of vaccination status and health history of the guests. Hotels were needed to provide these data to the respective health department to avoid spread of the virus. All these made necessary to make changes to the reservation software of hotels all over the world, thereby changing the rules of hospitability business to a great extent.

Keywords: Database, Covid19, Pandemic, Hotel reservation system, Vaccination.

Introduction:

The onslaught of the Covid-19 Pandemic has encouraged everyone and every system to look for alternative methods that allows for safe dealings of the day-to-day work. Along with business of all spheres, the tourism and hotel industry were also affected negatively. The start of restricted travelling got the hotel industry much needed respite leading to use of many hotels as paid Quarantine centers. With the advent of the Vaccinations air travelers and others were given certain relaxation from mandatory RAT and RT-PCR testing along with 14 days quarantine stay in isolated way. The Hotels in order to attract guests and provide assurance of safe-stay began to adapt themselves to the changing scenario. Changes were not only made to the rules for sanitization and cleaning but also in hotel booking systems and software. It is where the need for various modifications to the booking software started. It opened up the scope for altering the structure of the existing databases as well as creating new ones with compatible GUI. This paper discusses the development of such a hotel management system that books guests based on their vaccination status. This idea was used to develop an UG project by the students of the department of Computer Science, Assam University, Silchar.

Overview

In this paper "Adapting Hotel Reservation System to the Pandemic Scenario", we have tried to show how the information in hotels is managed. This is just an overview of management in hotels. It manages and maintains the records of customers, rooms, employees and drivers in the hotel. The project is aimed to maintain the day-to-day state of admission/vacation of Residents, List of employees, room details etc. Main objective of this project is to provide a solution for hotels to manage most their work using computerized processes during the covid19 situation. This application aims to help administrators to handle customer information, room allocation details, payment details etc. The rooms have categories like single bed, double bed etc. so their charges and records will be maintained accordingly. The application has been developed in a user-friendly interface, so that anyone can add, delete, update the entries and handle all the transactions easily. As a security we have provided Administrator username and password. The developed application is a desktop-based one that allows the hotel manager to handle all hotel activities online. Interactive GUI and the ability to manage various rooms, employees, drivers and customers make this system very flexible and convenient. This application gives administrators the power and flexibility to manage the entire system from a single online system. The system allows displaying available rooms in the system. Keeping the pandemic scenario in mind the application has provision for including vaccination data as well.

Detail analysis

a) Comparison with manual Systems: Many existing hotel management systems are pen-paper based. Hotel Management has to manage all records of customers and rooms on paper [1] [2]

b) Problem and weakness of Manual systems: Pen-paper based systems leads to tedious work and is time consuming. Human error and delays are common in such systems

c) Comparison with Existing Automated Systems: Current automated systems are all designed to handle pre-pandemic scenario bookings and are not able to keep track of vaccination status of guests.

Requirements for developing the system

Requirements of the user are such that the application should be able to allocate rooms automatically and maintain records of the customers [3]. System Requirements calls for the need of a database backup of application. This can be in the form of a Java supported framework for the system. Any current windows version can be opted as the operating system. Graphical User Interface, better known as GUI has to be developed that can hold the various features of the application under a single friendly and attractive umbrella. We opted for the following two choices as candidate systems: Abstract Windowing Toolkit or Swing. The Software requirements that were frozen are as follows:

- Operating System Windows10
- Front End Java, NetBeans
- Back End MySQL

The ultimate hardware requirements that were frozen are as follows

- Desktop PC or a Laptop
- Intel® CoreTM i3-6006U CPU @2.00GHz
- 4.00 GBRAM
- 64-bit operating system, x64 based processor
- 1024 x 768 monitor resolution
- Keyboard and Mouse
- Printer

Features included in the application

We have tried to include the features in the application as desired by most modern and current tourists [4].

- Hotel room bookings and reservation
- Vaccination data details
- Front desk operations
- Managing guest profile
- User privilege and security control
- Guest check-in check-out status
- Maintenance of hotel rooms.
- User friendly interface.

Challenges due to the pandemic

The Pandemic has created unforeseen challenges and risks that were never faced before. The Tourism industry including the hotel and resort chains had to make major changes to the existing rules to make the stay safe for their guests. This included sanitization and disinfectation. Vaccination and RAT/RT-PCR became the basic requirements to be included in hotels. The Covid19 pandemic has led to a major safety changeover for the tourism industry.

Design of the application

The design of the application has been done to accommodate the already desirable existing features [5] of a hotel management system with the advantage of inputting the vaccination status of guests.

E-R Diagram

As suggested by O'Fallon and Rutherford (2001), we have tried to maintain the structure of the Data base as by forming the detail E-R diagram and also following the principals of model structure in software engineering [6] The detail E-R diagram of any existing Hotel management system will look as in Fig. 1.

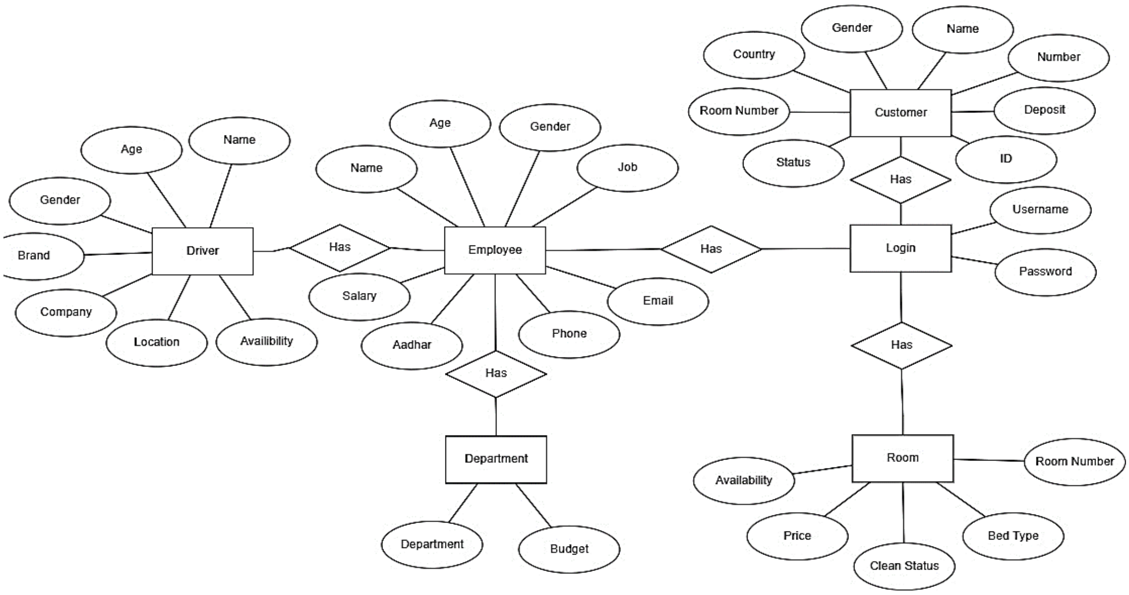

Fig. 1: E-R diagram of a regular hotel management system

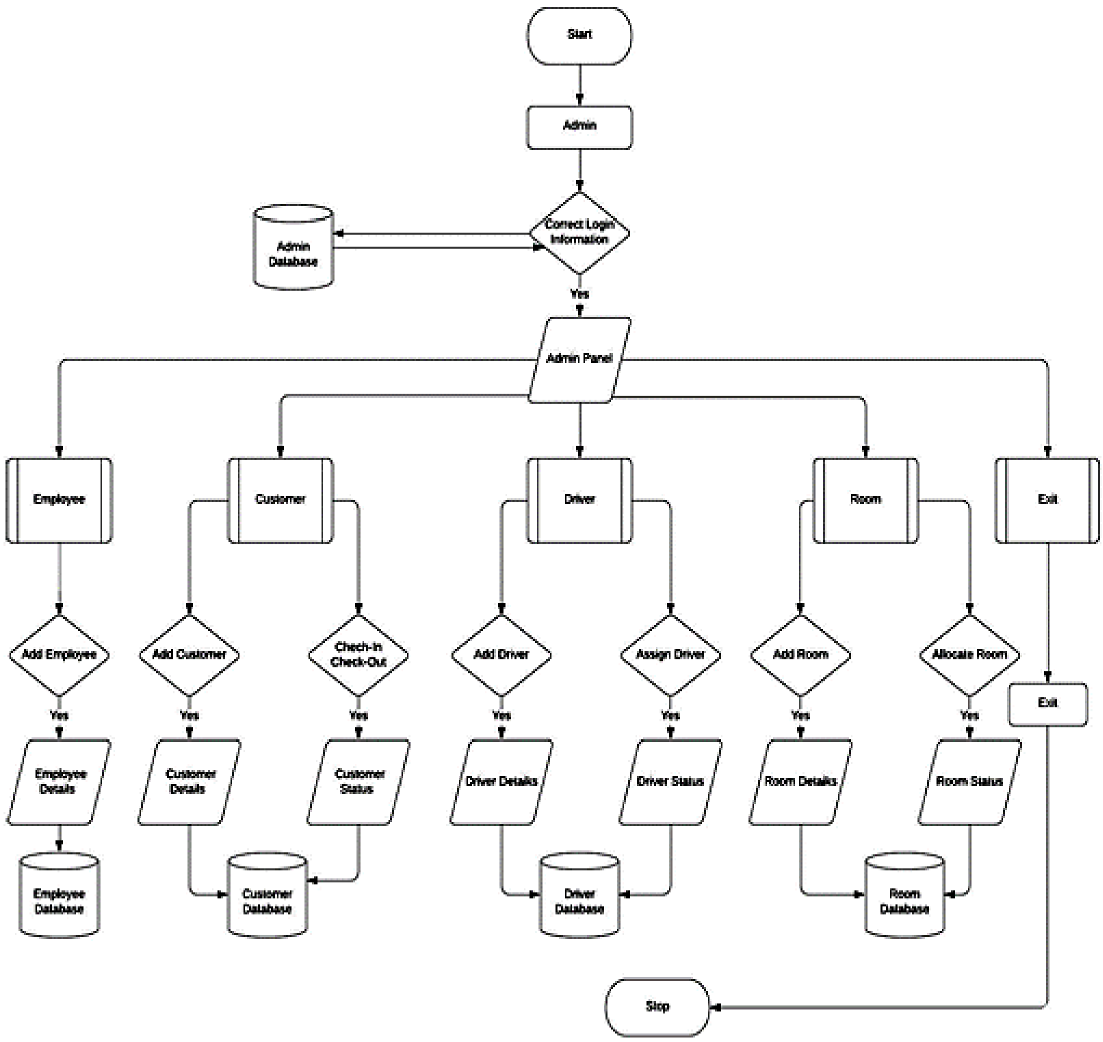

Fig. 2: Class diagram of the developed Hotel Management System

Screen shots of the application

Fig. 3: The Welcome page of the Application

The Total Layout as shown in the Fig2 and Fig 4 includes the basic features of any standard hotel management system with extra provisions of vaccination information of guests, staff and drivers

Fig. 4: General Layout for a Hotel Management System

The new customer form as depicted above shows that there are nine parameters for recording the details of the new customers/guests, they are as follows:

- Photo Identification proof (ID)
- Photo ID card number (NUMBER)
- Name
- Gender

- Country
- Allocated Room Number
- Checked in
- Deposit
- Vaccination status

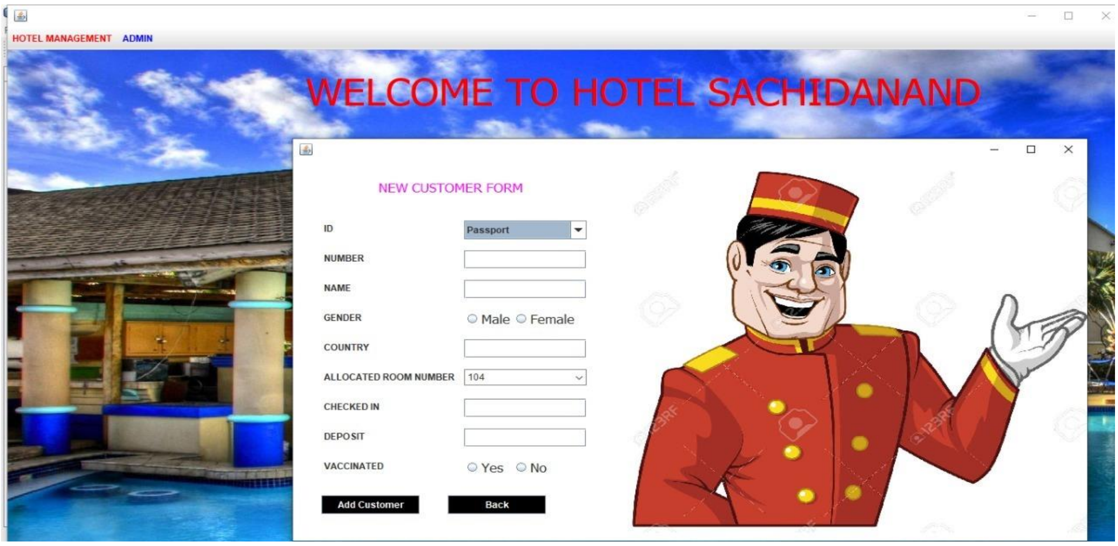

Fig. 5: New customer form with option for recording Vaccination information

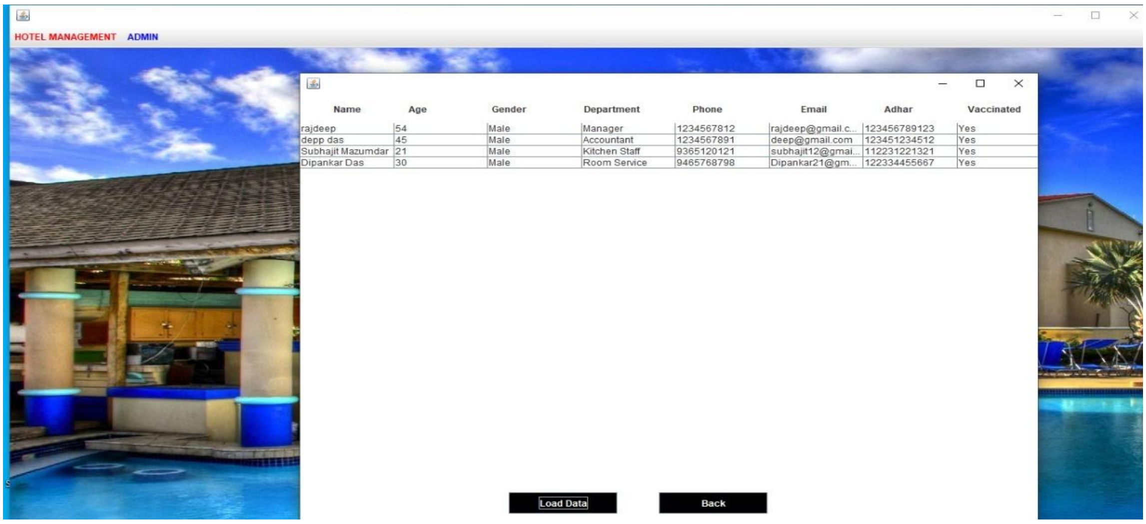

Fig. 6: Data of the staff in the database (Viewed through the GUI)

In the above figure we see that there are eight columns that records the details of the hospital staff, they are as follows:

- Name
- Age
- Gender
- Department
- Phone

- Email
- Addhar
- Vaccination status

Database structure of the system

We have tried to maintain the database of the project as simple as possible [7].the main idea was to develop the project keeping in mind the recent pandemic scenario where all the rooms need to be sanitized and cleaned. So, the room details as shown in fig 7. Highlights the following:

- Room Number
- Availability
- Status (cleaned/ sanitized or not)
- Price
- Bed type

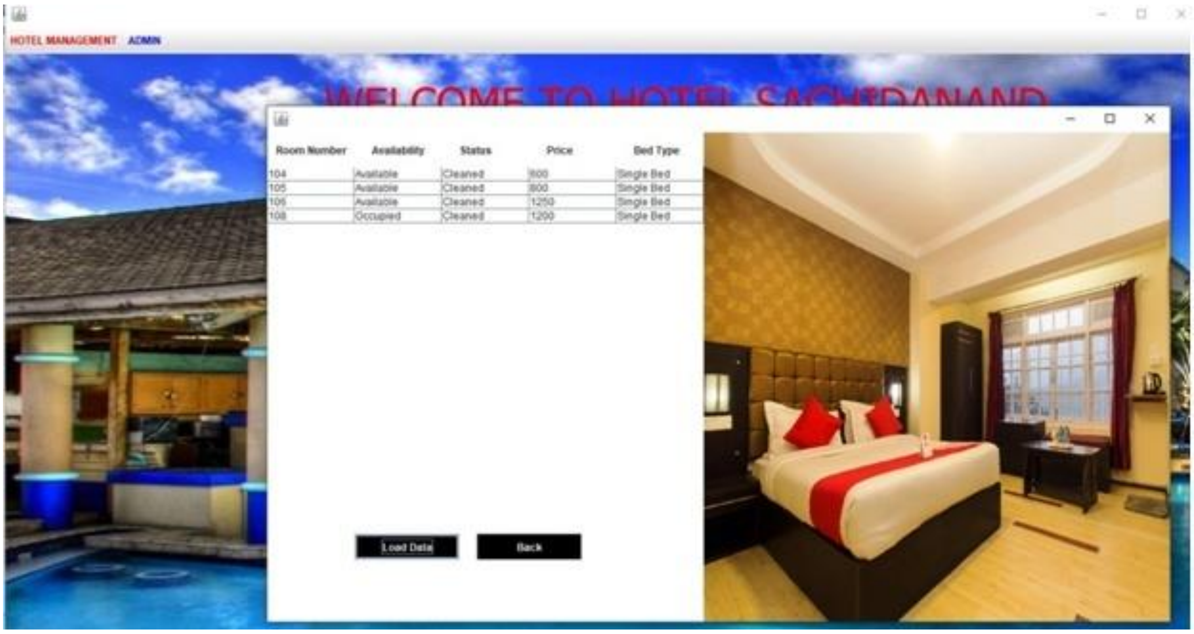

Fig. 7: Status of room (Cleaned and sanitized), displayed as "cleaned"

Advantage of the application

The application has been developed during the various phases of the Covid19 lockdown. It was developed when hotels were not only serving regular guests but also were being used as paid and government subsidized quarantine centers. The advantages of the developed application can be summarized as follows.

- Facility for updating of vaccination status.
- Shorter time for user to search rooms.
- The application can calculate exact cost of rooms for requested number of days.
- Saving of organization resources and expenses.

- Effective application leading to time and cost savings.
- Authorization facilities lead to restrict illegal access creating a secure system.
- Control is entirely in the hands of the administrator with different level of abstractions for others

Conclusion and future works:

The developed system is an adaptation to the existing Hotel Management system and is a stop-gap to address the concerns of the pandemic scenario. Future systems can be developed to trace the guests travel history along with various Health concerns such as comorbidity status. Future Hotel management applications can also be linked with popular apps like COWIN and others to keep track of guests' movement from affected areas and countries.

Acknowledgement:

This application was successfully completed and implemented with the active participation of Mr. Panchadeep Majumder, Mr. Dipankar Das, Mr. Subhajit Majumder, Mr. Tapadhir Das and Mr. Rohit Rishi, UG students of Department of Computer Science, Assam University, Silchar.

References:

1. Der Wagen, L. V. (2007). *Hospitality Management: Strategy & Operations, 2nd Edition*. Pearson Education Australia.
2. Fernández, B. E., & Yuan, X. (1999). An Analysis Pattern for Reservation and Use of Reusable Entities. Available at https://www.semanticscholar.org
3. Jayawardana, C., *et al.* (2013). Trends in the international hotel industry. *Worldwide Hospitality and Tourism Themes, 5*(2), 151-163. https://doi.org/10.1108/17554211311314100
4. Latin, W. L. (2011). *Modern Hotel Management*. W.H. Freeman. [Accessed: 2021/06/15]
5. Hotel Management Case Study. (2010). Available at: http://www.scribd.com/doc/27927992/Hotel-Management-Case-Study
6. Sommervile, I. (2008). *Software Engineering 8th Edition*. Pearson Education.
7. Navathe, E. (2008). *Fundamentals of Database Systems, 3rd Edition*. Pearson Education.
8. Jeffrey, S. H. (2003). Strategic analysis for the hospitality industry. *The Cornell Hotel and Restaurant Administration Quarterly*, *44*(2), 139-152.
9. O'Fallon, M. J., & Rutherford, D. G. (2001). *Hotel Management and Operations*. John Wiley and Sons.
10. Ramakrishna, R. (2003). *Database Management System, 3rd Edition*. McGraw-Hill.

TELEPHARMACY: REMOTE HEALTHCARE ACCESS AND MEDICATION MANAGEMENT

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Abstract:

"Telepharmacy is a growing field in healthcare that leverages technology to provide remote access to pharmaceutical services and medication management. This innovative approach to healthcare delivery allows patients to receive expert pharmacy care and medication consultations from the comfort of their homes, eliminating geographic barriers and increasing healthcare accessibility. Telepharmacy, an emerging paradigm in healthcare, is revolutionizing the way patients access pharmaceutical services and manage their medications remotely. This chapter delves into the transformative potential of telepharmacy, shedding light on its multifaceted impact on healthcare delivery and medication management. This chapter explores the concept of telepharmacy, its benefits, and challenges, as well as its impact on improving medication adherence, chronic disease management, and overall patient outcomes. The utilization of telepharmacy services can play a crucial role in transforming the healthcare landscape by making healthcare more accessible and convenient for patients, particularly in underserved or rural areas. Telepharmacy promotes equitable access, patient empowerment, and efficient medication management. By harnessing the potential of remote pharmaceutical services, healthcare can be more patient-centric, cost-effective, and inclusive.

Keywords: Teleconsultation, Remote healthcare, Virtual care, Telemedicine apps.

Introduction:

Telemedicine is a rapidly evolving field in healthcare that leverages modern technology to provide medical services and consultations at a distance. It has transformed the way patients and healthcare providers interact, making healthcare more accessible, convenient, and efficient. Telemedicine encompasses a wide range of medical services, including consultations, diagnosis, treatment, monitoring, and education, all conducted remotely through digital communication channels. The core components of telemedicine include videoconferencing, secure messaging, and digital health monitoring devices. These tools enable patients and healthcare professionals to communicate and exchange health information in real-time, transcending geographical barriers.

Telemedicine can be applied to various medical specialties, such as primary care, specialty consultations, mental health services, and even prescription management through telepharmacy.
The growth of telemedicine has been accelerated by several factors, including advances in technology, increased internet connectivity, and the need for more accessible healthcare, especially in underserved or remote areas. It offers numerous benefits, such as reducing travel time and costs for patients, improving healthcare access, and providing timely care for both acute and chronic conditions. Telemedicine has played a significant role in healthcare delivery during public health crises, such as the COVID-19 pandemic, by allowing patients to receive care while minimizing the risk of virus transmission. The benefits of telepharmacy extend beyond geographical reach. Patients with chronic conditions can experience improved disease management through personalized medication regimens and ongoing support. Medication adherence is bolstered as patients receive timely reminders and guidance, reducing the risk of adverse events. Telemedicine is reshaping the future of healthcare by making healthcare more convenient, accessible, and responsive to the needs of patients, ultimately improving overall healthcare outcomes and experiences.

Privileges of telemedicine:

1. Increased accessibility:

Telemedicine breaks down geographical barriers, ensuring that individuals in remote or underserved areas can access healthcare services without the need for extensive travel. Telemedicine improves accessibility in healthcare by Overcoming Geographic Barriers, Reducing Travel Burdens, Expanding Healthcare Options, Emergency Consultations, Eliminating Wait Times, Flexible Scheduling, Preventive Care, Chronic Disease Management, Access to Specialists, International Consultations, Healthcare Disparities.

2. Remote healthcare delivery:

The advantages of remote healthcare delivery in telemedicine are numerous and have a significant impact on healthcare accessibility, efficiency, and patient outcomes. Remote healthcare delivery provides numerous advantages Increased Accessibility, Convenience, Reduced Waiting Times, Enhanced Continuity of Care, Improved Patient Engagement, Cost Savings, Minimized Infection Risk, Remote Monitoring, Healthcare Integration, International Telemedicine, Educational Opportunities, Improved Medication Management.

3. Health monitoring:

Telemedicine often involves the use of digital health monitoring devices, allowing for the remote monitoring of vital signs and chronic conditions. Health monitoring in telemedicine involves the use of digital devices and technology to track and manage a patient's health remotely. It plays a vital role in preventive care, chronic disease management, and early intervention. Some details of health monitoring in telemedicine are Remote Vital Sign

Monitoring, Medication Adherence, Remote Patient Education, Early Detection of Abnormalities, Data Integration, Customized Care Plans.

4. Teletherapy and mental health:

Telemedicine extends to mental health services, providing remote therapy and counseling for individuals in need of mental health support. Teletherapy refers to the delivery of mental health services, such as counseling, psychotherapy, and psychological support, through telecommunication technologies. It is typically used for addressing various mental health concerns, including anxiety, depression, post-traumatic stress disorder, and more. Teletherapy sessions often take place through video calls, phone calls, or secure messaging platforms.

Teletherapy can offer increased accessibility to mental health care, as patients can receive treatment from the comfort of their own homes. The relationship between teletherapy and telepharmacy can be seen in scenarios where patients require both mental health support and medication management. For example, patients with conditions like depression or anxiety may benefit from teletherapy sessions to address their mental health concerns, while telepharmacy services can ensure that they receive the necessary medications and guidance related to their treatment.

5. Real-time communication:

It facilitates real-time communication between patients and healthcare providers through video conferencing secure messaging, and telepharmacy services. Real-time communication plays a critical role in telepharmacy, ensuring effective and timely interactions between pharmacists and patients. Some relevant real-time communication methods and technologies in the context of telepharmacy are Video Conferencing, Phone Calls, Secure Messaging Platforms, Live Chat, Mobile Apps, Telemedicine Platforms, Virtual Prescription Verification, Medication Synchronization Reminders, Emergency Consultations, Remote Medication Reviews and Flexible Scheduling.

Telemedicine is instrumental in international healthcare, allowing patients to seek second opinions or specialized care from experts worldwide. As healthcare disparities remain a concern, telemedicine serves to reduce these disparities by providing access to care for underserved populations and eliminating geographical and logistical barriers to healthcare. Privacy and security of patient data are paramount, with telemedicine platforms complying with healthcare regulations and standards. As insurance and reimbursement policies for telemedicine services continue to evolve, they impact its adoption and accessibility. In essence, telemedicine is reshaping the healthcare landscape. It prioritizes patient-centered care, offering convenient, personalized, and timely healthcare experiences. With ongoing innovations, including virtual reality, AI-driven diagnostics, and remote surgeries, telemedicine is set to continually transform the way healthcare services are delivered and received, making healthcare more accessible and patient-centric.

Conclusion:

Telemedicine represents a transformative force in the field of healthcare, offering a myriad of benefits and opportunities for both patients and providers. This innovative approach leverages technology to make healthcare more accessible, convenient, and patient-centered, ultimately reshaping the way medical services are delivered and received. Telemedicine provides a wide range of services, including remote consultations, mental health support, chronic disease management, and more. It offers flexibility in communication methods, enabling real-time and asynchronous interactions, which can be vital in accommodating the diverse needs of patients. Telemedicine's rapid adoption during the crisis has further accelerated its integration into the healthcare system, highlighting its importance in emergency preparedness and response. As technology continues to advance, telemedicine is poised for even more profound innovations. Virtual reality, artificial intelligence, and remote surgical procedures promise new frontiers in healthcare delivery. Furthermore, the ongoing evolution of telemedicine is essential in reducing healthcare disparities and reaching underserved populations, ultimately striving for equitable access to care. Telemedicine offers a patient-centric, cost-effective, and convenient approach to healthcare. It promotes preventive care, enhances chronic disease management, and enables immediate access to healthcare expertise. With its ever-expanding reach and potential for technological innovations, telemedicine is reshaping the healthcare landscape, improving patient outcomes, and making healthcare more accessible to individuals around the world. Its significance in modern healthcare cannot be understated, and it continues to evolve to meet the changing needs of the healthcare industry and its patients.

References:

1. Gajarawala, S. N., & Pelkowski, J. N. (2021). Telehealth benefits and barriers. *The Journal for Nurse Practitioners, 17*(2), 218-221.
2. Rai, R. K., Pandey, A., Gupta, A., Singh, G., & Rawat, J. (2022). Use of telemedicine in evaluation of pediatric surgical patients in COVID-19 time. *Annals of the National Academy of Medical Sciences (India), 58*(03), 164-167.
3. Williams, A. M., Bhatti, U. F., Alam, H. B., & Nikolian, V. C. (2018). The role of telemedicine in postoperative care. *Mhealth, 4*.
4. Ben-Pazi, H., Browne, P., Chan, P., Cubo, E., Guttman, M., Hassan, A., Shalash, A. (2018). The promise of telemedicine for movement disorders: an interdisciplinary approach. *Current Neurology and Neuroscience Reports, 18*, 1-10.

5. Sandberg, C. E., Knight, S. R., Qureshi, A. U., & Pathak, S. (2019). Using telemedicine to diagnose surgical site infections in low- and middle-income countries: systematic review. *JMIR mHealth and uHealth, 7*(8), e13309.
6. Khairat, S., Haithcoat, T., Liu, S., Zaman, T., Edson, B., Gianforcaro, R., & Shyu, C. R. (2019). Advancing health equity and access using telemedicine: a geospatial assessment. *Journal of the American Medical Informatics Association, 26*(8-9), 796-805.
7. Reddy, L. K., Madithati, P., Narapureddy, B. R., Ravula, S. R., Vaddamanu, S. K., Alhamoudi, F. H., Chaturvedi, S. (2022). Perception about Health Applications (Apps) in Smartphones towards Telemedicine during COVID-19: A Cross-Sectional Study. *Journal of Personalized Medicine, 12*(11), 1920.
8. Young, J. D., Abdel-Massih, R., Herchline, T., McCurdy, L., Moyer, K. J., Scott, J. D., Siddiqui, J. (2019). Infectious Diseases Society of America position statement on telehealth and telemedicine as applied to the practice of infectious diseases. *Clinical Infectious Diseases, 68*(9), 1437-1443.
9. Gonçalves, R. L., Pagano, A. S., Reis, Z. S., Brackstone, K., Lopes, T. C., Cordeiro, S. A., Batchelor, J. (2023). Usability of Telehealth Systems for Noncommunicable Diseases in Primary Care From the COVID-19 Pandemic Onward: Systematic Review. *Journal of Medical Internet Research, 25*, e44209.

UNLOCKING THE MYSTERY OF WILSON DISEASE: A COMPREHENSIVE GUIDE

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Abstract:

This chapter provides an in-depth exploration of Wilson disease, a rare but significant inherited disorder characterized by copper metabolism abnormalities. We delve into the epidemiology, genetic basis, clinical Presentation and treatment for this condition. Wilson disease affects multiple organ systems, and understanding its complexities is essential for healthcare providers, patients, and researchers.

Keywords: Copper Metabolism Disorder, Hepatolenticular Degeneration, ATP7B, Gene Copper Accumulation Liver, CirrhosisKayser-Fleischer RingsCopperChelation, Therapy

Introduction:

Wilson's disease is a genetic disorder in which excess copper builds up in the body. Symptoms are typically related to the brain and liver. Liver-related symptoms include vomiting, weakness, fluid build-up in the abdomen, swelling of the legs, yellowish skin, and itchiness. Brain-related symptoms include tremors, muscle stiffness, trouble in speaking, personality changes, anxiety, and psychosis [1].

Wilson's disease is caused by a mutation in the Wilson disease protein (ATP7B) gene. This protein transports excess copper into bile, where it is excreted in waste products. The condition is autosomal recessive; for people to be affected, they must inherit a mutated copy of the gene from both parents. Diagnosis may be difficult and often involves a combination of blood tests, urine tests and a liver biopsy. Genetic testing may be used to screen family members of those affected. Wilson's disease is typically treated with dietary changes and medication. Dietary changes involve eating a low-copper diet and not using copper cookware. Medications used include chelating agents, such as trientine and d-penicillamine, and zinc supplements. Complications of Wilson's disease can include liver failure, and kidney problems. A liver transplant may be helpful to those for whom other treatments are not effective or if liver failure occurs.

Wilson's disease occurs in about one in 30,000 people. Symptoms usually begin between the ages of 5 and 35 years. It was first described in 1854 by German pathologist Friedrich Theodor von Frerichs and is named after British neurologist Samuel Wilson [2].

Pathophysiology:

Wilson Disease is a rare genetic disorder characterized by the abnormal accumulation of copper in various tissues throughout the body. The pathophysiology of this condition revolves around disruptions in copper metabolism, primarily attributed to a mutation in the ATP7B gene, which plays a pivotal role in copper transport [3].

Genetic basis:

The journey into the pathophysiology of Wilson Disease begins at the genetic level. The ATP7B gene, located on chromosome 13, encodes a copper-transporting P-type ATPase. This enzyme is crucial for regulating copper levels in the body by facilitating its incorporation into ceruloplasmin and its excretion through the bile.

Copper accumulation:

In individuals with Wilson Disease, a mutation in the ATP7B gene impairs the normal functioning of this copper-transporting enzyme. As a result, copper accumulates in various tissues, particularly the liver, brain, and cornea.

Hepatic manifestations:

The liver, being a central hub for copper metabolism, bears the brunt of Wilson Disease. Copper buildup in hepatocytes leads to hepatocellular apoptosis and necrosis. This triggers an inflammatory response and can progress to fibrosis and cirrhosis, compromising the liver's ability to function adequately.

Copper redistribution:

Beyond the liver, the excess copper spills into the bloodstream, leading to its deposition in other organs. The central nervous system, kidneys, and cornea are particularly susceptible. Copper buildup in the brain contributes to neurological symptoms, including tremors, dystonia, and cognitive impairment.

Impaired copper excretion:

The ATP7B mutation not only hampers copper incorporation into ceruloplasmin but also impedes its excretion through the bile. Copper, instead of being efficiently transported to the bile canaliculi, is retained within hepatocytes, perpetuating the cycle of copper accumulation.

Systemic consequences:

The systemic repercussions of Wilson Disease extend beyond the liver and nervous system. Copper, an essential trace element, becomes a toxic entity when dysregulated. Its accumulation in extrahepatic tissues contributes to oxidative stress, inflammation, and cellular damage.

Variable presentation:

One intriguing aspect of Wilson Disease is its variable clinical presentation. Some individuals may remain asymptomatic for an extended period, while others may exhibit acute hepatic failure or neurological symptoms. The age of onset and the severity of manifestations are influenced by the specific ATP7B gene mutations [4].

Etiology:

Wilson disease is caused by mutations in the ATP7B gene, located on chromosome 13. ATP7B encodes a copper-transporting P-type ATPase responsible for transporting copper within the body and excreting excess copper into bile. Mutations in this gene result in impaired copper transport, leading to copper accumulation and release into the bloodstream. Excess copper can then deposit in various organs, causing tissue damage [5].

Epidemiology:

Wilson disease is a relatively rare disorder, with an estimated prevalence of 1 in 30,000 individuals worldwide. The exact prevalence may vary by region and population. It is more frequently observed in populations with a higher degree of consanguinity. The disease typically presents in individuals aged 5 to 35 years, although onset can occur at any age. Awareness of its epidemiological characteristics is crucial for healthcare providers to consider Wilson disease in their differential diagnoses.

Genetic basis:

This gene encodes a copper-transporting P-type ATPase responsible for copper transport and excretion. Mutations in ATP7B lead to impaired hepatic copper transport, resulting in copper buildup within the liver and subsequent release into the bloodstream, where it can deposit in various organs, including the liver, brain, and cornea. This section explores the genetic basis of the disease and the consequences of these mutations on copper metabolism [6].

Complications:

Wilson Disease, a rare genetic disorder characterized by abnormal copper metabolism, brings forth a myriad of complications that extend beyond the initial copper accumulation in various tissues. Understanding these complications is crucial for comprehensive management and improved outcomes for individuals grappling with this condition [7].

1. Hepatic complications:

Cirrhosis: Progressive copper buildup in the liver can lead to cirrhosis, a condition characterized by scarring and impaired liver function.

Hepatic failure: In severe cases, the liver's capacity to function adequately may be compromised, resulting in hepatic failure.

2. Neurological manifestations:

Tremors and Dystonia: Copper accumulation in the brain can manifest as tremors and involuntary muscle contractions (dystonia).

Psychiatric symptoms: Cognitive impairment, mood disorders, and personality changes may occur due to copper's impact on neural function.

3. Renal Complications:

Renal tubular damage: Copper deposition in the kidneys can lead to tubular damage, impacting renal function over time.

4. Ophthalmological Issues:

Kayser-Fleischer rings: Copper buildup in the cornea results in the characteristic golden-brown rings, known as Kayser-Fleischer rings.

Vision impairment: In advanced cases, copper deposition may affect the optic nerve, leading to vision impairment.

5. Hematological abnormalities:

Anemia: Copper's influence on iron metabolism can contribute to the development of anemia.

6. Joint issues:

Arthritis: Copper accumulation in joints can lead to arthritis, causing pain and discomfort.

7. Endocrine disturbances:

Pancreatic dysfunction: Copper deposition in the pancreas may contribute to insulin insufficiency and diabetes.

Menstrual irregularities: Wilson Disease can disrupt hormonal balance, leading to menstrual irregularities in affected individuals.

8. Psychosocial Impact:

Depression and anxiety: Chronic nature of the disease, coupled with its impact on daily life, can contribute to psychological distress.

Social isolation: Coping with the symptoms and lifestyle modifications may lead to social isolation, affecting the patient's mental well-being.

9. Risk of copper toxicity during treatment:

Neurological deterioration: Rapid mobilization of copper during treatment can, paradoxically, lead to neurological deterioration in some cases.

Hemolysis: Treatment with certain medications may induce hemolysis, necessitating careful monitoring.

10. Increased susceptibility to infections:

Immunosuppression: Chronic liver disease and the impact of copper on immune function can increase susceptibility to infections.

Clinical manifestations:

Signs and symptoms of Wilson Disease: Recognizing the Indicators of Copper Overload which are follows:[8]

Hepatomegaly: Enlargement of the liver due to the accumulation of copper.

Jaundice: Yellowing of the skin and eyes, indicative of liver dysfunction.

Abdominal pain: Discomfort or pain in the abdominal region.

Tremors: Fine, rhythmic tremors, especially noticeable in the hands.

Dystonia: Involuntary muscle contractions leading to abnormal postures.
Dysarthria: Impaired muscle control affecting speech, resulting in slurred or difficult-to-understand speech.
Difficulty swallowing: Coordination issues in the muscles involved in swallowing.
Personality changes: Altered behavior and personality.
Depression and anxiety: Mood disorders and heightened anxiety levels.
Cognitive impairment: Difficulties with concentration, memory, and cognitive functions.
Easy bruising: Impaired clotting factors due to liver dysfunction leading to easy bruising.
Palmar erythema: Reddening of the palms due to altered blood flow.
Menstrual irregularities: Hormonal imbalances causing irregular menstrual cycles.
Pancreatic dysfunction: Copper deposition impacting insulin secretion.
Arthritis: Joint pain and inflammation due to copper accumulation.

Diagnosis:

Diagnosing Wilson disease requires a combination of clinical evaluation, laboratory tests, imaging studies, and genetic testing. Key diagnostic tools include: [9]

Liver function tests: These may reveal elevated liver enzymes and impaired liver function.

Serum ceruloplasmin: Reduced levels of ceruloplasmin, a copper-transporting protein, are a common finding in Wilson disease.

Liver biopsy: This may be performed to assess the extent of liver damage and confirm copper accumulation.

Management:

Managing Wilson disease is essential to prevent further organ damage. Treatment aims to reduce copper levels and prevent further copper buildup. Key management strategies include: [10]

Copper chelation therapy: This involves using medications like D-penicillamine or trientine to bind excess copper and facilitate its excretion from the body.

Dietary modifications: Reducing dietary copper intake by avoiding high-copper foods, such as organ meats, shellfish, and chocolate, can help manage copper levels.

Zinc therapy: Zinc supplements can be used to block copper absorption in the intestines.

Liver transplantation: In severe cases of liver failure, liver transplantation may be necessary to replace the damaged liver with a healthy one.

Prognosis:

The prognosis of Wilson disease varies depending on the timeliness of diagnosis and initiation of treatment. When managed effectively, many patients can lead relatively normal lives. However, without treatment, Wilson disease can be life-threatening. Early diagnosis and appropriate treatment are pivotal in improving the prognosis.

Prognosis and future directions:

Early diagnosis and appropriate treatment are pivotal in improving the prognosis of individuals with Wilson disease. When managed effectively, many patients can lead relatively normal lives. Ongoing research is focused on developing more targeted therapies, enhancing genetic counselling, and improving our understanding of the disease's long-term outcomes. [11]

Conclusion:

Wilson disease is a complex, multi-system disorder with hepatic, neurological, and ophthalmological manifestations. A better understanding of its epidemiology, genetic basis, clinical presentation, diagnosis, and management is essential for healthcare providers, patients, and researchers. As the field of medical genetics and therapeutics advances, the prospects for individuals living with Wilson disease continue to improve, offering hope for better outcomes and a higher quality of life for those affected by this rare condition.

References:

1. Członkowska, A., Litwin, T., Dusek, P., Ferenci, P., Lutsenko, S., Medici, V., Schilsky, M. L. (2021). Wilson disease. *Nature Reviews Disease Primers, 4*(1), 21.
2. Mulligan, C., & Bronstein, J. M. (2020). Wilson disease: an overview and approach to management. *Neurologic Clinics, 38*(2), 417-432.
3. Ferenci, P. (2020). Pathophysiology and clinical features of Wilson disease. *Metabolic Brain Disease, 19*, 229-239.
4. Ala, A., & Schilsky, M. L. (2022). Wilson disease: pathophysiology, diagnosis, treatment, and screening. *Clinics in Liver Disease, 8*(4), 787-805.
5. Gitlin, J. D. (2021). Wilson disease. Etiology of Wilson Diseases. *125*(6), 1868-1877.
6. Behari, M., & Pardasani, V. (2022). Genetics of Wilson's disease. *Parkinsonism & Related Disorders, 16*(10), 639-644.
7. Gunjan, D., Nadda, N., Kedia, S., Nayak, B., Paul, S. B., Gamanagatti, S. R., & Acharya, S. K. (2023). Hepatocellular carcinoma: an unusual complication of longstanding Wilson disease. *Journal of Clinical and Experimental Hepatology, 7*(2), 152-154.
8. Dzieżyc-Jaworska, K., Litwin, T., & Członkowska, A. (2021). Clinical manifestations of Wilson disease in organs other than the liver and brain. *Annals of Translational Medicine, 7*(Suppl 2).
9. Schilsky, M. L. (2022). Wilson disease: clinical manifestations, diagnosis, and treatment. *Clinical Liver Disease, 3*(5), 104-107.
10. Ferenci, P. (2021). Diagnosis of Wilson disease. *Handbook of Clinical Neurology, 142*, 171-180.
11. Brewer, G. J., & Askari, F. K. (2022). Wilson's disease: clinical management and therapy. *Journal of Hepatology, 42*(1), S13-S21.

GREEN SYNTHESIS AND CHARACTERIZATION OF BENZOIN CATALYZED BY THIAMINE HYDROCHLORIDE

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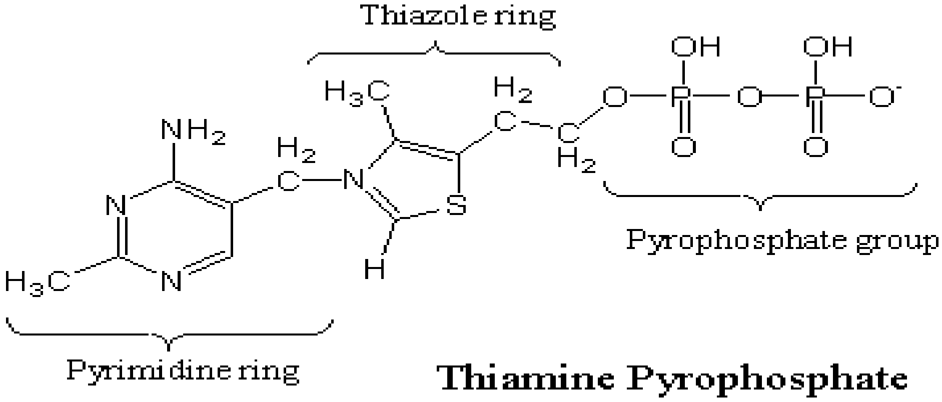
Abstract:

Thiamine hydrochloride as an efficient catalyst for the synthesis of substituted benzoin using anisaldehyde, benzaldehyde and p-tolualdehyde as starting materials. The desired products were obtained in proportionate yields. The assistance of thiamine hydrochloride has been confirmed by using thin layer chromatographic (TLC) studies. The newly synthesized product was characterized by FT-IR, ^{1}H-NMR and ^{13}C-NMR spectroscopy. The developed method is valid for substituted aldehyde, thus it constitutes a general synthetic method for these kinds of compounds. In all the cases aromatic aldehydes containing electron-withdrawing groups gave shorter time than that with electron-donating groups. The salient features of the present synthetic protocol are excellent yields, mild reaction conditions, high atom economy, easy isolation of products, eco-friendliness, reusability and recyclability of the catalyst.

Keywords: Green synthesis, Thiamine hydrochloride, Aromatic aldehyde, 4,4'-dimethylbenzoin

Introduction:

Vitamin B1, thiamine, as its pyrophosphate derivative (shown below), is a coenzyme universally present in all living systems. It was originally discovered as an essential nutrient required to prevent the human disease beriberi, which affects the peripheral nervous system. Symptoms include pain and paralysis of the extremities, emaciation, or swelling of the body. The disease is still common in the far East.



Thiamine Pyrophosphate

In biochemical terminology, thiamine functions as a coenzyme, a biological molecule that assists in enzymatic reactions. In most cases, coenzymes are directly involved in the biochemical reaction that the enzyme catalyzes since they usually bind the substrate (reactant) for the reaction. Without the coenzyme, no reaction will take place. The enzyme, which is the biological catalyst, binds the substrate, controlling stereochemistry, energetics and entropic factors. As indicated above, the vitamin thiamine is required for many enzymatic reactions. In the current experiment, we will use thiamine to catalyze the reaction of benzaldehyde into benzoin. Thiamine, functioning as a coenzyme, can be used for the non-oxidative decarboxylations of α-keto acids, the oxidative decarboxylations of α-keto acids and the formation of α-hydroxy ketones. Most biochemical processes are no more than organic chemical reactions carried out under special conditions. Like most reactions in organic chemistry, many biochemical reactions can now be explained using familiar reaction mechanisms. To enhance reactivity, and to be stereoselective, enzymes are used to bind the substrate in a manner that allows only a single reaction, with stereoselectivity to occur. In addition, enzymatic reactions can be carried out in mild conditions and at moderate pH values. Reactions which involve hydrophobic (lipid loving or water hating) conditions that might not otherwise be possible in an aqueous, biological environment.

The implementation of green synthetic methodologies to facilitate the preparation of specific molecules is an intense area of research. In this regard, efforts have been constantly made to introduce new methodologies that are efficient and more compatible with the environment. One of the most desirable approaches to address this challenge is a search for commonly employed green catalyst from various health and environmental reasons [1, 2]. "Green chemistry" is still an emerging field that strives to work at the molecular level to achieve sustainability. The field has received widespread interest in the past decade due to its ability to harness chemical innovation to simultaneously meet environmental and economic goals [3].

As there has been a tendency to avoid hazardous substances in green chemistry, organic reactions carrying out in the absence of conventional organic solvents have received more attention. Among various reactions, the solventless benzoin condensation of benzaldehyde has been reported to proceed efficiently using sodium methoxide and several imidazolium based ionic liquids as catalyst under microwave irradiation [4]. Employing imidazolium-based ionic liquid, 1-octyl-3-methylimidazolium bromide, as solvent/catalyst under ultrasonic irradiation also provided a quantitative yield of benzoin. In addition to ionic liquids, water is a greener alternative solvent for organic reactions [5-7]. Accordingly, benzoin condensations catalysed by N,N-dialkylbenzimidazolium salts in the presence of amine bases or NaOH in water gives_α-hydroxy ketones in moderate to excellent yields [8].

α-Hydroxy ketones are important building blocks for the synthesis of several drugs and natural products [9-11]. For this reason, many chemical methods for their synthesis are described in literature [12-15]. The cyanide ion-catalyzed condensation of aromatic aldehydes to the corresponding benzoins has great synthetic utility. According to a well documented classical benzoin condensation mechanism, cyanide ion catalyzed generation of acyl anion is the key step in this transformation [16]. But, as cyanide has great toxicity, it is essential to promote green synthetic method for the preparation of benzoins. Many improvements have been made for the symmetrical benzoin condensation utilizing thiazolium and triazolium salts [17, 18]. But syntheses of unsymmetrical benzoins, under traditional conditions, have problems associated with the formation of four possible benzoins, two of them being isomeric. Furthermore, some of the reported methods suffer from drawbacks such as longer reaction time, lower yields, expensive catalysts, harsh conditions or complexity of work-up.

So, the development of a milder, simpler, greener and more efficient procedure for the synthesis of symmetrical and unsymmetrical benzoin is highly desirable. Thiamine hydrochloride as a catalyst has been considered as a clean and useful protocol in organic synthesis as compared with traditional methods. Herein, we wish to report a general, efficient and eco-friendly method for the synthesis of benzoin catalysed by thiamine hydrochloride and its spectral characterization.

Materials and Methods:

All the chemicals and reagents were purchased from Merck Chemicals, India and were used without further purification. Reactions were monitored by TLC. Infrared spectrum was recorded using KBr pellet in nujol mull on Perkin-Elmer RX-I spectrophotometer in the range of 4000-500 cm^{-1}. Nuclear Magnetic Resonance (^{1}H-NMR) spectrum of newly synthesized products has been scanned on FT-NMR-Cryo magnet spectrum 400 MHz (Bruker) spectrometer. Also ^{13}C-NMR has been carried out at 75 MHz spectrometer. Chemical shifts were reported in ppm downfield from internal TMS standard. Melting points were determined with an electro thermal melting point apparatus and were approximate.

Synthesis:

The thiamine hydrochloride (1.75 gm) was dissolved in water (about 5ml) in 50ml round bottom flask ethanol (95%) 15 ml was added & the solution was cooled by swirling the flask in ice water bath. Meanwhile Sodium hydroxide solution (5 ml) was cooled in small conical flask in an ice bath. Then over a period of about 10 minutes the sodium hydroxide was added drop wise to the thiamine solution. Fresh anisaldehyde (10ml) was added to the reaction mixture. The mixture was heated gently in water bath for about 90 minute. The mixture was cooled to room temperature & then in ice bath to in this induce crystallization of the 2-hydroxy-1,2-bis-(4methoxyphenyl)ethan-1one. If product separate as oil, the mixture was reheated until it was once again homogeneous. The reaction was monitored by TLC. The synthetic chemical reaction and its mechanism have been represented in Figure 1 and 2 respectively [19].

Reaction:

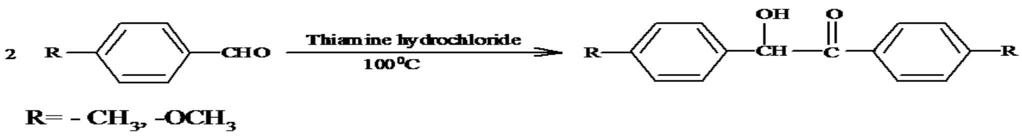


Fig. 1: Chemical reaction of benzoin condensation

Mechanism:

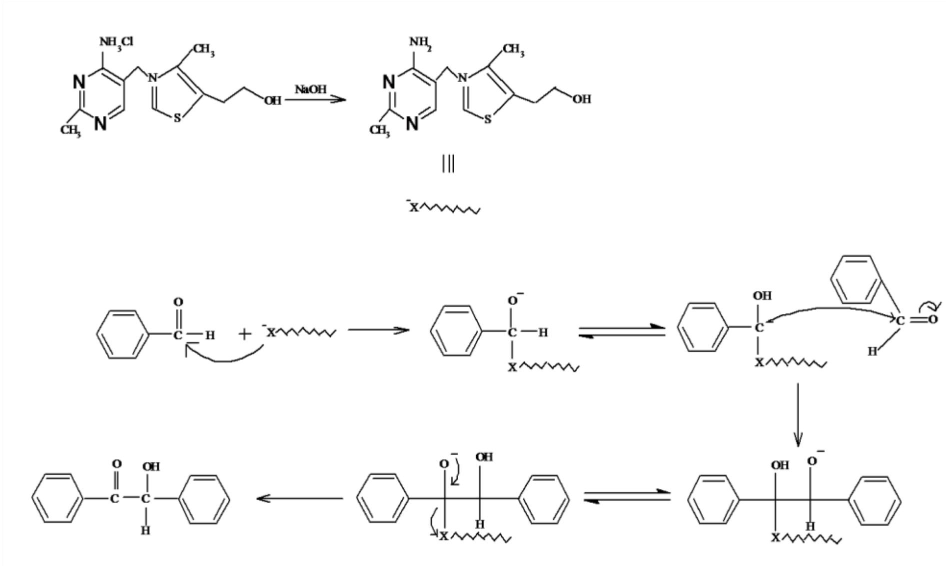


Fig. 2: Reaction mechanism of benzoin condensation

Table 1: Synthesis of benzoins

Product	Aldehyde	Time(min)	Yield %	Melting point ^{0}C
1a	C_6H_5	75	40	135
1b	4-CH_3-C6H4	110	37	131
1c	4-OCH_3-C6H4	161	31	129

Spectral data for synthesized product:

2-hydroxy-1,2-diphenylethan-1-one(1a):

FT-IR (KBr, cm^{-1}): 3414(-OH); 1657(C=O); 1242(C-O);

^{1}H-NMR (500 MHz, DMSOd6, δ ppm): 7.21-8.29 (m, 10 H, Ar-H), 6.47 (S, 1H,- CH), 5.41 (S,1H,-OH).

^{13}C-NMR (75 MHz, DMSO-d6): d= 87.6, 127.6, 128.8, 128.6, 129.2, 129.6, 133.1, 136.7, 136.8, 194.2 ppm

2-hydroxy-1,2-di-p-tolylethan-1-one(1b):

FT-IR (KBr, cm^{-1}): 3404(-OH); 1679(C=O); 1263(C-O); 2900(-CH_3).

^{1}H-NMR (500 MHz, DMSOd6, δ ppm): 6.83-7.67 (m, 8 H, Ar-H), 6.30 (S, 1H, -CH), 5.19 (S,1H,-OH), 2.28-2.56 (S,6H,-CH_3).

^{13}C-NMR (75 MHz, DMSO-d6): d= 21.3, 87.6, 126.6, 129.5, 133.6, 128.7, 137.3, 133.7, 142.8, 194.2 ppm.

2-hydroxy-1,2-bis(4-methoxyphenyl)ethan-1-one(1c):

FT-IR (KBr, cm^{-1}): 2850 (OCH_3), 1258 (C-O Str.), 2983.7 (-OH), 2842(Ar-CH), 1675(C=O).

^{1}H-NMR (500 MHz, DMSOd6, δ ppm): 6.70-7.84 (m, 8H, Ar-H), 3.90 (S, 6H, - CH_3), 6.52 (S, 1H,-CH), 5.27(S, 1H, -OH).

^{13}C-NMR (75 MHz, DMSO-d6): d= 55.8, 87.6, 114.2, 114.8, 128.9, 129.8, 131.6, 159.5, 165.0, 194.2 ppm. [20-24]

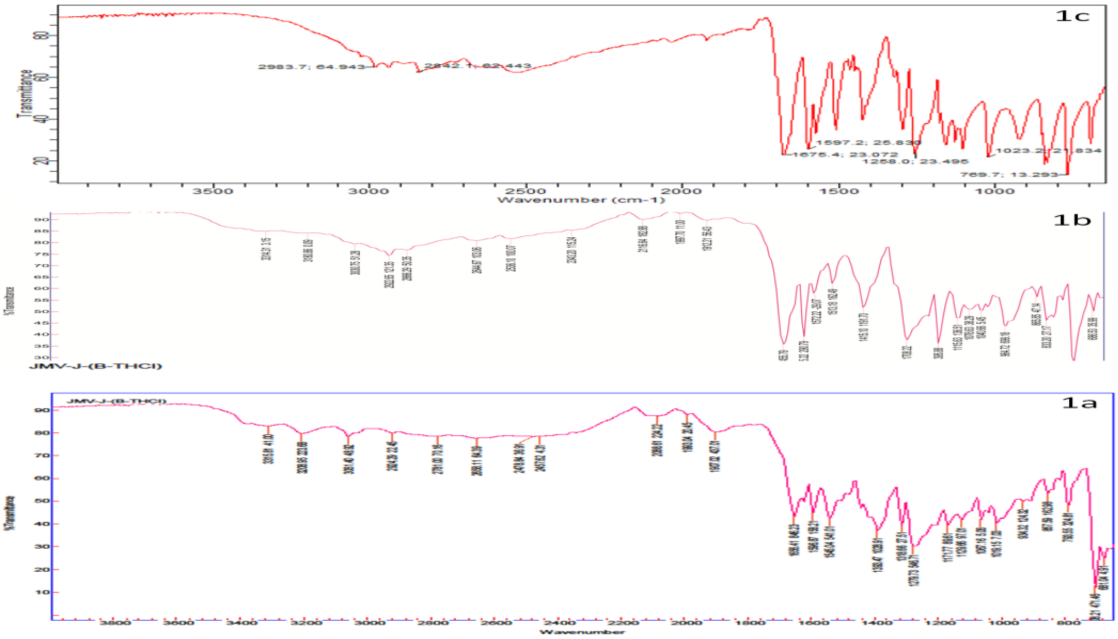


Fig. 3: FT-IR spectra of benzoins

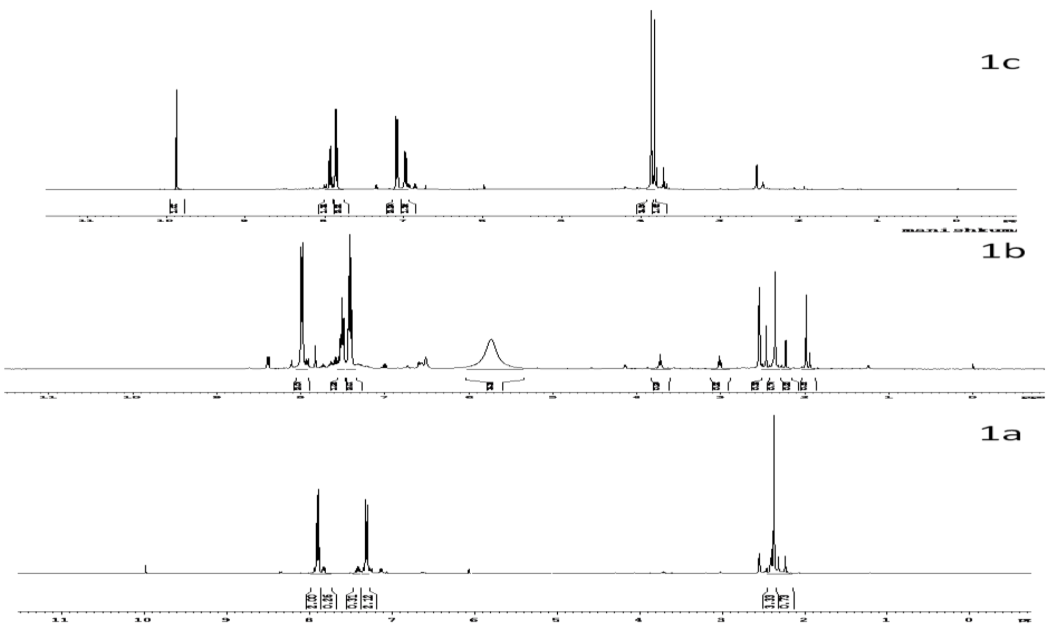


Fig. 4: ^{1}H-NMR spectra of benzoins

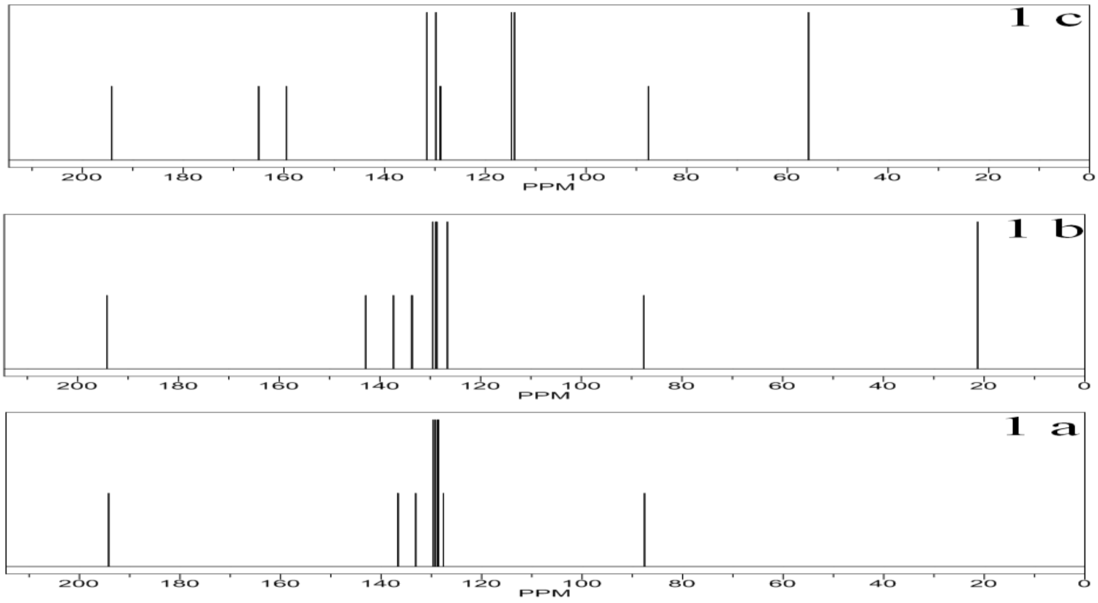


Figure 5: ^{13}C-NMR spectra of benzoins

Result and Discussion:

α-Hydroxyketones are versatile intermediates in organic synthesis. They can be converted into α-haloketones, which provide a variety of useful compounds on reaction with a large number of nucleophiles [25]. Also substituted amino ketones and amino alcohols derived from corresponding benzoin intermediates exhibit necrotising action against mammalian tumors [26]. Various halogenated benzoins possess antimalarial and antiinsecticidal activities; they are also important intermediates in synthesizing molecules having CNS activity and some are also found useful as inhibitors of cholesterol biosynthesis [27]. Several derivatives of substituted benzoins are found to be important drug intermediates for the synthesis of non-prostanoid prostacyclin mimetics [28].

To optimize the reaction conditions, the reaction of anisaldehyde, benzaldehyde and p-tolualdehyde was selected as a model. The shortest time and best yield were achieved for 1a. Next, to found the optimum quantity of thiamine hydrochloride, the reaction of anisaldehyde, benzaldehyde and p-tolualdehyde and thiamine hydrochloride was carried out under the previously mentioned conditions using different quantities of catalyst at 60^0C, the use of 1.75 g of catalyst resulted in the highest yield in 75 min.

Next, the scope and limitations of this process were explored using a wide range of aromatic aldehyde containing both electron-donating and electron withdrawing groups attached to the aromatic ring. Thus, we prepared a range of benzoins under the optimized reaction conditions. In all cases, aromatic aldehydes with substituents carrying either electron-donating or electron withdrawing groups reacted successfully and gave the expected products in reported yields and short reaction times. The possible role of thiamine hydrochloride is shown in the proposed mechanism (Scheme 2). The results are shown in (Table 1). After the completion of the reaction, the reaction mixture was cooled to room temperature and hot ethanol was added. With respect to green context hazardous and poisonous cyanide ion is replaced by thiamine hydrochloride as green catalyst and reaction is affected at lower temperature [29-35].

Conclusion:

We have demonstrated that Thiamine hydrochloride is a new efficient and green catalyst for synthesis of substituted benzoins. All the products were synthesized via a benzoin condensation reaction of anisaldehyde, benzaldehyde and p-tolualdehyde in the presence of Thiamine hydrochloride as a catalyst. The newly synthesized products were characterized and confirmed by spectral analysis. The thermal green procedures offer advantages such as shorter reaction times, simple work-up, environmentally benign, cost effective, recovery and reusability of catalyst for a number of times without appreciable loss of activity.

References:

1. Andrade, C. K. Z., & Alves, L. M. (2005). Curr. Org. Chem., 9, 195–218.
2. Chanda, A., & Fokin, V. V. (2009). Chem. Rev., 109, 725–748.
3. Anastas, P., & Eghbali, N. (2010). Green Chemistry: Principles and Practice. Chem. Soc. Rev., 39, 301–312.
4. Estager, J., L´evˆeque, J. M., Turgis, R., & Draye, M. (2006). J Mol Catal A, 256, 261–4.
5. Estager, J., L´evˆeque, J. M., Turgis, R., & Draye. (2007). Tetrahedron Lett, 48, 755–9.
6. Li, C. J. (2005). Chem Rev, 105, 3095–165.
7. Li, C. J., & Chan, T. H. (2007). Comprehensive Organic Reactions in Aqueous Media 2nd edn, Wiley & Sons, Hoboken.
8. Iwamoto, K. I., Hamaya, M., Hashimoto, N., Kimura, H., Suzuki, Y., & Sato, M. (2006). Tetrahedron Lett, 45, 7175–7.
9. Chaudhary, A. G., & Kingston, D. G. I. (1993). Tetrahedron Lett., 34, 4921.
10. Uchida, R., Shiomi, K., Sunazuka, T., Inokoshi, J., Nishizawa, A., Hirose, T., ... Omura, S. (1996). J. Antibiot., 49, 886.
11. Roush, W. R., Briner, K., Kesler, B. S., Murphy, M., & Gustin, D. J. (1996). J. Org. Chem., 61, 6098.
12. Adam, W., Muller, M., & Prechtl, F. (1994). J. Org. Chem., 59, 2358.
13. Adam, W., Fell, R. T., Stegmann, V. R., & Saha-Moller, C. R. (1998). J. Am. Chem. Soc., 120, 708.
14. Adam, W., Saha-Moller, C. R., & Zhao, C. -G. (1998). Tetrahedron: Asymm., 9, 4117.
15. Adam, W., Fell, R. T., Saha-Moller, C. R., & Zhao, C. -G. (1998). Tetrahedron: Asymm., 9, 397.

16. Kuebrich, J. P., Schowen, R. L., Wang, M. S., & Lupes, M. E. (1971). J. Am. Chem. Soc., 93, 1214.
17. White, M. J., & Leeper, F. J. (2001). J. Org. Chem., 66, 5124.
18. Enders, D., & Kallfass, U. (2002). Angew. Chem. Int. Ed., 41, 1743.
19. Lampman, P. D. L., & Chriz, G. M. (1982). Introduction to organic lab techniques, College Publishing, New York.
20. Kalsi, P. S. (2004). Spectroscopy of Organic Compounds, New Age International Publishers, 2, 9-20.
21. Vogel, A. I. (1989). Textbook of practical organic chemistry; Longman Scientific and Technical: UK.
22. Stuart, B. H. (2004). Infrared Spectroscopy: Fundamentals and Applications; Wiley: New York.
23. Silverstein, R. M., & Basslel, G. C. (1987). Spectrometric Identification of Organic Compounds, 2nd Ed; Wiley: New York.
24. Pretsch, E., Buhlmann, P., & Afflolter, C. (2000). Structure Determination of Organic Compounds; Springer: New York.
25. Lee, J. C., Park, J. Y., Yoon, S. Y., Bae, Y. H., & Lee, S. J. (2004). Tetrahedron Lett., 45, 191.
26. Lutz, R. E., & Murphy, R. S. (1949). J. Am. Chem. Soc., 71, 478.
27. Procopiou, P. A., Draper, C. D., Hutson, J. L., Inglis, G. G. A., Ross, B. C., & Watson, N. S. (1993). J. Med. Chem., 36, 3658.
28. Meanwell, N. A., Rosenfeld, M. J., Trehan, A. K., Romine, J. L., Wright, J. J. K., Brassard, C. L., ... Seiler, S. M. (1992). J. Med. Chem., 35, 3498.
29. Giusti, L. (2009). Waste management, 29(8), 2227-2239.
30. Honeycutt, T. W. (1994). U.S. Patent No. 5, 352, 368.
31. List, B. (2007). Introduction: Organocatalysis. Chemical Reviews, 107(12), 5413-5415.
32. MacMillan, D. W. (2008). Nature, 455(7211), 304-308.
33. Yang, J. W. (2010). Chem World, 50(1), 19-24.
34. Zhu, P., Chen, X., & Roberts, C. G. (2006). U.S. Patent No. 7, 041, 220.
35. Bishop, M. J., Vander Woude, J., & Posscher, M. A. (2023). Chemistry Teacher International, 5(3), 275–282.

SUSTAINABILITY BY DESIGN: MODERNIZING FOOD PROCESSING WITH NOVEL TECHNIQUES

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Abstract:

This abstract explores the transformative impact of innovative thermal and non-thermal food processing techniques on sustainability within the food industry. The study underscores the pivotal role these methods play in addressing critical issues such as energy consumption, food waste, and nutritional preservation. By conducting a comprehensive examination of recent research and practical applications, this abstract highlight the potential of these techniques to revolutionize traditional food processing practices, contributing to a more sustainable and environmentally conscious food supply chain. Non-thermal processes, acknowledged as value-added technologies, have emerged as sustainable alternatives to conventional food processing. These methods not only directly reduce energy and water consumption during processing but also contribute to minimizing energy impact during storage. This dual benefit positions non-thermal processes as key players in enhancing sustainability in the food industry. Furthermore, the replacement of energy-intensive conventional food processing with cutting-edge technologies, such as novel thermodynamic cycles and non-thermal heating processes, presents additional opportunities to curtail energy consumption, reduce production costs, and improve overall sustainability in food production. This abstract advocates for a paradigm shift toward these novel techniques, emphasizing their potential to drive positive environmental change and promote a more resource-efficient food processing industry.

Introduction:

One of the most important processes in the modern world is food processing, which uses a variety of technologies and methods to turn raw food components into consumable food products. It involves several, extensive procedures for processing food ingredients, ensuring that the processed food is of high quality, has a longer shelf life, and satisfies consumer demands. The metabolic activities within the food products, respiration, ethylene synthesis, moisture content present in the food materials, and microbial contamination easily spoil and deteriorate the food products. To ensure that the food products are free from spoilage, the products involve several methods and processes to kill the present microbes, reduce the metabolic activities, and reduce moisture content. Foods can be processed using both thermal and non-thermal methods for storage and processing. The application of heat and the resulting increase or decrease in heat are key components of thermal processing. Non-thermal processing methods to preserve food goods include high pressure processing, pulsed electric field, ultrasound, pulsed light, ultraviolet light, irradiation, and oscillating magnetic field. Heat-sensitive food ingredients are treated non-thermally to preserve nutrient quality, preserve flavor, etc. There are numerous studies that illustrate food processing.

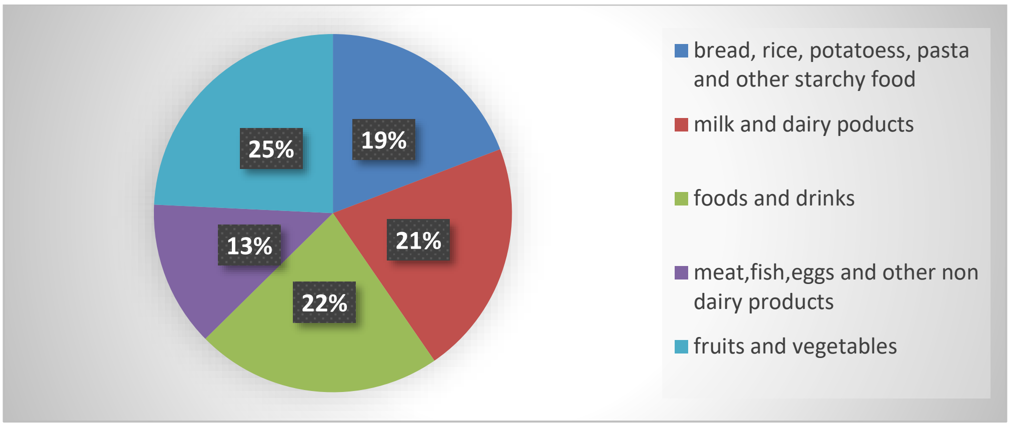

Fig. 1: Processing of food products

Basic principles of food processing

Food items that have undergone processing to make them more sterile and extend their shelf-life by turning raw components into finished goods. This can be achieved in a few ways, such as by lowering the moisture content, raising, or lowering the temperature, or boosting the amount of sugar, salt, or acid in food goods.

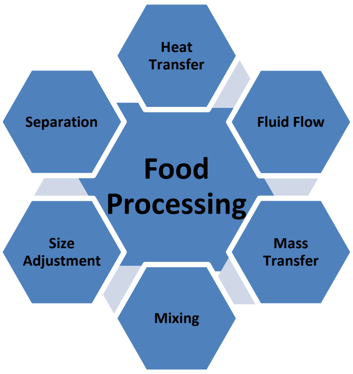

Fig. 2:Principles of food processing

Water activity (a_w)

The difference between the vapor pressure of food (P) and the vapor pressure of pure water (P0) is known as water activity. One of the causes of food product degradation is water activity. The speed with which bacteria, fungus, and molds proliferate and contaminate food increases with water activity. In order to preserve the product's quality and shelf life, water activity in the food is crucial.

Table 1: Food products and its water activity in the food

Food products	Water activity(a_w)
Cooked meat, bread	0.91-0.95
Jams	0.75-0.80
Honey	0.75-0.80
Dry cereals	0.65-0.75
Candies	0.60-0.65
Dried fruits	0.60-0.75
Powdered milk, dried pasta, spices	0.20-0.60
Sugars and syrups	0.60-0.75

Thermal processing of foods

Food that has undergone thermal processing has been heated up. Farhana Mehraj Allai and Z.R. Azaz Ahmad Azad *et al.* (2023) It is a method of preservation that uses the principle of heat at the right temperature and duration to thwart the growth of microorganisms and the action of enzymes. By eliminating the pathogenic bacteria present in the food products, thermal processing of food helps to prevent food waste and spoiling. By heating it, you can stop food from deteriorating by lowering the water activity (a_w) in the food goods. The other qualities of the food are likewise impacted by the heat treatments. The food's shelf life is increased by the gentle heat treatments that kill germs and poisons. Heat is transferred by Conduction, Conduction & Radiation.

Jianing Liu and Jinfeng Bi, *et al.* (2020) Through the mechanism of conduction, heat permeates the meal thoroughly, reducing the likelihood that the food would perish. Similar to sluggish in conductors, food also heats up slowly. In a liquid, convection occurs when heat is transferred from one molecule to another. Considering that food contains solids, heat is simultaneously transported by conduction and convection. Both conduction and convection occur in solid food and liquid, respectively. Blanching, canning, pasteurization, sterilization, and other thermal procedures are a few examples.

Blanching

Blanching is a technique for treating food items like fruits and vegetables in hot water. In order to kill any germs or other pests that are present for a brief period of time, fruits and vegetables are blanched by being submerged or dipped in hot water at a desired temperature. The preparation step before canning, freezing, and drying is known as blanching. The blanching method is applied to the fruits and vegetables before storage. As a result, fruits and vegetables have less enzymatic activity, less ethylene produced, and other metabolic activity. R.N. Periera, A.A.Vincete (2010) Blanching helps to preserve the fruit and vegetables color, texture, flavour, and any nutritional content. Through this procedure, the trapped air and metabolic gases from the vegetable cells are eliminated. To make the food easier to pack, it is done before the canning process. For 2-3 minutes, a temperature of 100°C or lower is frequently employed in the blanching process. Food items are based on time and temperature to prevent food product deterioration. Blanching aids to get rid of the parasites, preserve colour, flavour, and texture, eliminate externally adhered microorganisms, wash the fruits and vegetables' exterior surfaces, facilitate the enzyme in fruits and vegetables to be deactivated, limit the rate of breathing, to peel veggies and fruits loosely. It has been documented that fluidized bed blanchers, which use a steam and air mixture, are sometimes used. Benefits include reduced wastewater, quicker processing times, more uniform heating, and a decrease in the amount of soluble and heat sensitive components. Because it reduces leaching losses, this is the recommended method for foods with large cut surface areas. Food is typically transported through a stream environment on a mesh belt or rotary cylinder, with the conveyor’s speed or rotation controlling the residence time. Frequently, uneven heating throughout the food’s layers causes the outer layers to overheat when the center reaches the necessary time temperature.

Canning

The raw food ingredients are prepared and sealed in an airtight container as part of the preservation procedure known as canning. Because the food products are cooked at a high temperature, they have a longer shelf life than regular food goods and don't spoil as easily. It is one of the finest ways to keep food materials during the off-season or when a certain food resource is unavailable. The food materials are processed and used. Processing of produce, meat, and other perishable food items is a part of this technique. Food has been heat-preserved needs to be kept in airtight, hermetically sealed containers to prevent recontamination from ambient microbes. Most thermally preserved goods come in metal can. Some are packaged in glass jars, plastics, or laminated pouches made of plastic and aluminium.

Cans sometimes known as tins are made from tinplate. Typically, they are cylindrical. Cans so come in other shapes, though, like rectangular or pear shapes. Tinplate is made of steel plates that have both sides electrolyte coated with tin. Typically, the steel body has a thickness of 0.22-0.28mm. the thickness of the tin layer ranges from 0.38-3.08µm. A synthetic material lines the inside of the cans to stop any chemical reaction between the food inside and the tinplate.

Sterilization

The sterilization method is used to destroy any heat-resistant organisms that may appear during the pasteurization process. When the spores that the organisms produce are not removed, vegetative microorganisms may appear and thrive when the environment is favorable for the bacteria. As a result, the food products are spoiled more efficiently by the microbes that persist even after heat treatments. The sterilization procedure's primary goal is to eradicate all germs and the spores they produce from the items. Heat treatment will undoubtedly render bacteria dormant or kill them, even those that can withstand heat, like Bacillus and Clostridium.To kill the germs, present inside food containers, food products that are sealed in a container are sterilized in a pressure cooker at a temperature of 100°C, or depending on the type of food product, the temperature may vary from 100-121°C. If the temperature is lower, the process could take longer even if it might be quick. The nutritional value, flavour, and scent of the food products could change because of sterilizing them at a high temperature. Both packaged and aseptically sterilized products are included in the sterilization process. In aseptic sterilization, food products and packaging materials are both sterilized separately and packaged in a manner that is appropriate for the products. In packed sterilization, food products are packaged in a container that can withstand the sterilization temperature, such as canned food products. This procedure is used to sterilize milk that has a longer shelf life as well as soups.

Non-thermal method of food processing

Heat is applied to food products to prevent spoilage and lengthen shelf life by eliminating bacteria. However, the nutritional value and sensory qualities of the food may be harmed by the thermal processes that are being used. *Jianing Liu and Jinfeng Bi, et al.* (2020) Due to the global population's demand for food with adequate nutrition, non-thermal ways have been developed to meet the public's needs. This technique is used to treat and preserve food products that are extremely heat-sensitive. R. N. Periera, A. A. Vincete (2010) By using these methods, the loss of nutrition, flavors, quality, and texture is minimized. It is also possible to protect food against the bacteria that lead to food rotting. In the modern world there are several methods for the non-thermal processing of food which do not make any changes to the physical, chemical, and biological properties of the food products.

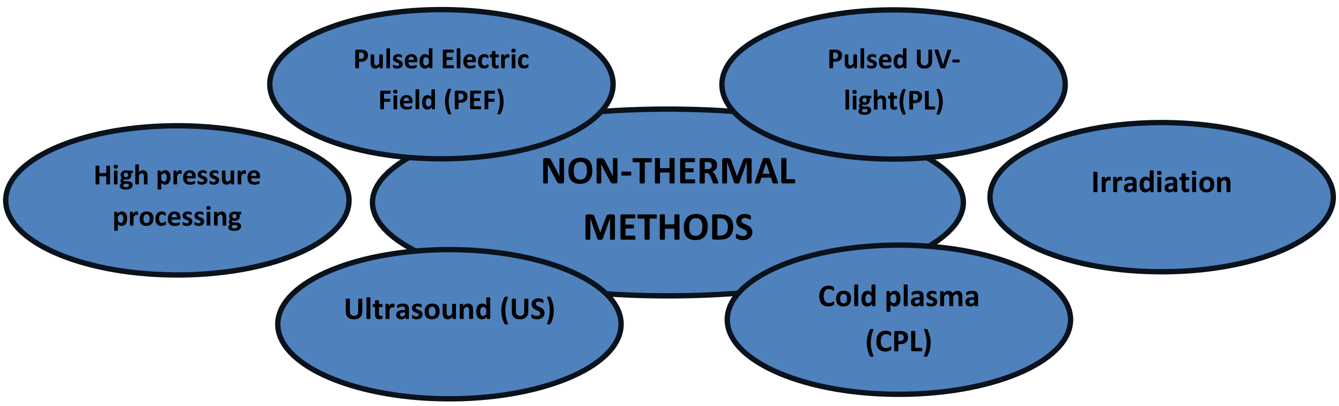

Fig. 3: Non-thermalmethods of processing food

Pulsed UV-Light (PL)

A preservation method known as pulsed UV-light uses ultraviolet light to kill bacteria. The UV lamp produces UV-light, and the light ray from the lamp quickly strikes the surface of food products to kill any bacteria or other microorganisms that may be present there. To eliminate contaminating bacteria on the surface of the packaging materials, this procedure can also be used on already-packaged items. *F. Fine and P. Gervais, et al.* (2001) The pulsed UV light (PL) used in food processing has a range of wavelengths, including UV light with a wavelength between 200 and 400 nm, visible light (VIS) with a wavelength between 400 and 700 nm, and infrared light (IR) with a wavelength between 700 and 1100 nm. The microbial burden on the surface of the food items is reduced during this process.

Rai Naveed Arshad *et al.* (2021) Using a brief pulse or white light with a wavelength between 200 and 280 nm, this approach is used to render inactive the microorganisms that are present on the surface of food goods. The DNA of microorganisms' cells absorbs UV radiation, which causes cell death. The sensory quality of the food products being processed is unaffected by pulse UV radiation. It helps to inactivate microorganisms and can make both vegetative cells and spores inactive.

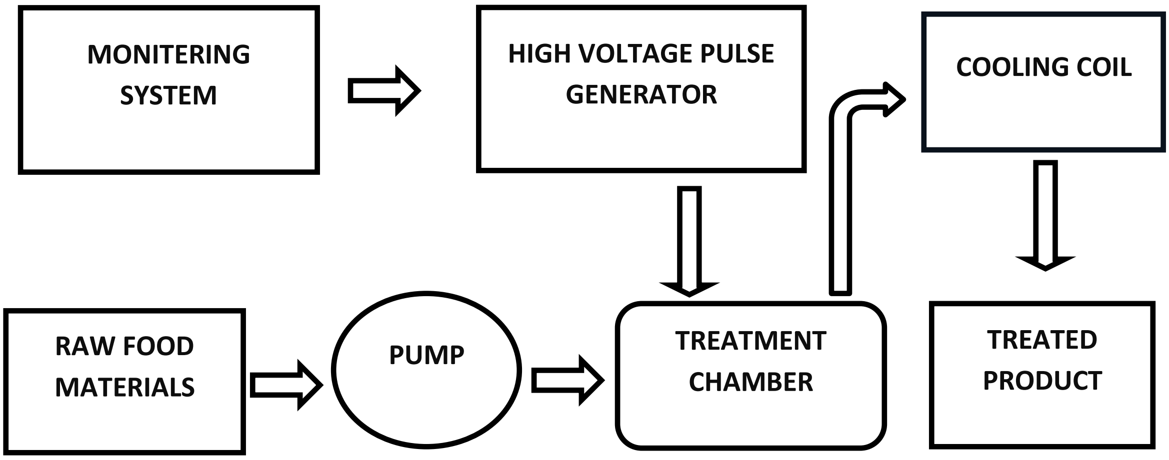

Fig. 4:Block diagram of Pulsed UV-Light

Irradiation

Food goods that are pre-packaged or in large numbers are subjected to radiation as part of a preservation process to reduce the microbial load. The three types of radiation that are most frequently used to process food are X-rays, gamma rays, and electrons that have been accelerated by an electron gun. In certain situations, these radiation types are mixed. This technique can be used to process foods that are extremely heat-sensitive. Rayna Stefanova *et al.* (2010) Irradiation is a physical procedure in which food products are subjected to radiant energy at a controlled rate to halt the ripening process, eradicate the microbes that lead to food degradation, and eliminate any existing insects or pests. Using this method, using this process, it can also reduce the sprouting and senescence in the fruits and vegetables.

Table 2: Dosage used in irradiation process

Dosage Level	Application of the Process	Dose (kGy)
Low dosage (up to 1 kGy)	In potatoes, onions, garlic inhibits sprouting	0.06-0.2
	Delay ripening of fruits.	0.5-1.0
	Kill insects in grains,	0.15-1.0
	cereals, coffee beans, spices, dried fruits, and nuts. Inactivates the parasites.	0.3-1.0
Medium dosage (1kGy-10kGy)	Shelf life in fresh fish, sea foods and fish products	4.5-7.0
	Shelf-life frozen meat products	1.0-7.0
	Reduces microbes in meat fish and poultry products	3.0-7.0
High dosage > 10kGy	Inactivates enzymes.	10.0
	Sterilization of vegetables.	30.0
	Packaging materials and products sterilization	10.0-25.0

Cold plasma

In the world, matter exists in three different states: solid, liquid, and gas. Plasma is the fourth state of matter. When a solid material is exposed to continuous energy, it transforms into a liquid, and when a liquid is exposed to further continuous energy, it transforms into a gas. Further energy applied to the gas causes the production of free electrons and the dissociation of ions from their orbital. Plasma is the name given to this form of resulting stuff. One non-thermal procedure that uses energetic or reactive gases to render germs inert that infect food products like meats, fish, poultry, fruits, and vegetables is called cold plasma. When the gas is partially ionized at atmospheric pressure or in a low-level vacuum in this type of food preparation, cold plasma is produced. Free electrons, ions, UV radiation, and reactive substances including O3, NO, and NO2 are present in the plasma employed in this process. The physical and chemical characteristics of the food products that are treated to this method don't alter because just a small amount of heat is generated during this process. The freshness of the fruits and vegetables utilized in this method is maintained, and neither the nutritional content nor the sensory qualities of the finished items are altered. Benefits of cold plasma technology include the ability to treat items that are sensitive to heat, the microorganisms on the surfaces are eliminated, preserves the fruits' and veggies' freshness, the amount of nutrients remains constant.

Ultra-Sound (US)

The technique that employs sound to digest food includes a non-thermal process called ultrasound. It is used in a wide variety of laboratories and food-related sectors. The advantage of this innovative method is that it preserves the product's quality while being easy to use and the ultrasound waves don't alter the product's structure or content. It basically functions using the ultrasonic principle. Bhargava, Nitya, *et al.* (2021) The frequency of sound employed in the ultrasound procedure is divided into three groups. 20–100 kHz for low frequencies, 100–1 kHz for intermediate frequencies, and 1–10 MHz for high frequencies. Large amplitude waves are used in the low frequency procedure. The production of free radicals and the activation of chemical reactions take place during the ultrasound process' intermediate frequency. The expansion and contraction of the food ingredients' particles is caused by the sound waves' ability to pass through them at both intermediate and low frequencies. High frequency sound waves are utilized in the procedure to diagnose food goods.

High Pressure Processing (HPP)

By using high pressure to inactivate pathogenic organisms that cause food products to spoil, also known as pasteurization, high pressure processing is a non-thermal method of processing food products. Muntean, Mircea-Valentin, *et al.* (2016) Food goods are kept fresh in refrigerators or at low heat temperatures by 400-600 MPa of strong pressure. The physical and chemical characteristics of the food products are minimally impacted by this technique. This technique allows for the reduction of excessive heat utilization. This procedure is based on the use of high pressure. HPP is a batch or semi-continuous food processing method in which pressure is consistently and concurrently applied to the goods. It is made up of a pressure vessel that holds the food products and is designed to withstand high pressure easily. A high-pressure pump creates high pressure, and hydraulic fluids are then used to transfer the pressure from the high-pressure pump to the food products while also ensuring that the pressure is distributed evenly across the products. Pressure sensors are employed to measure the vessel's internal pressure. Some HPP equipment has temperature sensors to keep the temperature constant throughout the operation, pressure-tight mechanisms, and loading and unloading systems for the food products. The benefits include lowering the microbial load, lengthening the product's shelf life, and lowering waste output.

Pulsed Elecrtic Field (PEF)

A method of food preservation known as pulsed electric field employs a high voltage electric current to travel through food goods and inactivate any germs present. It is utilized in food items that are liquid or semi-solid when electrodes are inserted in the food goods and current is passed into it while having the least number of alterations to the physical, sensory, and nutritional contents of the products and suppresses microbial development in the product. It consists of a pulse electric field generator, which generates an electric field with a high voltage. The food products that need to be treated are then placed in a treatment chamber and processed in the electric field, which is sent by the pulse generator. This kills the bacteria. Juices, dairy products, eggs, meat, and seafood are examples of food items. Rai Naveed Arshad *et al.* (2021) By employing these techniques, bacteria, yeast, and mold are inactivated, and the enzyme activity in food products is suppressed. The shelf-life of food goods is extended through the inactivation of microorganisms and enzymes. It aids in keeping the food's flavour, color, and nutritional value.

Controlled Atmosphere Storage (CAS)

We eat food grains, which are an essential component of the world's food supply since they provide nourishment for everyone. It is exceedingly challenging to store grains in a way that ensures their long-term preservation and protection against a variety of variables, including pests, moisture, and fluctuations in the environment's temperature. Chong, Kok Lin, *et al.* (2013), One of the cutting-edge techniques for preventing the deterioration of food grains and post-harvest goods is controlled atmosphere storage (CAS). By employing a computer and sensors, the grains are kept in a room with oxygen in this technique of storage. The idea behind controlled atmospheric storage is to store food grains by lowering the oxygen content of the air while raising the carbon dioxide level. By using this technique, it is possible to keep food grains in their ideal condition and nutritional content while also reducing the growth of pests, insects, and microbes that can lead to product degradation. Food grains kept in CAS include rice, maize, wheat, and legumes. The major goal of this procedure is to reduce post-harvest losses globally. Pesticides are not necessary because CAS prevents the growth of pests in food goods. The difficulty with CAS is that maintaining the storage environment for the preservation of the food grains costs more and consumes more energy. CAS stores goods like grains, legumes, and oilseed.

Modified Atomsphere Storage (MAS)

Food preservation is crucial today to prevent food products from spoiling because it is a vital part of daily life. A brand-new technology has been developed for the preservation of food products and post-harvest goods called modified environment storage. By preserving oxygen, carbon dioxide, and the relative humidity in the storage environment, it preserves the freshness and quality of the food goods and slows the development of germs like fungus, bacteria, and pests that deteriorate food products. Chong, Kok Lin, *et al.* (2013), This process relies on the controlled atmosphere storage (CAS) principle, in which the oxygen content is decreased, CO_2 is increased to reduce metabolic activities like the production of ethylene, which causes fruits to ripen, and the humidity level is maintained to prevent water loss and freshness, which increases the shelf-life and quality of the food products. It is natural and healthy for consumers to purchase and consume because it does not require the use of chemical preservatives or pesticides to destroy insects or pests in the food goods. To maintain the quality and freshness of the products for a long period, things like fruits and vegetables, meat and seafood, bakery goods like bread and pastries, and dairy goods like cheese and yoghurt are stored in MAS.

Active packaging

Packing is crucial for keeping the goods in place, transporting them to far-off locations, and storing them in areas with a strong demand for food products. Smart packaging is another name for active packaging. Zareena Azhuvalappil, Xuetong Fan, *et al.* (2010) and P. Kumar, J.H. Han, *et al.* (2012), It is a cutting-edge technique that involves packing the food products where they emit or absorb compounds from the environment to lower the rate of microbial spoilage, maintain the moisture content in the food products, ensure their quality, and extend their shelf life for longer periods of storage by reducing the oxygen content. Food goods are kept fresh by being shielded from oxygen, UV radiation, and other chemical and microbial elements.

Table 3*: Properties of active packaging*

Properties	Compounds
Microorganism controlling	Packing materials with surface treatment and ultraviolet
Temperature maintains	Temperature-sensitive materials are used, as well as insulating and self-heating materials.
Removing	It removes lactose by catalyzing dietary ingredients.
Releasing	Release of CO_2, ethanol, preservatives, flavours, and antioxidants
Absorbing	Absorbs flavors, moisture, ethylene, taints, CO_2, oxygen, and ultraviolet light.

Reduction of energy usage

To enhance the energy efficiency within the food industry, it is essential to decrease the specific energy consumption in facilities engaged in activities such as cooling, heating, drying and high-temperature processes. Conserving energy is crucial for the sustainable growth of the food industry. The adaptation of innovative technology like novel thermodynamic cycles, non-thermodynamic cycles, and new heating methods offers a promising avenue to decrease energy usage, lower production cost, and enhance the overall sustainability of food production. Farhana Mehraj Allai and Z.R. Azaz Ahmad Azad, *et al.* (2023) To enhance the energy efficiency in blanching of fruits and vegetables, optimizing the parameters like temperature and time, favoring advanced blanching like microwave blanching. Improve insulation, recycle heat, and streamline production process by sorting fruits before blanching. Monitoring water usage, adopt energy-efficient equipments, and explore renewable resources. Regular maintenance ensures equipment performance.

Establishing precise energy targets is on the way that food and beverage sector may use automation, monitoring, and control systems currently in place to save energy. Merely taking this action will result in a decrease energy usage across many departments inside the company. Utilizing modern technology to keep an eye on kilowatt usage, maximize equipment use, and develop a reliable control mechanism to synchronize th system with plant operation. Between 30%-80% of energy usage may come from cooing and refrigeration. Some specific strategies to increase productivity in this field by using heat exchangers with high efficiency, utilizing the refrigerant system with the highest efficiency rating that is most appropriate putting in place a reliable maintenance system including cleaning, leak detection, and ideal temperature set points. Operating costs for electricity driven equipment can be cut by up to 50% by using variable speed drives.

Reduction of food wastage

Food that is unfit for consumption is considered as waste food. It is morally required to increase the amount of food products that is consumed because there are lot of hungry people in the world and there is pressure in land. Global greenhouse gas emissions are primarily cause by the production of processed food products, and waste food products additional emissions without providing any nutritional value. Cutting down on food waste is essential to slowing down the climate change. During manufacturing process, selecting the appropriate packaging can extend the shelf life, minimize handling, increase productivity, and cut down on waste. But there is a growing trend of striking the shelf of products and cutting back on plastic and non-recyclable materials. You may waste ingredients and raw materials as a result of inaccurate forecasting. One of the main causes for the waste in food industry is ordering enough ingredients to make certain volume of products, but in reality, producing less, especially when using fresh or perishable ingredients. You cannot determine whether waste is being reduced or determine its true costs without measuring it. Manufactures can streamline processes and cut waste by identifying inefficiencies and waste by feeding this data into company-wide systems for central analysis.

Conclusion:

The goal of recent advancements in food processing is to apply novel food processing methods to a wide range of food products. There are many thermal and non-thermal techniques that can be used to improve the sustainability of food items. The purpose of utilizing this technique is to increase the product's nutritional value and extend its shelf life. Fresh and minimally processed food products are becoming more and more in demand. The food's germs are rendered inactive by it. to keep food goods safe and maintain their quality. Some food products must be treated using non-thermal techniques because they cannot be processed thermally. Due to its effects on health advantages and little processing of food products, it decreases consumer concerns about processed food. By improving the nutritional value, shelf life, safety, and quality of the food items as well as their viability in the global market, it replaces the traditional methods of food processing.

References:

1. Pereira, R. N., & Vincente, A. A. (2010). Environmental impact of novel thermal and non-thermal technologies in food processing. *Food Research International*, 43(7), 1936-1943.
2. Allai, F. M., Ahmad Azad, Z. R., *et al.* (2023). Recent advances in non-thermal processing technologies for enhancing shelf life and improving food safety. *Applied Food Research*, 3(1), 100258.
3. Iqbal, A., Murtaza, A., *et al.* (2019). Activation and inactivation mechanisms of polyphenol oxidase during thermal and non-thermal methods of food processing. *Food and Bioproducts Processing*, 117, 170-182.
4. Garde-Cerdán, T., Arias-Gil, M., *et al.* (2007). Effects of thermal and non-thermal processing treatments on fatty acids and free amino acids of grape juice. *Food Control*, 18, 473-479.
5. Azhuvalappil, Z., Fan, X., *et al.* (2010). Thermal and nonthermal processing of apple cider: Storage quality under equivalent process conditions. *Journal of Food Quality*, 33(5), 612-631.
6. Kumar, P., & Han, J. H. (n.d.). Packaging materials for non-thermal processing of food and beverages. In *Emerging Food Packaging Technologies, Principles and Practice* (pp. 323-334). Woodhead Publishing Series in Food Science, Technology and Nutrition.
7. Trudeau, M. P., Verma, H., *et al.* (2012). Comparison of Thermal and Non-Thermal Processing of Swine Feed and the Use of Selected Feed Additives on Inactivation of Porcine Epidemic Diarrhea Virus (PEDV).
8. Liu, J., & Bi, J., *et al.* (2020). Impacts of thermal and non-thermal processing on structure and functionality of pectin in fruit- and vegetable-based products: A review. *Journal of Carbohydrate Polymers*, 250, 116890.
9. Stefanova, R., Vasilev, N. V., & Spassov, S. L. (2010). Irradiation of Food, Current Legislation Framework, and Detection of Irradiated Foods. *Food Analytical Methods*, 3(3), 225-252.
10. Arshad, R. N., Abdul-Malek, Z., *et al.* (2021). Pulsed electric field: A potential alternative towards sustainable food processing. *Trends in Food Science & Technology*, 111, 43-54.

11. Fine, F., Gervais, P., *et al.* (2004). Efficiency of Pulsed UV Light for Microbial Decontamination of Food Powders. *Journal of Food Protection*, 67(4), 787-792.
12. Chong, K. L., *et al.* (2013). Food sustainability by designing and modelling a membrane-controlled atmosphere storage system. *Journal of Food Engineering*, 114(3), 361-374.
13. Jayas, D. S., & Jeyamkondan, S. (2002). PH—postharvest technology: modified atmosphere storage of grains meats fruits and vegetables. *Biosystems Engineering*, 82(3), 235-251.
14. Bhargava, N., *et al.* (2021). Advances in the application of ultrasound in food processing: A review. *Ultrasonics Sonochemistry*, 70, 105293.
15. Muntean, M. V., *et al.* (2016). High-pressure processing in the food industry – characteristics and applications. *Agriculture and Agricultural Science Procedia*, 10, 377-383.

MULTIFERROIC PROPERTIES OF $GDMnO_3$ & $GdFeO_3$ NANOPARTICLES

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Abstract:

In the present work, $GdMnO_3$, and $GdFeO_3$, nanoparticles have been synthesized by a chemical co-precipitation method in evaluating their multiferroic properties. In order to develop single phase materials, these two undertaken samples have been sintered at different temperatures in determining their optimized sintering temperatures. For these samples, we have carried out measurements on structural, magnetic and electrical properties, so as to investigate their multiferroic behaviors which eventually develop a strong coupling between magnetic and ferroelectric order, such a situation leads to the progress of newer and effective materials for their use in multifunctional devise applications.

Keywords: Nanoparticles; Multiferroic; Electric, Magnetic

Introduction:

In recent times, rare earth manganites in the compositional formula of RMnO, (where R = Gd, Eu, Sm, Tb & Dy) have been investigated as those possess significant importance due to the existence of strong magnetic interactions which could play a vital role in inducing magnetoelectric effect [1-4]. Especially $GdMnO_3$, reveals a strong magneto-dielectric coupling and as a consequence of that, different spin excitations could exist as electro active magnons, spin waves those could be excited by electric fields. Such materials are useful in tailoring the property of ferromagnetism by an external electric field or vice versa. [5].

Rare earth orthoferrites in the compositional formula of $RFeO_3$ (where R=Gd, Eu & Sm) are also another important set of multiferroic materials and $GdFeO_3$ material has a distorted perovskite structure; it is possibly because of the occurrence of tilting in rigid FeO_6 octahedral symmetry. It occurs when the A-site cation is too small for its 12-coordinate cavity in the cubic perovskite structure thereby result in lowering of the symmetry from a cubic (Pm3m) to an orthorhombic (Pnma). In such materials, ferroelectric polarization is generated by the striction through the exchange interaction between the Gd and Fe spins and antiferromagnetic ordering of material related to the size of the tilt angle, with larger values of a leading to higher Neel temperatures. Keeping this in view, we have undertaken the $GdFeO_3$ material to study their multiferroic behaviours. [6-9].

Therefore, such materials having magnetoelectric coupling, demonstrates the possibilities of mutual controllability of M and P with E and magnetic field (H) that are of primary importance. Rare earth orthoferrites and rare earth magneties are promising candidates as multiferroic materials [10, 11]. In the present work, it is intended to explore the presence of multiferroic properties that could be retained in their nanoparticles form as such a study could exhibit significant trends in their physical properties compared to their bulk counterparts due to their large surface to volume ratio. In the present work, $GdMnO_3$ and $GdFeO_3$ samples have been synthesized by a co-precipitation method to understand their structural, thermal, magnetic, electrical properties systematically.

Experimental studies

Preparation of $GdFeO_3$ and $GdMnO_3$ nanoparticles

Preparation of Preparation of $GdFeO_3$ and $GdMnO_3$ nanoparticles by chemical co-precipitation method is as follows.

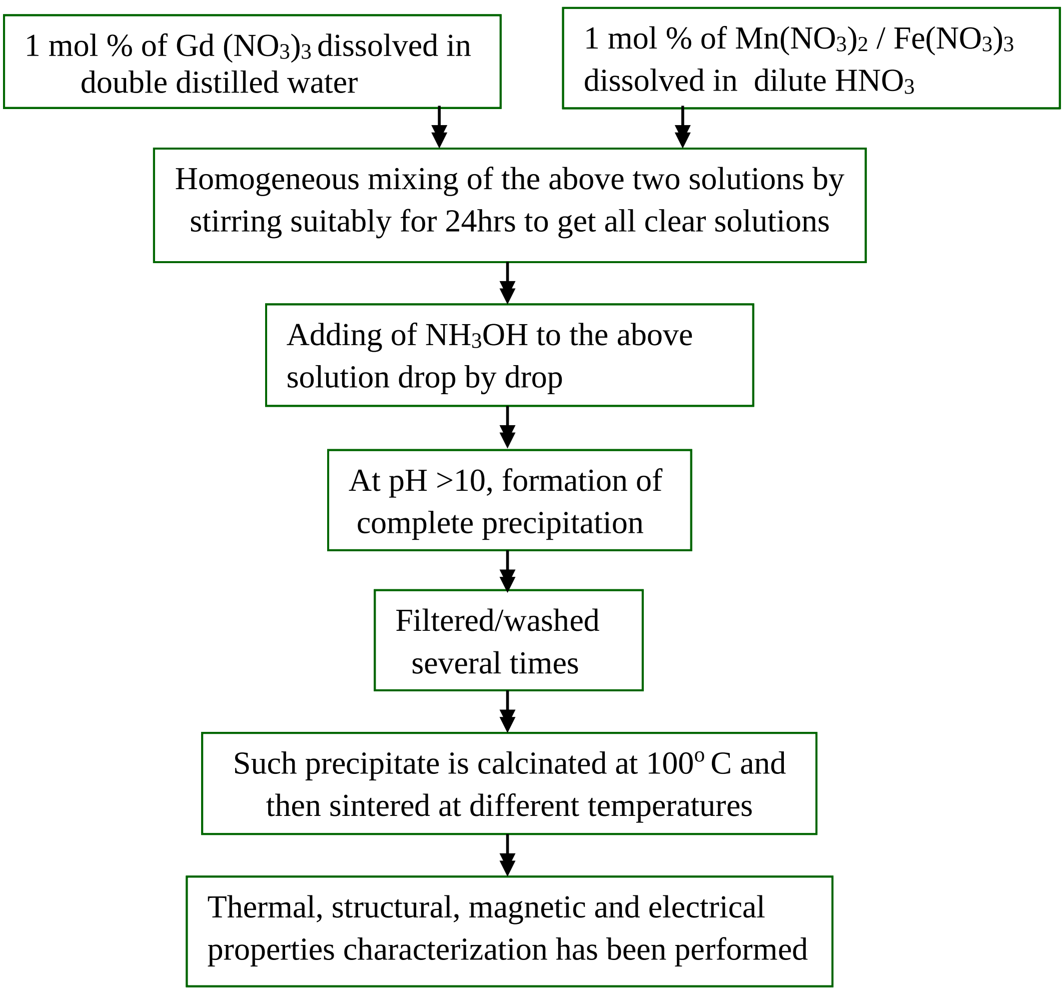


Fig. 1: Preparation of $GdFeO_3$ and $GdMnO_3$ nanoparticles

Measurements

Simultaneous measurement of TGA-DTA has been measured for $GdMnO_3$, & $GdFeO_3$, samples in nitrogen (N2) atmosphere at a heating rate of 10 °C/min on a Netzesch STA 449F1 simultaneous thermal analyzer. Based on the weight losses of the samples from the TG graph, the samples were sintered at different temperatures. XRD patterns were recorded for the $GdMnO_3$, and $GdFeO_3$, samples sintered at various temperatures using XRD 3003TT Seifert diffractometer with Cuk, radiation (-1.5406 A) at 40 KV and 20 mA with a Si detector. The morphology of the $GdMNO_3$, and $GdFeO_3$, samples was examined on a FEI Quanta FEG 200-High resolution scanning electron microscope along with elemental analysis (EDAX).

Magnetic hysteresis loops (M-H) of the $GdMnO_3$, and $GdFeO_3$ samples at different temperatures from 20-300 K. Ferroelectric hysteresis loop measurements were performed on the sample sintered at different temperatures of $GdMnO_3$, and $GdFeO_3$, nanoparticles under studying at a switching frequency 50Hz using Sawyer- Tower circuit setup at room temperature

Results and Discussion:

TGA-DTA profile of $GdMnO_3$, and $GdFeO_3$, samples as a function of temperature in a nitrogen (N2) atmosphere as shown in Fig.2.

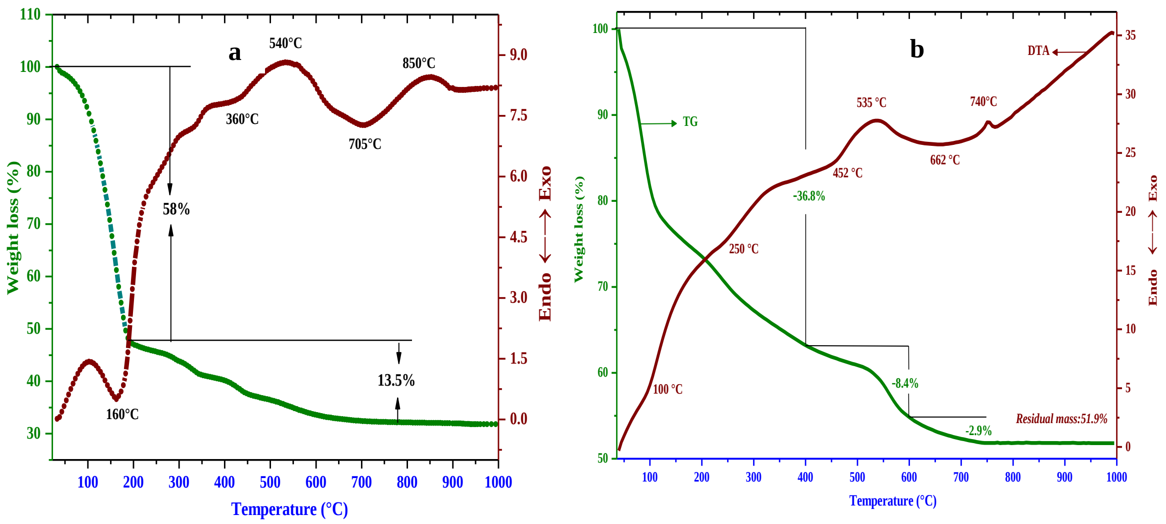


Fig. 2: TG-DTA profiles of as synthesized samples of (a) $GdMnO_3$, & (b) $GdFeO_3$,

Form the results of TGA-DTA of $GdMnO_3$, and $GdFeO_3$ shows that the major weigh loose of the $GdFeO_3$, sample occurring at lower temperature than comparing to the $GdMnO_3$ sample; from this it is that we can come to conclude that stability of $GdMnO_3$, is more than the GdFeO3 sample. But in these two samples the weight losses become constant approximately at the same temperature. Specific heat of the sample $GdMnO_3$, is more than the $GdFeO_3$, sample, it confirmed from the existing values in Y- axis in DTA curve. In case of $GdFeO_3$ nanoparticles pure single phase crystallinity is forming at low temperature comparing to $GdMnO_3$, naoparticles it is confirmed by measurement of XRD profiles. All details of the TG-DTA profiles of $GdMNO_3$ and $GdFeO_3$ are tabulated here:

Table 1: TG-DTA profile of $GdMnO_3$ nanoparticles

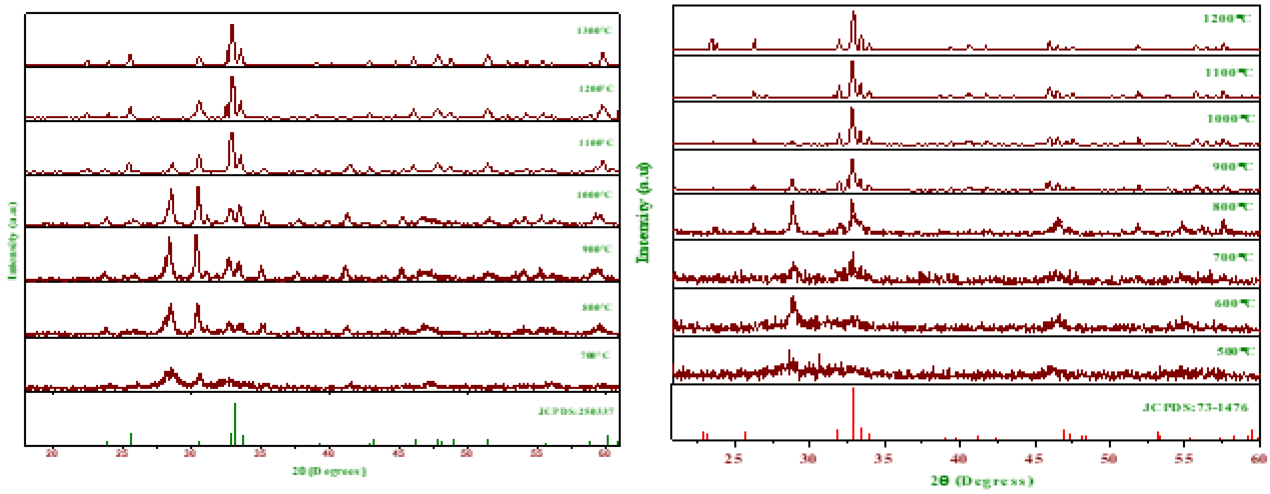
Temperature range	**TGA Profile**		**DTA Profile**	
	Initial weight of the sample: 17.71 mg			
	Weight loss (%)	**Weight loss(mg)**	**Exothermic (ºC)**	**Endothermic (ºC)**
30 ºC - 400 ºC	36.8	6.51	--	100, 250
400 ºC-600 ºC	8.4	1.48	535	452
600 ºC-800 ºC	2.98	0.52	740	662
800 ºC-1000 ºC	onstant	Constant	--	--
Residual weight of the sample 8.51mg (51.9%)				

Table 2: TG-DTA profile of $GdFeO_3$ nanoparticles

Temperature range	**TGA Profile**		**DTA Profile**	
	Initial weight of the sample: 55.4 mg			
	Weight loss (%)	**Weight loss (mg)**	**Exothermic (ºC)**	**Endothermic (ºC)**
28 ºC - 200 ºC	58	32.2	--	160
400 ºC-700 ºC	13.5	15.8	360 ºC	540 ºC
700 ºC-1000 ºC	Constant	Constant	705 ºC	850 ºC
Residual weight of the sample at 1000 ºC: 15.8 mg, (25.5%)				

Initially, as prepared sample (semi solid), sample having the high Helmholtz Free Energy with respect to surrounding create the mobility among atoms in addition to external heat. Further it has been reduced due to evaporation of volatile evaporation of water, residual solvent and other. During the heating of the sample, entropy of sample has been changed based on existence of thermodynamic reactions. Enthalpy of the sample is positive which indicates the bond energy and formation of crystal structure and it is occurred the spontaneously where Gibbs Energy is negative.

X-ray diffraction profiles of the $GdMnO_3$ and $GdFeO_3$ samples sintered at different temperature as shown in Fig.3.



a b

Fig. 3: XRD profiles of (a) $GdMnO_3$, & (b) $GdFeO_3$ samples sintered at different temperatures

From Fig.3a, The samples sintered at 1200°C and 1300° C are good agreement with JCPDS card No: 250337 with orthorhombic in crystal structure with pbnm space group and its lattice parameters are a = 5.310Å, b = 5.840Å and c = 7.430 Å [12]. It clearly observed from XRD data the samples sintered below 1100 °C shows an impurity phase of the Gd2O3 which represents that the total amount of Gd and Mn initial precursor has not completely transformed to take part in formation of single phase of GdMnO3 nanoparticles. But increasing the sintering temperature above 1000 °C intensity of impurities peaks decrease at 1100 °C and further increasing of sintering temperature impurities peaks diminished at 1200 1300 °C which indicates formation of the pure single phase $GdMnO_3$ nanoparticles. The average crystallinity size is calculated from Scherrer's formula and its average crystallite at1200 °C and 1300 °C are 33 and 39 nm.

From Fig.3b. Shows, on sintering $GdFeO_3$ samples crystallinity is improvised from amorphous nature to pure single phase crystalline structure is observes. The samples 1100° C and 1200° C are well matched with JCPDS card No: 74-1476 The XRD $GdFeO_3$ in orthorhombic crystal structure with pbnm (62) sapec group and its lattice parameters are a = 5.349Å, b = 5.611Å and c = 7.669 Å [13, 14]. The average crystallinity size is calculated from Scherrer's formula and its values are 36,41 and 49nm at 1000° C, 1100° C and 1200 °C respectively [15, 16].

Fig.4a. shows HRSEM images revealing the morphology of the GdMnO3 nano particles, sintered at different temperatures. Systematic study of the microscopy reveals the sample sintered at 1000 °C shows the porous and loosely packed grains in microscopy and grains are appear to be like spherical shape with uniform in size and the average grain sizes are in nm range. Upon increasing the temperature the grains sizes are continuously increasing at 1100 C and 1200 C show grain boundaries are overlapped to each other and sample sintered at 1300°C shows grain boundaries are completely overlapped to each other. In case $GdMNO_3$ samples increasing the sintering temperature a normal grain growth is observed and grain are in nanorange.

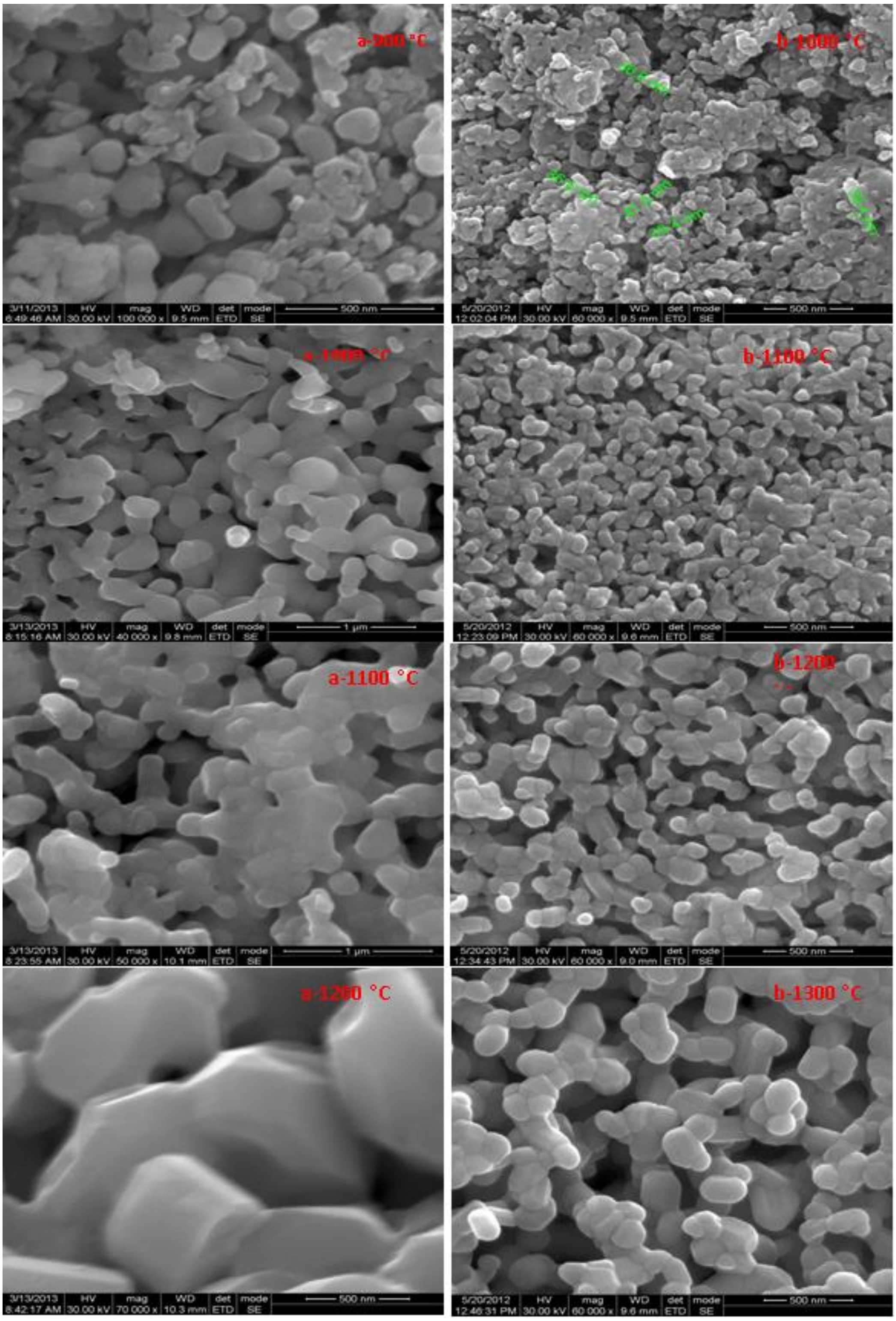
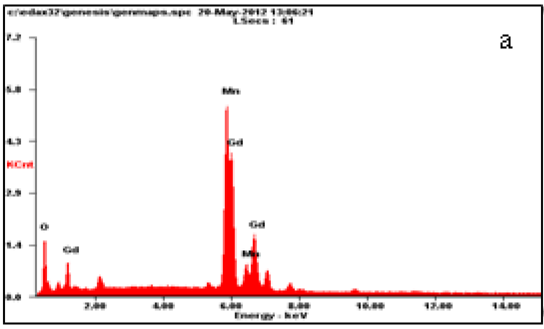


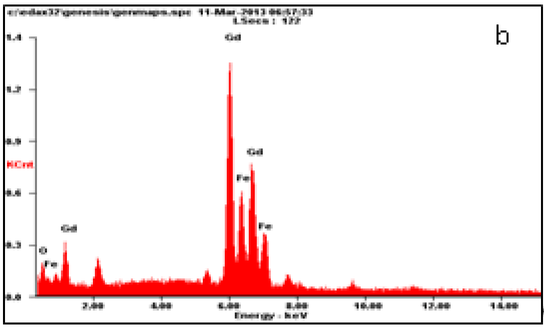
Fig. 4: HR SEM images of (a) GdMnO3 (b) GeFeO3 samples at different temperatures

Fig.4b. Shows HRSEM images of the $GdFeO_3$ nano particles, increase the grain sizes with increasing the sintered temperatures. But grain growth in this case observes to be abnormal in which small grain are overlapping with forming as larger grains

Fig.5. shows the EDAX elemental analysis of the $GdMnO_3$ & $GdFeO_3$ samples. Based on these profiles, we were confirmed the presence of the gadolinium (Gd), manganese (Mn) and iron (Fe), Oxygen (O) with weight percentage and atomic percentage in $GdMnO_3$ & GdFeO samples sintered at 1300° C & 1200° C respectively.



Element	Wt%	At%
OK	10.26	40.88
MnK	30.13	34.95
GdL	59.61	24.16
Matrix	Correction	ZAF



Element	Wt%	At%
OK	17.35	60.71
GdL	67.39	23.99
FeK	15.26	15.30
Matrix	Correction	ZAF

Fig. 5: EDAX elemental analysis of a) $GdMnO_3$ & b) $GdFeO_3$

Fig.6. Magnetic behavior of GdMnO3 and GdiFeO3 nanoparticles are studied by (M- H) hysteresis loops of the samples at different temperatures. Fig.6a. shows $GdMnO_3$ (sintered at 1300° C) nanoparticles shows antiferromagnetism at 20K. In this material magnetic frustration occurring due to competing exchange integrals between successive neighbours stabilizes a spiral magnetic phase below the Neel temperature result. in which the Mn spins are antiferromagnetically arranged in the a-b plane and Gd spins stacked ferromagnetically up the c-axis [17]. As result the canting of anti-ferromagnetically Mn moments along the a-b axis over comes ferromagnetically Gd spins along the c-axis result C- type anti-ferromagnetic behavior below the Neel temperature. On increasing the temperature of GdMnO3 sample at 100K it shows the paramagnetic in nature. $GdMnO_3$ sample under goes from antiferromagneytic nature to paramagnetic nature below the 100K. In which antiferromagnetically Neel temperature exist at 65K (TN). Decreasing the temperature below 20K there will be an weak-ferromagnetic behavior is observed due to the contribution of the net moment of the Gd spins is larger than that of the antiferromagnetically canted state of the Mn spins, giving rise to a ferromagnetic like loop because the external magnetic field aligns the Gd moments [18].

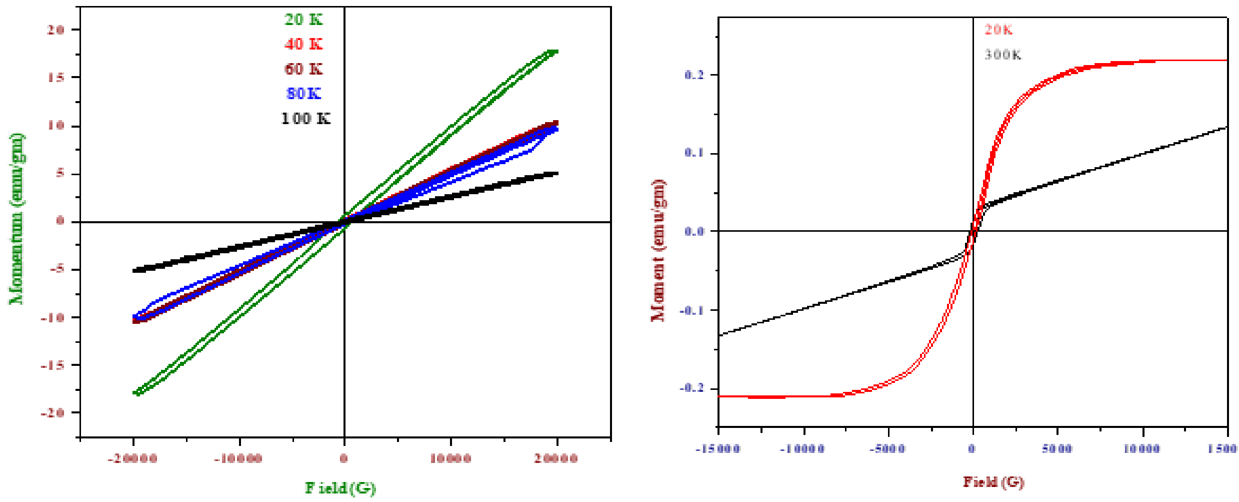


Fig. 6: M-H Hysteresis loops of a) GdMnO3 & b) GdFeO3 sintered at1300° C &1200° C.

Fig. 6b. from the M-H hysteresis loop GdFeO3 nanoparticles exhibits weak ferromagnetism at room temperature and the magnetization increased with decreasing the temperature from 300K to 20K. Which provide weak ferromagnetism at room temperature because of a residual moment caused by a canted spin structure exists in the sample. The weak ferromagnetism arises from the low symmetry of the magnetic unit cell, producing, a spin canted structure of the Fe s sublattice, which is due to the tilting of the Fe-O-Fe bonds. The reason for decreasing the magnetization with temperature at 300K is due to the very the ordering of the Gd and Fe magnetic sub lattices. In case of $GdFeO_3$ under goes from the antiferromagnetic to paramagnetic atT_N= 657K [19] Multiferroic materials possess spontaneous polarization which can be reversed by application of electric field.

The existence of P-E hysteresis loop in dielectric materials implies that the substance possesses a spontaneous polarization and the value of the remanent polarization depends on the number of factors such as the dimensions of the specimen, the temperature, thermal and electrical properties of materials.

Fig.7. shows the P-E hysteresis loops of GdMnO3 and GdFeO3 nanoparticles at different temperatures. P-E hysteresis loops of GdMnO3 and GdFeO3 nanoparticles sintered at various temperatures measured at room temperatures. It is observed that as the temperature is increased the degree of loop squareness increases in a better homogeneity and nearly uniformity of grain size and also based on the morphological studies by SEM images. It is observed that as increasing the sintering temperature incases the remnant the polarization (P.) increases indicating high internal polarization, strain, electromechanical coupling and electroptic activity. [20].

From.7a. Sample GdMnO**3** sintered at 1200°C shows hysteresis loop with saturated polarization 0.016 $\mu C/cm^2$ and increasing the temperature at 1300°C of the sample with well shaped hysteresis loop occurs, which belong to non centrosymmentry orthorhombic structure with saturation polarization 0.2 $\mu C/cm^2$. It is observe that above two cases there is a small leakage current in the sample which result in unclosed hysteresis loop this may be due to deviation from oxygen stoichiometry leads to valence fluctuation of Mn ions +3 to +2 state, which is indicated by open loop [21].

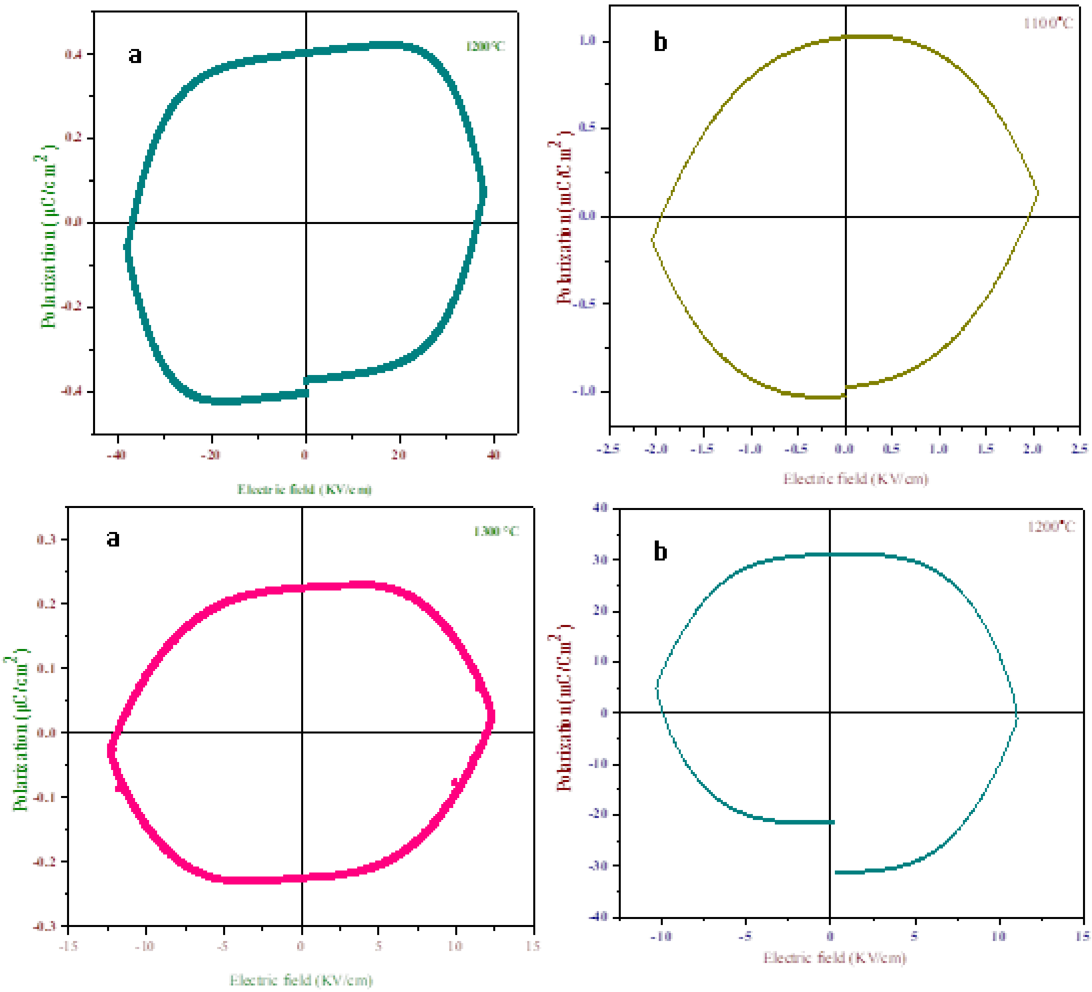


Fig. 7: P-E hysteresis loops of a) GdMnO3 (1200 & 1300° C) b) GdFeO3 (1100 & 1200°C)

From.7b. sample $GdFeO_3$, sintered at 1100°C shows hysteresis loop with saturated polarization Ipc/em and the $GdFeO_3$, nanoparticles sintered at 1200°C shows hysteresis loop with saturated polarization 30C/cm^3. However, in above two cases there is a small leakage current in the sample which result in unclosed hysteresis loop is observed. In generally small leakage of maybe due to deviation from oxygen stoichiometry leads to valence fluctuation of Fe ions+3 to +2 state in $GdFeO_3$[22]. The generation of ferroelectric polarization in $GdFeO_3$ crystals due to the striction through the exchange interaction between the Gd and Fe spins.

Conclusion:

In summary, it could be concluded that $GdMnO_3$ & $GdFeO_3$; nanoparticles have successfully been synthesized using chemical co-precipitation method and thus we got good quality single phase samples by sintering the sample at different temperatures. XRD analysis of the $GdMnO_3$ & $GdFeO_3$ samples shows the optimized sintered temperature 1300° C and 1200° C. Both structural and morphological understandings of the samples have been made based on the measurements of SEM, and EDAX, features. TG curve, thermal decomposition processes is analyzed and during the thermal process energy change in sample and its crystallinity based on the exothermic peak have been analyzed for these two samples. In case of $GdMnO_3$, nanoparticles antiferromagnetisum is observed at 20K and its Neel temperature is TN = 65K. From the M-H hysteresis loopof $GdFeO_3$ nanoparticles are show weak ferromagnetism at 20K and its magnetization is decreased at room temperature and its Neel temperature is at 657K. Ferroelectric critical temperature exists at different temperatures 335°C, 405°C and 486°C due to the structural phase transition. From the ferroelectric measurement $GdMnO_3$ & $GdFeO_3$ nanoparticles samples exhibiting at room temperature P-E hysteresis loop saturation polarization is 0.2 pc/cm² (1300°C) and 30 μC/cm² (1200°C) respectively.

References:

1. Feyerherm, R., Dudzik, E., Wolter, A. U. B., Valencia, S. (2009). Magnetic-field induced effects on the electric polarization in RMnO. *Phys. Rev. B, 79*, 134426.
2. Chupis, F. (2011). Some features of the phase diagram of the ferroelectromagnet TbMnO3. *LowTemp. Phys., 37*, 126-132.
3. Arima, T.-H. (2011). Spin-Driven Ferroelectricity and Magneto-Electric Effects in Frustrated Magnetic Systems. *J. Phys. Soc. Jpn., 80*, 052001.
4. Andreev, N., Abramov, N., Chichkov, V. (2010). Fabrication and Study of GdMnOs Multiferroic Thin Films. *Acta. Phys. Pol. A., 117*, 218-220.
5. Pimenov, A., Mukhin, A. A., Ivanov, V. Y. (2006). Possible evidence for electromagnons in multiferroic manganites. *Nat. Phys., 2*, 97-100.
6. Mostovoy, M. (2006). Ferroelectricity in spiral magnets. *Phys. Rev. Lett., 96*, 067601.
7. Tokunaga, Y., Furukawa, N. (2009). Composite domain walls in multiferroic perovskite ferrite. *Nat. Mater., 8*, 558-562.
8. Tokura, Y. (2007). Multiferroics towards strong coupling between magnetization and polarization in solid. *J. Magn. Magn. Mater, 310*, 1145-1150.
9. Geller, S. (1956). Crystal structure of gadalonium orthoferrite GdFeO3. *J. Chem. Phys., 24*, 1236-1239.
10. Ramesh, R., Spaldin, N. A. (2007). Multiferroics: Progress and prospects in thin films. *Nat. Mat., 6*, 21-29.
11. Yamasaki, Y. (2007). Electric control of spin helicity in a magnetic ferroelectric. *Phys. Rev. Lett., 98*, 147204.
12. Ramachandran, V. S., Paroli, R. M. (2002). *Handbook of thermal analysis of construction materials.* Noyes Publications, Norwich, New York.

13. Ohta, S., Kosaka, T., Sato, K. (2010). Study of Gadolinium-doped Cerium Oxide by XRD, TG-DTA, impedance analysis, and positron lifetime spectroscopy. *J. Phys: Conference Series., 225*, 012043.
14. Hui, S., Jiayue, X., Anhua, W. (2010). Preparation and characterization of perovskite RE FeO3 nanocrystalline powders. *J. Rare Earths*, *28*, 416-419.
15. Soderlindl, S. F., Fortin, M. A. (2008). Collidel Synthesis and characterization of ultrafine perovskite GdFeO3 nanocrystals. *Nanotechnology*, *19*, 085608.
16. Saurabh, S., Sengar, K. (2012). Size and alloying induced changes in lattice constant, core and valance band binding energy in Pd-Ag, Pd and Ag nanoparticles: Effect of in-flight sintering temperature. *J. Appl. Phys., 112*, 014307.
17. Xavier, S., Thankachan, S. (2013). Effect of sintering temperature on the structural and magnetic properties of Cobalt ferrite nanoparticles. *Nanosystems: Phys., Chem., Mat., 4*, 430-437.
18. Kim, B. H., Min, B. I. (2009). *Phys. Rev. B, 80*, 064416.
19. Dzyaloshinsky. (1958). *J. Phys, chem. Solids., 4*, 241-255.
20. Wang, Y. P., Zhou, L., Zhang, M. F. (2004). Room temperature saturated ferroelectric polarization in BiFeO3 ceramics synthesized by rapid liquid phase sintering. *Appl. Phys. Latt., 84*, 1731-1733.
21. Samataray, S., Mishra, D. K. (2013). Correlation between structural, electric and magnetic properties of GdMnO3 bulk ceramics. *J. Magn. Magn. Mater., 339*, 168-174.
22. Rahman, S. A. (2006). Temperature, frequency and composition dependence of dielectric properties of Nb substituted Li-Ferrites. *Egypt. J. Solids., 29*, 131.

CONSTRUCTED WETLAND- A WAY FORWARD TO NATURAL TREATMENT

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Abstract:

Wetlands, either constructed or natural, offer a cheaper and low-cost alternative technology for wastewater treatment. A constructed wetland system that is specifically engineered for water quality improvement as a primary purpose is termed as a 'Constructed Wetland Treatment System' (CWTS). In the past, many such systems were constructed to treat low volumes of wastewater loaded with easily degradable organic matter for isolated populations in urban areas. However, widespread demand for improved receiving water quality, and water reclamation and reuse, is currently the driving force for the implementation of CWTS all over the world. Constructed wetland system are engineered systems that have been designed and constructed to utilize the natural process involving wetland vegetations, soils and their associated microbial assemblages to assist in treating waste water. They are designed to take advantages of many of the process that occur in natural wetlands, but do so within a more controlled environment. Synonymous terms to constructed wetland include manmade, engineered or artificial wetlands.

Keywords: Constructed wetland-types-wetland plants-Design-Nutrient removal

Why constructed wetland

Constructed wetlands can treat wastewater from a variety of sources. One of the more common uses is to provide additional or advanced treatment of wastewater from homes, businesses and even communities. Wetlands treat wastewater that has already had most of the solid materials removed from it through some type of primary or secondary treatment.

Homes, businesses, farms, schools and other individual wastewater sources in rural areas sometimes can add a constructed wetland to a septic system or other onsite system to replace or assist a soil absorption field. Some onsite systems can be specifically designed from the start to use a constructed wetland in addition to a soil absorption field on properties with site constraints, such as tight or saturated soils.

Wetlands are good at handling intermittent periods of both light and heavy wastewater flows. Therefore, they often work well with wastewater treatment systems that serve hotels, campsites, resorts and recreational areas. In environmentally sensitive areas, constructed wetlands can be used with onsite systems to improve the quality of the effluent before it is returned to the environment. They are also used on farms as an inexpensive way to provide extra treatment to animal wastes and by certain industries such as pulp and paper mills. Constructed wetlands are common in mining regions and are used to treat mine drainage.

Wetlands are not practical for treating industrial wastewater that includes pesticides, herbicides or large amounts of ammonia. Additionally, wetland plants may accumulate high concentrations metals from some wastewater sources. This may affect the habitat value of the wetland.

Natural wetlands vs. constructed wetlands

Constructed wetlands, in contrast to natural wetlands, are man-made systems or engineered wetlands that are designed, built and operated to emulate functions of natural wetlands for human desires and needs. It is created from a non-wetland ecosystem or a former terrestrial environment, mainly for the purpose of contaminant or pollutant removal from wastewater (Zhang *et al*., 2014).

These constructed wastewater treatments may include swamps and marshes. Most of the constructed wetland systems are marshes. Marshes are shallow water regions dominated by emergent herbaceous vegetation including cattails, bulrushes, rushes and reeds.

Types and wise use of constructed wetland treatment systems

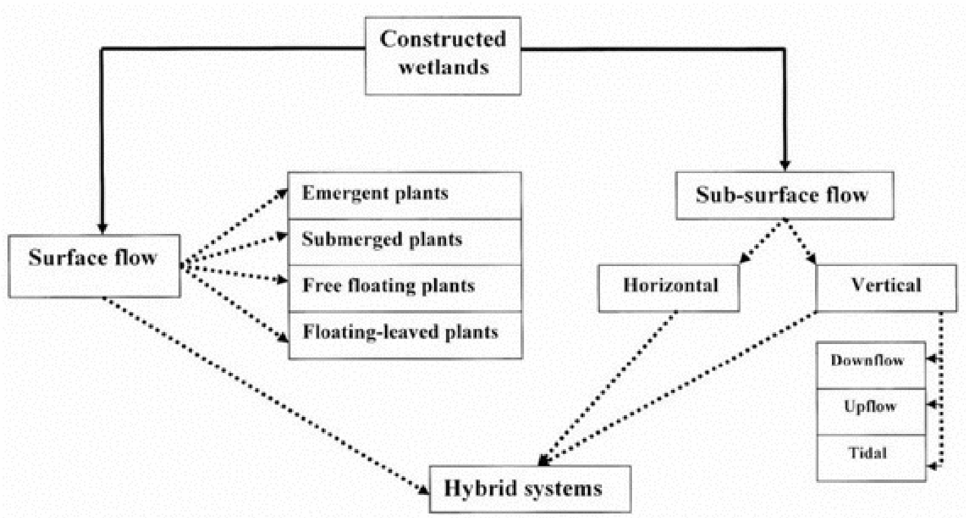

Fig. 1: Classification of constructed wetlands for wastewater treatment

Constructed wetlands could be classified according to the various parameters but two most important criteria are water flow regime (Surface and subsurface) and the type of macropytic growth (Fig.1). Different types of constructed wetlands may be combined with each other (so called hybrid of combined system) in order to exploit the specific advantages of the different systems. The quality of the final effluent from the systems improves with the complexity.

Horizontal flow system (HFS) is, wastewater is fed at the inlet and flows horizontally through the bed to the outlet. Vertical flow systems (VFS) are fed intermittently and drain vertically through the bed via a network of drainage pipes.

Surface Flow (SF): The use of SF systems is extensive in North America. These systems are used mainly for municipal wastewater treatment with large wastewater flows for nutrient polishing. The SF system tends to be rather large in size with only a few smaller systems in use. The majority of constructed wetland treatment systems are Surface-Flow or Free-Water surface (SF) systems. These types utilise influent waters that flow across a basin or a channel that supports a variety of vegetation, and water is visible at a relatively shallow depth above the surface of the substrate materials. Substrates are generally native soils and clay or impervious geotechnical materials that prevent seepage (Vymazal, 2007). Inlet devices are installed to maximise sheetflow of wastewater through the wetland, to the outflow channel. Typically, bed depth is about 0.4 m

Sub-surface Flow (SSF) system: The SSF system includes soil-based technology which is predominantly used in Northern Europe and the vegetated gravel beds are found in Europe, Australia, South Africa and almost all over the world. In a vegetated Sub-surface Flow (SSF) system, water flows from one end to the other end through permeable substrates which is made of mixture of soil and gravel or crusher rock. The substrate will support the growth of rooted emergent vegetation. It is also called "Root-Zone Method" or "Rock-Reed-Filter" or "Emergent Vegetation Bed System". The media depth is about 0.6 m deep and the bottom is a clay layer to prevent seepage. Media size for most gravel substrate ranged from 5 to 230 mm with 13 to 76 mm being typical. The bottom of the bed is sloped to minimize water that flows overland. Wastewater flows by gravity horizontally through the root zone of the vegetation about 100-150 mm below the gravel surface. Many macro and micro-organisms inhabit the substrates. Free water is not visible. The inlet zone has a buried perforated pipe to distribute maximum flow horizontally through the treatment zone. Treated water is collected at outlets at the base of the media, typically 0.3 to 0.6 m below bed surface (Cui *et al*., 2015).

Establishment of constructed wetland treatment systems

The creation of a constructed wetland treatment system can be divided into a wetland construction and vegetation establishment stage. Wetland construction includes pre-construction activities such as land clearing and site preparation, followed by construction of a wetland landform and installation of water control structures. In the stage of site clearing and grubbing, the site is cleared and existing vegetation is removed to allow construction of wetland cells. All tree root stumps and rubble below ground should be removed. Some endemic species with conservation values should be transferred off site for ex-conservation or protected intact on the site. For land forming, tractors are used to remove and stockpile top soil's from the created wetland to be reused. General contours of the wetland are graded, followed by the construction of wetland cell berms by compacting soil and installing of liners. Deep zones and islands will be created. Final site grading consists of leveling the wetland cell bottom to optimize the spreading and sheet flow of wastewaters in the completed wetland. The wetland cells are flooded to a 'wet' condition for planting. Wetland plants are transferred to the site and planted manually. After plants are established, water levels are gradually increased to normal water levels, and wetlands are completely created.

Role of wetlands plants in wastewater treatment

In general, the most significant functions of wetland plants (emergent) in relation to water purification are the physical effects brought by the presence of the plants. The plants provide a huge surface area for attachment and growth of microbes. The physical components of the plants stabilize the surface of the beds, slow down the water flow thus assist in sediment settling and trapping process and finally increasing water transparency.

Wetland plants play a vital role in the removal and retention of nutrients and help in preventing the eutrophication of wetlands. A range of wetland plants has shown their ability to assist in the breakdown of wastewater. The Common Reed *Phragmites karka* and Cattail *Typha angustifolia* are good examples of marsh species that can effectively uptake nutrients. These plants have a large biomass both above (leaves) and below (underground stem and roots) the surface of the substrate. The sub-surface plant tissues grow horizontally and vertically, and create an extensive matrix, which binds the soil particles and creates a large surface area for the uptake of nutrients and ions.

Hollow vessels in the plant tissues enable oxygen to be transported from the leaves to the root zone and to the surrounding soil (Hadidi, 2021). This enables the active microbial aerobic decomposition process and the uptake of pollutants from the water system to take place.

The roles of wetland plants in constructed wetland systems can be divided into 6 categories:

(i) Physical: Macrophytes stabilize the surface of plant beds, provide good conditions for physical filtration, and provide a huge surface area for attached microbial growth. Growth of macrophytes reduces current velocity, allowing for sedimentation and increase in contact time between effluent and plant surface area, thus, to an increase in the removal of Nitrogen.

(ii) Soil hydraulic conductivity: Soil hydraulic conductivity is improved in an emergent plant bed system. Turnover of root mass creates macropores in a constructed wetland soil system allowing for greater percolation of water, thus increasing effluent/plant interactions.

(iii) Organic compound release: Plants have been shown to release a wide variety of organic compounds through their root systems, at rates up to 25% of the total photo synthetically fixed carbon. This carbon release may act as a source of food for denitrifying microbes (Wang et al., 2017). Decomposing plant biomass also provides a durable, readily available carbon source for the microbial populations.

(iv) Microbial growth: Macrophytes have above and below ground biomass to provide a large surface area for growth of microbial biofilms. These biofilms are responsible for a majority of the microbial processes in a constructed wetland system, including Nitrogen reduction.

Plants create and maintain the litter/humus layer that may be likened to a thin biofilm. As plants grow and die, leaves and stems falling to the surface of the substrate create multiple layers of organic debris (the litter/humus component). This accumulation of partially decomposed biomass creates highly porous substrate layers that provide a substantial amount of attachment surface for microbial organisms. The water quality improvement function in constructed and natural wetlands is related to and dependent upon the high conductivity of this litter/humus layer and the large surface area for microbial attachment.

(v) Creation of aerobic soils: Macrophytes mediate transfer of oxygen through the hollow plant tissue and leakage from root systems to the rhizosphere where aerobic degradation of organic matter and nitrification will take place. Wetland plants have adaptations with suberized and lignified layers in the hypodermis and outer cortex to minimize the rate of oxygen leakage.

The high Nitrogen removal of *Phragmites* is most likely attributable to the characteristics of its root growth. *Phragmites* allocates 50% of plant biomass to root and rhizome systems. Increased root biomass allows for greater oxygen transport into the substrate, creating a more aerobic environment favoring nitrification reactions. Nitrification requires a minimum of 2 mg O2/l to proceed at a maximum rate. It is evident that the rate of nitrification is most likely the rate limiting factor for overall Nitrogen removal from a constructed wetland system (Cangioli et al., 2022)

(vi) Aesthetic values: The macrophytes have additional site-specific values by providing habitat for wildlife and making wastewater treatment systems aesthetically pleasing.

Selection of wetland plants

Floating and submerged plants are used in an aquatic plant treatment system. A range of aquatic plants have shown their ability to assist in the breakdown of wastewater. The Water Hyacinth (*Eichhornia crassipes*), and Duckweed (*Lemna*) are common floating aquatic plants which have shown their ability to reduce concentrations of BOD, TSS and Total Phosphorus and Total Nitrogen. However prolonged presence of *Eichhornia crassipes* and *Lemna* can lead to deterioration of the water quality unless these plants are manually removed on a regular basis. These floating plants will produce a massive mat that will obstruct light penetration to the lower layer of the water column that will affect the survival of living water organisms. This system is colonised rapidly with one or only a few initial individuals. The system needs to be closely monitored to prevent attack from these nuisance species. Loss of plant cover will impair the treatment effectiveness. Maintenance cost of a floating plant system is high. Plant biomass should be regularly harvested to ensure significant nutrient removal. Plant growth also needs to be maintained at an optimum rate to maintain treatment efficiency.

The Common Reed (*Phragmites* spp.) and Cattail (*Typha* spp.) are good examples of emergent species used in constructed wetland treatment systems. Plant selection is quite similar for SF and SSF constructed wetlands. Emergent wetland plants grow best in both systems. These emergent plants play a vital role in the removal and retention of nutrients in a constructed wetland. Although emergent macrophytes are less efficient at lowering Nitrogen and Phosphorus contents by direct uptake due to their lower growth rates (compared to floating and submerged plants), their ability to uptake Nitrogen and Phosphorus from sediment sources through rhizomes is higher than from the water.

Design and principles of constructed wetland systems

The principal design criterion for a constructed wetland system includes substrate types, pollutant loading rate and retention time. Some design criteria are discussed in detail as below.

Choice of wetland plant species: The selected wetland plants are preferred because they have a rapid and relatively constant growth rate. In a tropical system, wetland plants have a higher growth rate. These wetland plants are easily propagated by means of runners and by bits of mats breaking off and drifting to new areas. This will help in increasing the capacity of pollutant absorption by the plants. The plants should also be able to tolerate waterlogged-anoxic and hyper-eutrophic conditions (Wang *et al*., 2018).

The plant species should be local species and widely distributed in the country. Use of exotic plants in constructed wetland systems should be avoided as they are highly invasive and difficult to control. The plant should be a perennial with a life cycle of more than one year or two growing seasons to ensure the sustainability of the constructed wetland system. Wetland plants with aesthetic appeal will provide a landscape-pleasing environment.

Substrates: Substrates may remove wastewater constituents by ion exchange/non-specific adsorption, specific adsorption/precipitation and complexation.

The choice of substrate is determined in terms of their hydraulic permeability and their capacity to absorb nutrients and pollutants. The substrate must provide a suitable medium for successful plant growth and allow even infiltration and movement of wastewater (Wang *et al*., 2018). Poor hydraulic conductivity will result in surface flow and channeling of wastewater, severely reducing the effectiveness of the system.

A successful operation requires a hydraulic conductance of approximately 10^{-3} to 10^{-4} m^{-1} s^{-1}. The chemical composition of the substrate will also affect the efficiency of the system. Soils with low nutrient content will encourage direct uptake of nutrients from the wastewater by plants. Substrate with high Al or Fe content will be most effective at lowering Phosphate concentrations in the influent. Gravels are washed to reduce clogging (increase void spaces) for better filtration. The reed system on gravel reached better nitrification rates, while denitrification was higher in the soil-based reed system (Haiming *et al*., 2015).

A mixture of organic clay soils, sand, gravels and crushed stones could be used to provide support for plant growth. These substrates are ideal reactive surfaces for ion complexation and microbial attachment, also provide a sufficiently high hydraulic conductivity to avoid short-circuiting in the system.

Area of reed bed: Most wastewater treatment wetlands have been designed for minimum size and cost to provide the required level of pollutant removal. However, operation and maintenance costs may be high. The creation of a maximum effective treatment area will reduce the short-circuiting problem. Generally, horizontal flow wastewater treatment systems should have a 3-4: 1 length to width ratio and be rectangular in shape if minimal treatment area is available. A long length-width ratio is required to ensure plug flow hydraulics (Rahman *et al*., 2020). The required surface area for a sub-surface flow system is calculated according to an empirical formula for the reduction of BOD5 in sewage effluent (Moreira and Dias, 2020).

$$\mathbf{Ah = KQd\ (In\ C0 - In\ Ct)}$$

Where,

Ah = surface area of bed, m^2

K = rate constant, $m\ d^{-1}$

Qd= average daily flow rate of wastewater ($m^3\ d^{-1}$)

C0 = average daily BOD5 of the influent ($mg\ L^{-1}$)

Ct = required average daily BOD5 of the effluent ($mg\ L^{-1}$)

The value of K = 5.2 was derived for a 0.6 m deep bed and operating at a minimum temperature of 80C. For less biodegradable wastewater, K values of up to 15 may be appropriate. Using this formula, a minimum area of 2.2 $m^2\ pe^{-1}$ is obtained for the treatment of domestic sewage. In practice, most design systems operate on the basis of 3-5 m2 pe^{-1}.

Nature, loading and distribution of effluent: The long-term efficiency of an emergent bed system is improved if the effluent is pre-treated prior to discharge to the active bed. Suspended particles are settled during storage in a settlement tank or a pond for 24 hours. The BOD of the primary effluent may be reduced by 40%. The removal of Nitrogen and Phosphorus for secondary wastewater is higher (Hammer, 2020).

The flow of wastewater through the emergent bed system is slow, giving a long retention time, therefore the flow must be regulated so that retention times are sufficiently long for pollutant removal to be efficient. A higher reduction efficiency for mass balances of N and P could be achieved by *Phragmites* if water retention time is more than 5 days. Shorter retention times do not provide adequate time for pollutant degradation to occur. Longer retention times can lead to stagnant and anaerobic conditions. Evapotranspiration can significantly increase the retention time.

Examples of wetland plants

There is a variety of marsh vegetation that is suitable for planting in a CWTS (Table 1). These marsh species could be divided into deep and shallow marshes.

Table 1: List of emergent wetland plants used in constructed wetland treatment systems

Planting zones	**Common name**	**Scientific name**
Marsh and deep marsh (0.3-1.0 m)		
	Common Reed	*Phragmites karka*
	Spike Rush	*Eleocharis dulcis*
	Greater Club Rush	*Scirpus grossus*
	Bog Bulrush	*Scirpus mucronatus*
	Tube Sedge	*Lepironia articulata*
	Fan Grass	*Phylidrium lanuginosum*
	Cattail	*Typha angustifolia*
Shallow marsh (0-0.3 m)		
	Golden Beak Sedge	*Rhynchospora corymbose*
	Spike Rush	*Eleocharis variegata*
	Sumatran Scleria	*Scleria sumatrana*
	Globular Fimbristylis	*Fimbristylis globulosa*
	Knot Grass	*Polygonum barbatum*
	Asiatic Pipewort	*Erioucaulon longifolium*

Constructed wetland treatment mechanisms

Wetlands have been found to be effective in treating BOD, TSS, N and P as well as for reducing metals, organic pollutants and pathogens. The principal pollutant removal mechanisms in constructed wetlands include biological processes such as microbial metabolic activity and plant uptake as well as physico-chemical processes such as sedimentation, adsorption and precipitation at the water-sediment, root-sediment and plant-water interfaces (Malyan *et al.*, 2021).

Microbial degradation plays a dominant role in the removal of soluble/colloidal biodegradable organic matter in wastewater. Biodegradation occurs when dissolved organic matter is carried into the biofilms that attached on submerged plant stems, root systems and surrounding soil or media by diffusion process. Suspended solids are removed by filtration and gravitational settlement.

A pollutant may be removed as a result of more than one process at work.

Nitrogen removal mechanisms: There are sufficient studies to indicate some roles being played by wetland plants in Nitrogen removal but the significance of plant uptake vis-à-vis nitrification/denitrification is still being questioned. Nitrogen (N) can exist in various forms, namely Ammoniacal Nitrogen (NH_3 and NH_4^+), organic Nitrogen and oxidised Nitrogen (NO^{2-} and NO^{3-})· The removal of Nitrogen is achieved through nitrification/denitrification, volatilisation of Ammonia (NH_3) storage in detritus and sediment, and uptake by wetland plants and storage in plant biomass (Ge *et al*., 2020). A majority of Nitrogen removal occurs through either plant uptake or denitrification. Nitrogen uptake is significant if plants are harvested and biomass is removed from the system.

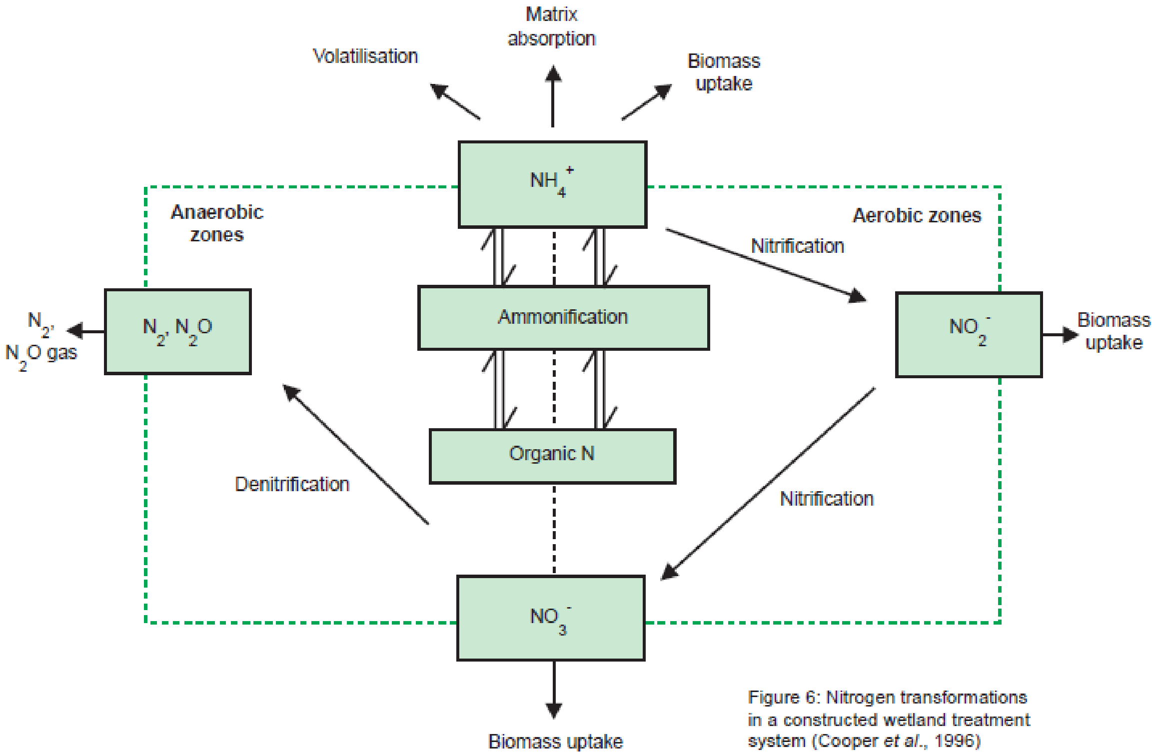

Fig. 2: Nitrogen transformations in a constructed wetland system

At the root-soil interface, atmospheric oxygen diffuses into the rhizosphere through the leaves, stems, rhizomes and roots of the wetland plants thus creating an aerobic layer similar to those that exists in the media-water or media-air interface. Nitrogen transformation takes place in the oxidised and reduced layers of media, the root-media interface and the below ground portion of the emergent plants. Ammonification takes place where Organic N is mineralised to NH_4^+-N in both oxidised and reduced layers. The oxidised layer and the submerged portions of plants are important sites for nitrification in which Ammoniacal Nitrogen (AN) is converted to nitrite N (NO_2-N) by the *Nitrosomonas* bacteria and eventually to nitrate N (NO_3-N) by the *Nitrobacter* bacteria which is either taken up by the plants or diffuses into the reduced zone where it is converted to N_2 and N_2O by the denitrification process.

Denitrification is the permanent removal of Nitrogen from the system, however the process is limited by a number of factors, such as temperature, pH, redox potential, carbon availability and nitrate availability. The annual denitrification rate of a surface-flow wetland could be determined using a Nitrogen mass-balance approach, accounting for measured influx and efflux of Nitrogen, measured uptake of Nitrogen by plants, and sediment, and estimated NH_3 volatilisation (Vymazal, 2013).

The extent of Nitrogen removal depends on the design of the system and the form and amount of Nitrogen present in the wastewater (Fig 2). If influent Nitrogen content is low, wetland plants will compete directly with nitrifying and denitrifying bacteria for NH_4^+ and NO_3-, while in high Nitrogen content, particularly Ammonia, this will stimulate nitrifying and denitrifying activity (Vymazal, 2013).

Phosphorus removal mechanisms: Phosphorus is present in wastewaters as Orthophosphate, Dehydrated Orthophosphate (Polyphosphate) and Organic Phosphorus. The conversion of most Phosphorus to the Orthophosphate forms (H_2PO_4-, Po_4^{2-}, $PO_4^{3-)}$ is caused by biological oxidation.

Most of the Phosphorus component may fix within the soil media. Phosphate removal is achieved by physical-chemical processes, by adsorption, complexation and precipitation reactions involving Calcium (Ca), Iron (Fe) and Aluminium (Al). The capacity of wetland systems to absorb Phosphorus is positively correlated with the sediment concentration of extractable Amorphous Aluminium and Iron (Fe).

Although plant uptake may be substantial, the sorption of Phosphorus (Orthophosphate P) by anaerobic reducing sediments appears to be the most important process. The removal of Phosphorus is more dependent on biomass uptake in constructed wetland systems with subsequent harvesting.

Plant uptake: Nitrogen will be taken up by macrophytes in a mineralised state and incorporated it into plant biomass. Accumulated Nitrogen is released into the system during a die-back period. Plant uptake is not a measure of net removal. This is because dead plant biomass will decompose to detritus and litter in the life cycle, and some of this Nitrogen will leach and be released into the sediment.

Metals: Metals such as Zinc and Copper occur in soluble or particulate associated forms and the distribution in these forms are determined by physico-chemical processes such as adsorption, precipitation, complexation, sedimentation, erosion and diffusion. Metals accumulate in a bed matrix through adsorption and complexation with organic material. Metals are also reduced through direct uptake by wetland plants. However over-accumulation may kill the plants.

Pathogens: Pathogens are removed mainly by sedimentation, filtration and absorption by biomass and by natural die-off and predation.

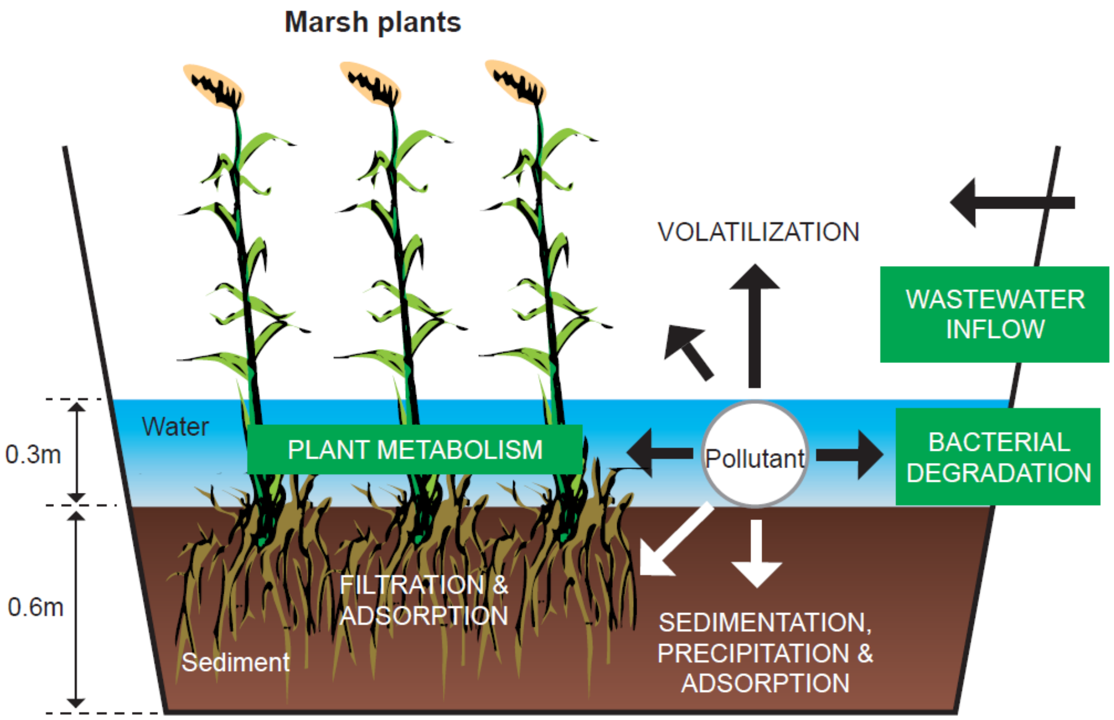

Fig. 3: Pollutant removal processes in a constructed wetland system

Other pollutant removal mechanisms: Evapotranspiration is one of the mechanisms for pollutant removal. Atmospheric water losses from a wetland that occurs from the water and soil is termed as evaporation and from emergent portions of plants is termed as transpiration. The combination of both processes is termed as evapotranspiration (Fig 3).

Daily transpiration is positively related to mineral adsorption and daily transpiration could be used as an index of the water purification capability of plants. Precipitation and evapotranspiration influence the water flow through a wetland system. Evapotranspiration slows water flow and increases contact times, whereas rainfall, which has the opposite effect, will cause dilution and increased flow. Precipitation and evaporation are likely to have minimal effects on constructed wetlands in most areas. If the wetland type is primarily shallow open water, precipitation/evaporation ratios fairly approximate water balances. However, in large, dense stands of tall plants, transpiration losses from photosynthetically active plants become significant.

Wetland monitoring and maintenance

Monitoring and maintenance of the wetland areas is a key issue in maintaining wetland functioning. Wetland monitoring is required to obtain sufficient data to determine the wetland performance in fulfilling the objectives. Wetland maintenance is required to manage macrophytes and desirable species, to remove invading weeds, to remove sediment from the wetlands, and to remove litter from the wetlands (Wu *et al*., 2015).

Effective wetland performance depends on adequate pretreatment, conservative constituent and hydraulic loading rates, collection of monitoring information to assess system performance, and knowledge of successful operation strategies. The CWTS system could be rather easy to design and construct, however it needs to be closely monitored and maintained.

Sustaining a dense stand of desirable vegetation within the wetland is crucial to ensure treatment efficiency. Aggressive species will out-compete less competitive ones and cause gradual changes in wetland vegetation. Certain undesirable plant species or weeds may be introduced to the wetland from the catchment. Natural succession of wetland plants will take place. However, some aquatic weeds may require maintenance by manually being removed. Weed invasion can dramatically reduce the ability of wetlands to meet its design objectives. For example, Pondweed (*Azolla*), Duckweed (*Lemna*), Water Fern (*Salvinia molesta*) and Water Hyacinth (*Eichhornia crassipes*) can form dense mats, exclude light and reduce dissolved oxygen in the water column, and increase the movement of nutrients through the system. Water level management is crucial to control weed growth.

Floods will cause plants to be scoured from the wetland and/or drowned. If a large area of plants is lost, re-establishment will need to be carried out. Small areas will generally recover naturally while larger areas above 5 m^2 may require replanting.

Plant viability is vital to water quality improvement in wetlands. Visible signs of plant distress or pest attack should be investigated promptly. Some common pest insects include Lepidopterrous Stem Borers on *Scirpus grossus*, aphids on *Phragmites karka* and Leaf Roller on *Phragmites karka*. Severe infestation could lead to severe stunting and death of plants. Biopesticides or narrow spectrum-pest specific insecticides could be used if pest population exceeds a certain threshold value. Other pests include the Golden Apple Snail *Pomacea sp*, which feeds actively on wetland plants.

Water levels are important in wetlands with effects on hydrology and hydraulics and impact on wetland biota. Water level should be monitored using water level control structures to ensure successful plant growth. A recirculation system should be in place to allow water from outlet points to be fed back to the wetlands to supplement catchment flows during dry periods. Suspended solids from effluents and litter fall from plants will accumulate in time and gradually reduce the pore space which has to be flushed to prevent short-circuiting. Monitoring of mosquito populations should be undertaken to avoid diseases, which can result in a local health problem.

Water quality monitoring

Water quality data are a good indication of wetland performance. Water quality should be monitored through assessment of inflow and outflow water quality parameters. Some important water quality parameters to be monitored include Dissolved Oxygen, redox potential, water temperature, pH value and turbidity, which are the in-situ parameters while laboratory analysis parameters include Total Suspended Solids (TSS), chemical conductivity, Ammoniacal Nitrogen (AN), Nitrate-Nitrogen, Phosphorus, Potassium, Magnesium, Soluble Fe, Mercury, Lead, Zinc, Iron, Cyanide, Arsenic, Phenols, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Faecal Coliforms, and Oil and Grease (Rowe and Abdel Magid, 2020).

Conclusion:

Constructed wetlands are among the recently demonstrated technologies to have a great potential for efficient wastewater treatment and management in rural and urban areas. When properly designed and operated, constructed wetlands have great advantages over conventional treatment systems for their relatively low cost, easy operation, and maintenance

References:

1. Cangioli, L., Salobehaj, M., Del Duca, S., Fagorzi, C., Berardi, C., Coppini, E., Fibbi, D., Fani, R., Vassallo, A. (2022). Effect of Wastewater on the Composition of Bacterial Microbiota of Phragmites australis Used in Constructed Wetlands for Phytodepuration. *Plants (Basel), 11*(23), 3210. doi: 10.3390/plants11233210.
2. Cui, L. (2015). Removal of nutrients from septic tank effluent with baffle subsurface-flow constructed wetlands. *J. Environ. Manage., 153*, 33-39. https://doi.org/10.1016/j.jenvman.2015.01.035
3. Ge, X., Cao, X., Song, X., Wang, Y., Si, Z., & Zhao, Y. (2020). Bioenergy generation and simultaneous nitrate and phosphorous removal in a pyrite based constructed wetland-microbial fuel cell. *Biores. Technol., 296*, 122350.
4. Hadidi, L. A. (2021). Constructed wetland: a comprehensive review. *Inter. J. Res., 9*(8), 395-417.
5. Haiming, W. U., Zhang, J., Hao, Ngo, H., Guo, W., Hu, Z., Liang, S., Fan, H., Liu, H. (2015). A review on the sustainability of constructed wetlands for wastewater treatment: Design and operation. *Biores. Technol., 175*, 594-601. doi: 10.1016/j.biotech.2014.10.068.
6. Hammer, D. A. (2020). Constructed wetlands for wastewater treatment: municipal, industrial and agricultural: CRC Press. Retrieved from https://doi.org/10.1201/9781003069850
7. Malyan, S. K., Yadav, S., Sonkar, V., Goyal, V. C., Singh, O., Singh, R. (2021). Mechanistic of the pollutant removal and transformation processes in the constructed wetland system. *Water Environ Res., 93*(10), 1882-1909. doi: 10.1002/wer.1599.

8. Moreira, F. D., & Dias, E. H. O. (2020). Constructed wetlands applied in rural sanitation: A review. *Environ. Res., 190,* p. 110016. Retrieved from https://doi.org/10.1016/j.envres.2020.110016
9. Rahman, M. E., Bin Halmi, M. I. E., Bin Abd Samad, M. Y., Uddin, M. K., Mahmud, K., Abd Shukor, M. Y., Sheikh Abdullah, S. R., Shamsuzzaman, S. M. (2020). Design, Operation and Optimization of Constructed Wetland for Removal of Pollutant. *Int. J. Environ. Res. Public Health., 11*(22), 8339. doi: 10.3390/ijerph17228339.
10. Rowe, D. R., & Abdel-Magid, I. M. (2020). Handbook of wastewater reclamation and reuse: CRC press. Retrieved from https://doi.org/10.1201/978013875251
11. Wang, H. X., Xu, J. L., Sheng, L. X., Liu, X. J. (2018). A review of research on substrate materials for constructed wetlands. *Mat. Sci. Forum., 913*, 917-929.
12. Vymazal, J. (2013). The use of hybrid constructed wetlands for wastewater treatment with special attention to nitrogen removal: A review of a recent development. *Wat. Res., 47*(14), 4795-4811.
13. Vymazal, J. (2007). Removal of nutrients in various types of constructed wetlands. *Sci. Total. Environ., 380*(1-3), 48-65.
14. Wang, M., Zhang, D. Q., Dong, J. W., Tan, S. K. (2017). Constructed wetlands for wastewater treatment in cold climate - A review. *J Environ Sci., 57*, 293-311. doi: 10.1016/j.jes.2016.12.019. 28647250.
15. Wu, H., Zhang, J., Ngo, H. H., Guo, W., Hu, Z., Liang, S. (2015). A review on the sustainability of constructed wetlands for wastewater treatment: Design and Operation. *Biores. Technol., 175*, 594-601.
16. Zhang, D. Q., Jinadasa, K. B., Gersberg, R. M., Liu, Y., Ng, W. J., Tan, S. K. (2014). Application of constructed wetlands for wastewater treatment in developing countries--a review of recent developments. *J Environ Manage., 141*, 116-31. doi: 10.1016/j.jenvman.2014.03.015.

HOW QUICKLY DO WE FORGET? - THE EBBINGHAUS MODEL

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Introduction:

"I hear and I forget. I see and I remember. I do and I understand." – Confucius. Capacity of human brain to retain memories has attracted a great deal of study so far. This chapter discusses an easy way to model the same by using a first order differential equation, as suggested by Hermann Ebbinghaus. The model is based upon the assumptions made by him, and verified experimentally time and again. It presents an excellent example of an interdisciplinary application of differential equations.

Differential equations have the potential ability to model the world around us, and hence, are widely used in various disciplines such as Economics, Psychology, Demography etc. apart from their common usage in Natural Sciences. Mental states of every kind, – sensations, feelings, ideas, – which were at one time present in consciousness and then have disappeared from it, have not with their disappearance absolutely ceased to exist [1]. Human beings tend to 'forget' the memories with time, if no attempts are made to retain them. This decline in memory retention with respect to time could be modeled mathematically. In the late 19th century, Hermann Ebbinghaus made the first attempts to apply mathematical modeling to memory and prescribed what is now known as the 'forgetting curve'. A German by birth, after receiving a doctorate in Philosophy at the age of 23, he worked in England and France for few years for livelihood. Later, he shifted to University of Berlin where he began his experiments on memory and published his famous work titled 'Memory: A Contribution to Experimental Psychology' in 1885. He made several findings including the learning curve, forgetting curve and serial position effect. Ebbinghaus performed repeated experiments by memorizing the 'non-sense syllables' (i. e. a consonant-vovel-consonant combination having no meaning) such as KUQ, ZOF and plotted the results to create the 'forgetting curve' which fitted well with an equation of the form:

$$R = e^{-t/S} \tag{1}$$

Where, R is the retrievability (how easy it is to retrieve a particular piece of information) and S is the stability (how fast the information is forgotten in the absence of revision) of the memory. It indicates that the information stored in the memory is lost exponentially.

The Ebbinghaus Model

The model could be stated with the help of following example: When a course ends, students start to forget the material they have learned. The rate at which a student forgets the material is directly proportional to the difference between the material currently remembered and some positive constant 'a' [2]. Let, $y = f(t)$ be the fraction of original material remembered t weeks (or days, for that matter) after the course has ended. Accordingly, we have,

$$\frac{dy}{dt} = -k(y - a) \tag{2}$$

Initially, at $t = 0$, if the fraction of material learnt and remembered is $y = 1$, the solution of equation (2) is:

$$y = (1 - a)e^{-kt} + a \tag{3}$$

This solution to equation (2) gives meaning to the constant 'a' in the model. Clearly, as the time $t \rightarrow \infty$, $y \rightarrow a$. Thus, 'a' is the fraction of material learnt which one would never forget. Hence, 'a' has to be less than y for all t. Further, since y is the fraction of material remembered $0 \leq y \leq 1$. The other constant 'k' determines the quality of memory, or the capability of an individual to remember things.

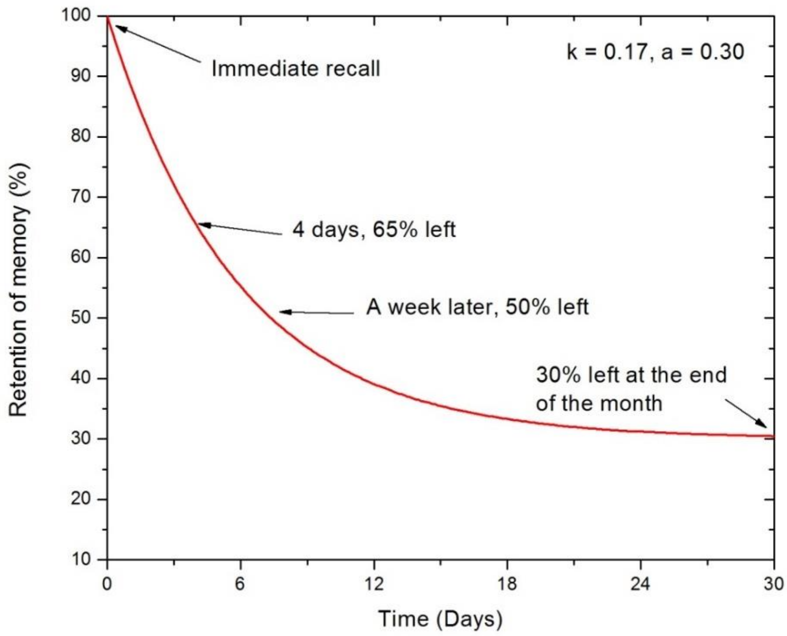

Fig. 1: The forgetting curve

How does the curve look like?

Let us try to have a visual of what is happening to the retention of memories over time. Let us have a model person with $a = 0.30$ and $k = 0.17$, and choose the time axis in days. The percentage retention decreases exponentially, as shown in Figure (1).

Clearly, the person forgets half of the material learnt within the period of a week; and by the end of the month, eventually remembers only the residual 30% (since, a has been set equal to

0.30). The nature of curve for three different values of k for a = 0.30 is displayed in Figure (2). Smaller the value of k, better is the ability of memory retention, as such a person forgets comparatively slowly. But, eventually the retention is going to fall to the same residual value, unless there is an effort to recall the memories. Sometimes, a constant which is the inverse of k is introduced for a better understanding, since k^{-1} would have dimensions of time. This new constant is analogous to the constant S in equation (1). Of course, there must be a way out to retain the memories for a longer duration (if one wishes, forever!). Ebbinghaus experimented and came out with a solution as well.

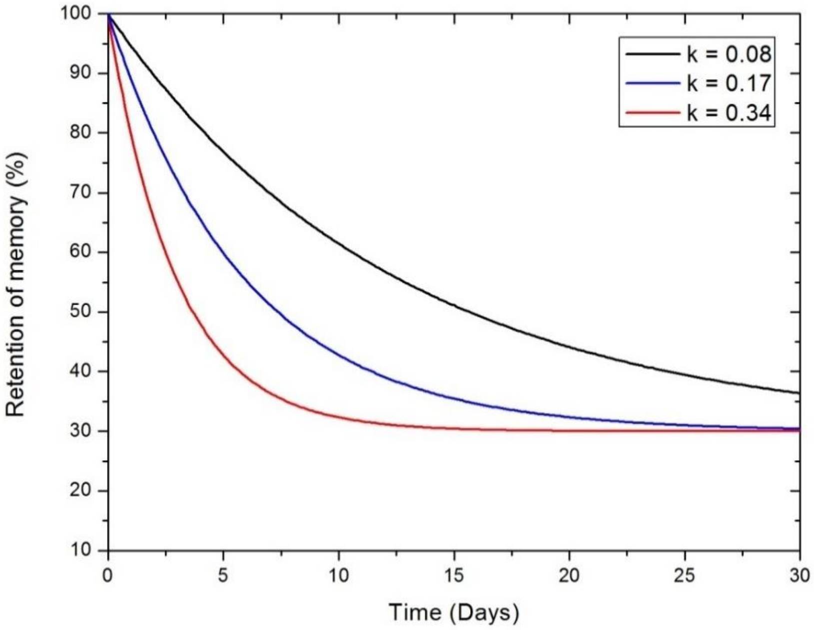

Fig. 2: Dependence on k

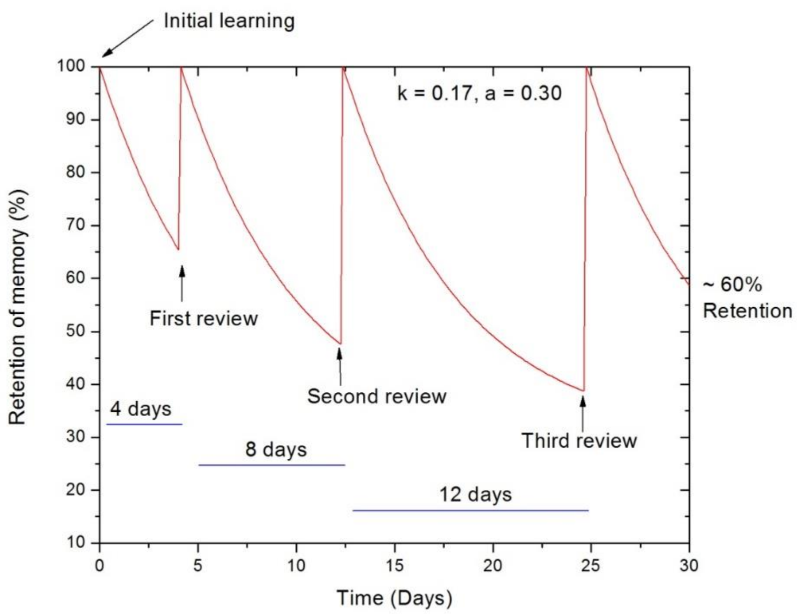

Fig. 3: Improve retention due to repetition

How to retain more?

According to Ebbinghaus [1], there are two major factors which affect the level of retention, viz. repetition and quality of memory representation. More frequently and earlier we repeat something, more likely and longer it would be retained. Thus, constant reviewing at regular intervals improves the retention. Moreover, less frequent review is required over time.

The role first of these factors could easily be understood by introducing 'reviews' in equation (3). The Figure (3) makes it clear, which shows the increased retention levels after a repeated revision of the content learnt. It is evident that at the end of the month, the retention level is much improved (to about 60% i.e. twice the residual value). Further, the duration between successive reviews goes on increasing as well. We must note that, reviewing has its own limitations. Though, reviewing the content learnt helps retention, one still tends to forget the same over time. Here comes the role of quality of memory retention, which is related to the techniques to improve the values of a and k in equation (3). If a person is able to make more meaningful connections of the new material grasped with the already learnt information, the memory retention would be better. It is intuitive enough to see how the differential equations help model the very world around us.

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References:

1. Ebbinghaus, H. (1964). *Memory: A contribution to experimental psychology (English Translation).* Dover.
2. Hughes-Hallett, Gleason, et al. (1998). *Calculus: Single Variable.* John Wiley & Sons.

A REVIEW ON LIQUID FERTILIZER PRODUCTION AND GROWING PLANTS IN HYDROPONIC CONDITION

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Abstract:

Hydroponic cultivation provides a sustainable and efficient method for growing plants in particular controlled environments, but it relies heavily on nutrient-enriched solutions. To reach these requirements of nutrients while minimizing environmental impact, producing a liquid fertilizer from beneficiary microbes has gained predominance. The cultivation process starts with the cultivation of beneficial microbes, such as nitrogen-fixing bacteria. The microorganisms involved in the degradation of substrates in the fermentation process. These microbes are then fermented in a nutrient-enriched medium which results in the production of a liquid solution containing essential plant nutrients and this carefully formulated to provide the necessary nutrients to hydroponic plants and it can be customized for specific plant types and growth stages. The main application of liquid microbial fertilizer is, that it enhances nutrient uptake by plants, leading to improved growth and increased yields and this approach reduces the reliance on chemical fertilizers, contributing to a more sustainable and environmentally friendly agricultural practice. These fertilizers produce nutritionally enriched plants that are eco-friendly. Hydroponic cultivation is an alternative to soil farming which can be advantageous in the efficient usage of nutrient and water content, pest management of plants, and usage of space.

Keywords: Hydroponic cultivation, nitrogen-fixing bacteria, fermentation process, microbial fertilizer.

Introduction:

Hydroponics is defined as the growth of plants without soil, in which the roots of plants absorb their essential nutrients from a nutrient solution (Sardare and Admane, 2013). Producing liquid fertilizer from microbes and cultivating plants in hydroponic systems represent a revolutionary approach to technological agriculture. Liquid organic fertilizer contains essential nutrients and beneficiary microorganisms that are recyclable. The important role of microorganisms is degradation of the substrates in the fermentation process. Liquid organic fertilizers contain phytohormones such as Cytokinin and Auxin, Organic acids, and Plant growth hormones in the end process of fermentation. In the hydroponics method, the nutrients were fed directly to the roots. Comparatively growing plants under the condition of soil-less based culture are over the soil based culture (Savvas, 2002). Five types of hydroponic systems are recognized.

Conventional hydroponic systems primarily use inorganic fertilizers, which can accumulate harmful nitrates in vegetables, posing risks to human health and plant growth (Anjana and Iqbal, 2007; Ikemoto *et al*., 2002; Ishiwata *et al.*, 2002). The liquid fertilizer is used as an attractive solution for hydroponics; it slowly releases nutrients through microbial conversion. They efficiently absorbed the essential macro and micronutrients for plant growth (Nasir *et al.*, 2012). This is explored using agricultural residues and waste to produce liquid organic fertilizer and evaluated its effectiveness in promoting the growth of plants in hydroponic systems. This kind of approach aligns with sustainability goals, offering a potential alternative to chemical fertilizers in hydroponics.

Fig. 1: Hydroponic farming

1. Hydroponic systems:

The systems are customized and modified based on the recycling and reusing of nutrient solutions and supporting media. Wick, drip, ebb-flow, deep water culture, and nutrient film techniques NFT) are commonly used systems.

Wick system – This is the simplest system which does not require electricity, a pump, and aerators (Shrestha and Dunn, 2013). This system relies on a wick to transport water and nutrients to the plant roots. It works depending on capillary action and Nutrient transport.

Ebb and Flow system – It works on the principle of flood and drain. It operates on a cyclic basis, periodically flooding the plant's root zone with a nutrient solution and then draining it away. It works depending on the flood cycle, absorption, and rest period (Nielsen *et al.*, 2006).

Drip system – It is also known as a drip irrigation system, and is a highly efficient method of delivering water and nutrients to plants in both traditional gardening and hydroponic setups. It works by dripping a controlled amount of water directly onto the root zone of plants (Rouphael and Colla, 2005).

Deep water culture system – It's effective for growing plants, especially in commercial setups, and for cultivating larger plants like lettuce. This method involves suspending plant roots in nutrient-rich water, allowing maximum oxygen uptake. It is mandatory to monitor the oxygen and nutrient concentrations, salinity, and pH as algae and moulds rapidly grow in reservoirs. It depends on nutrient solution, plant placement, aeration, and nutrient uptake (Domingues *et al.*, 2012).

Nutrient Film Technique (NFT) system – is well-suited for growing a variety of plants, especially leafy greens and herbs. It operates by continuously flowing a thin film of nutrient-rich water over the roots of plants, providing them with water, oxygen, and nutrients. It works depending on nutrient solution flow, gravity flow, and root absorption (Domingues *et al.*, 2012).

Fig. 2: Hydroponic systems (Wick system, Ebb & Flow system, and Drip system)

Table 1: Summarizes the sources and benefits for plants using the liquid fertilizer

Liquid organic fertilizer	**Source**	**Benefits for plants**
Compost tea	Compost or worm castings steeped in water	Rich in nutrients, microbes, and beneficial organisms. Supports overall plant health and soil biology.
Fish emulsion	Fish processing by-products	High in nitrogen and trace minerals, promotes vigorous growth, and is quickly absorbed by plants.
Seaweed extract	Kelp and other seaweed species	Contains a wide range of trace elements, vitamins, and growth hormones. Enhances root development and stress resistance.
Bone meal extract	Ground animal bones	Provides phosphorous and calcium for strong root and flower development.
Manure tea	Well-aged animal manure steeped in water.	Rich in organic matter and nutrients, improves soil fertility and promotes robust plant growth.
Worm tea	Vermicom post steeped in water.	Enriched with beneficial microbes and nutrients, enhances soil health and boosts plant growth.
Liquid humic acid	Leonardite or lignite	Improves soil structure, increases nutrient uptake, and enhances plant resilience against stress.

Source (Fertosy, 2003 and Allaf, Iyad Hani Ismail, 2019)

2. Nitrogen fixation:

Nitrogenous is an enzyme complex that is responsible for converting molecular nitrogen into ammonia (Ferguson *et al.,* 2007). It exists in various forms, with the most common one containing molybdenum (Mo-nitrogenase). Some bacteria have nitrogenases with vanadium or only iron. Nitrogenase is composed of two metalloproteins: Mo-Fe protein and Fe protein (Azatobacter and several photosynthetic nitrogen fixers carry additional forms of nitrogenase that carry vanadium). Mo-Fe protein has α and β subunits and contains FeMoCo prosthetic groups, it is a tetramer of 220,000Da. There are also prosthetic groups called 'P-clusters' (covalently bound to a cysteine residue of MoFe protein and bridging the two subunits) and Fe-S clusters (which are linked to Fe protein). (Hu *et al.,* 2021)

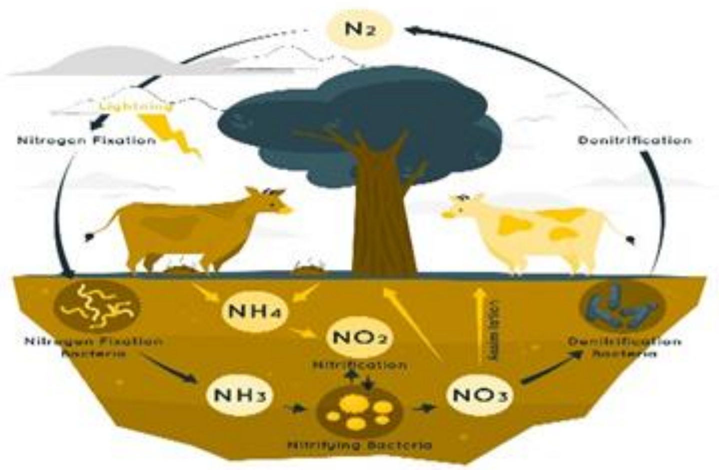

Figure 3: Process of Nitrogen fixation

This process involves two key components: the larger Mo-Fe-protein and the smaller Fe-protein.

- The Fe-protein interacts with ATP and $Mg^{\cdot\cdot}$ and receives electrons from ferredoxin or flavodoxin when it is oxidized.
- The Mo-Fe-protein, part of the nitrogenase complex, combines with N_2 and other reducible substrates to yield NH_3 through a stepwise reduction process.
- This reduction of N_2 into NH_3 occurs without breaking the N-N bond until the final reduction step.
- After the reduction, two molecules of N_2 and $NH_3$are released from the enzyme.
- Electrons are transferred to oxidize the Mo-Fe-protein, which becomes reduced, while the Fe-protein is oxidized.
- The reduced form of Mo-Fe-protein can then combine with N_2 and other substrates to produce NH_3 and various other products.
- H_2 is produced during this reaction and can be further utilized by microorganisms possessing hydrogenase, increasing nitrogenase activity by preventing H_2 inhibition.

- Ammonia is not typically accumulated in microbial cells but is instead incorporated into organic forms by combining with organic acids like α-keto-glutaric acid to produce amino acids like glutamic acid. It can be also combined with organic molecules to yield alanine or glutamine.

2.1. Nitrogen-fixing bio-fertilizers:

Nitrogen-fixing bio-fertilizers play a crucial role in enhancing soil fertility and promoting plant growth by converting atmospheric nitrogen into a usable form for plants. These biofertilizers consist of various nitrogen-fixing bacteria (NFB) and organisms, which can be grouped into different categories:

1. Free-Living Bacteria: Examples include *Azotobacter* and *Azospirillum*. These bacteria exist freely in the soil and can fix atmospheric nitrogen, making it available to plants (Bakulin.*et al*., 2007).
2. Symbiotic Bacteria: These include *Rhizobium* and *Frankia*. They form symbiotic relationships with specific plants, such as legumes and actinorhizal plants, respectively, to facilitate nitrogen fixation (White *et al.,* 2007).
3. Blue-Green Algae: Some blue-green algae, like *Azolla*, are also capable of nitrogen fixation and can be used as biofertilizers.
4. Non-legume Associated Bacteria: Various genera and species of nitrogen-fixing bacteria, such as *Achromobacter*, *Bacillus*, and *Klebsiella*, can be found in the rhizosphere of non-legume plants (Richardson *et al.*, 2009).

While there are many genera and species of nitrogen-fixing bacteria, *Azotobacter* and *Azospirillum* have been extensively studied and tested for their ability to increase crop yields, especially for cereals and legumes, in field conditions. These biofertilizers are a sustainable way to improve soil fertility and reduce the need for synthetic nitrogen fertilizers.

Conclusion:

In recent days hydroponics has been seen as a promising strategy for growing different kinds of crops. In this farming nitrogenous bio-fertilizers boost crop yield through increased BNF (Biological Nitrogen Fixation), nutrient uptake, plant growth stimulation, and organic residue decomposition. They rely on costly chemical N-fertilizers, cutting expenses and curbing environmental pollution. This shift toward biological and organic fertilizers fosters sustainable, low-input farming, promoting farm sustainability. The hydroponics make it possible to grow short-duration vegetables with limited spacing and with low labour. To encourage the commercialization of the hydroponic farm, this is important to develop low-cost technologies that reduce human dependence and operational costs.

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References:

1. Allaf, I. H. I. (2019). The importance of liquid organic fertilizers and biofertilizers in improving the growth of fruit seedlings. Department of Horticulture and Garden Engineering, College of Agriculture and Forestry, University of Al Mosul.
2. Anjana, & Iqbal. (2007). Nitrate accumulation in plants, factors affecting the process, and human health implications: A review. *Agronomy for Sustainable Development, 27*, 45-57.
3. Bakulin, M. K., Grudtsyna, A. S., & Lu Pletneva, A. (2007). Biological fixation of nitrogen and growth of bacteria of the genus Azotobacter in liquid media in the presence of perfluorocarbons. *Prikl Biokhim Mikrobiol, 43(4)*, 443-449.
4. Domingues, D. S., Camara, C. A. P., Takahashi, H. W., & Nixdorf, S. (2012). Automated system developed to control pH and concentration of nutrient solution evaluated in hydroponic lettuce production. *Computers and Electronics in Agriculture, 84*, 53-61.
5. Ferguson, S. D., Saliga, R., & Omaya, S. T. (2014). Investigating the effects of hydroponic media on quality of greenhouse grown leafy greens. *Dept. Agri. Nutri. Vertinary Science, University Reno, USA, 02(03)*, 227-234.
6. Fertosy, B. A. J. (2003). Effect of Water Soluble Extract of Some Organic Manure on Wheat Growth Tritcum aestivuim. Thesis for a Master of Science in Soil Science, Department of Agriculture, University of Baghdad, 112.
7. Hu, H.-Y., Li, H., Hao, M.-M., Ren, Y.-N., Zhang, M.-K., Liu, R.-Y., ... Kuzyakov, Y. (2021). Nitrogen fixation and crop productivity enhancements co-driven by intercrop root exudates and key rhizosphere bacteria. *58(10)*, 2243-2255.
8. Ikemoto, Y., Teraguchi, M., & Kogayashi, Y. (2002). Plasma level of nitrate in congenital heart disease: Comparison with healthy children. *Pediatr Cardiol, 23,* 132–136.
9. Ishiwata, H., Yamada, T., Yoshiike, N., Nishijima, M., Kawamoto, A., & Uyama, Y. (2002). Daily intake of food additives in Japan in five age groups estimated by the market basket method. *Eur Food Res Technol, 215*, 367–374.
10. Nasir, A. M., Khalid, S., Anwar, C., Arslan, M. J., & Sultan Akhtar, M. (2012). Evaluation on bio-fertilizer application to ameliorate the environment and crop production. *Pak J Agric Sci, 49(4)*, 527–531.
11. Nielsen, C. J., Ferrin, D. M., & Stanghellini, M. E. (2006). Efficacy of biosurfactants in the management of Phytophthora capsici on pepper in recirculating hydroponic systems. *Canadian Journal of Plant Pathology, 28(3)*, 450-460.

12. Richardson, A. E., Barea, J. M., McNeill, A. M., & Prigent-Combaret, C. (2009). Acquisition of phosphorus and nitrogen in the rhizosphere and plant growth promotion by microorganisms. *Plant Soil, 321*, 305-339.
13. Rouphael, Y., & Colla, G. (2005). The impact of irrigation methods and growing seasons on zucchini squash growth, yield, fruit quality, and nutrient uptake. *In Scientia Horticulturae, 105 (2)*, 177-195.
14. Sardare, & Admane. (2013). A Review on plant without soil – Hydroponics. *International Journal of Research in Engineering and Technology, 2(3)*, 299-304.
15. Shrestha, A., & Dunn, B. (2013). Hydroponics. Cooperative Extension Services in Oklahoma HLA-6442.
16. Savvas, D. (2002). Nutrient solution recycling in hydroponics. In: *Hydroponic Production of Vegetables and Ornamentals (Savvas D; Passam H C, eds)*, Embryo Publications, Athens, Greece, 299-343.
17. White, J., Prell, J., James, J., & Poole, J. (2007). Nutrient sharing between symbionts. *Plant Physiol, 144(2)*, 604–614.

PHARMACEUTICAL CARE: A PARADIGM SHIFT IN PHARMACY PRACTICE FOR OPTIMAL DRUG THERAPY

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Abstract:

Presently, there exist significant disparities between the current state of medication utilization in the United States and the attainment of the goal of "optimal medication therapy." Despite being well trained and easily accessible, pharmacists are often underused as vital healthcare professionals. Leveraging their clinical expertise, pharmacists can play a crucial role in advancing us towards better medication therapy outcomes for patients. This includes leading diabetes medication management programs, aligning with the "medical home" model that emphasizes collaborative efforts among primary care providers for patient-centered care. Pharmacists, through monitoring and managing diabetes medication plans, contribute positively to health outcomes and empower patients in proactively managing their well-being. Furthermore, pharmacists can act as valuable resources for other healthcare providers and payers, ensuring the safe, appropriate, and cost-effective use of diabetes medications.

Keywords: Collaborative Drug-Therapy Management, Diabetes Management, Medication Therapy Management, Pharmacists, Role of Pharmacists

Introduction:

In 2005, the Joint Commission of Pharmacy Practitioners, consisting of 11 pharmacy practitioner organizations, outlined the role of pharmacists in its Vision of Pharmacy Practice as follows: "Pharmacists will be the healthcare professionals responsible for providing patient care that ensures optimal medication therapy outcomes." Notably, there are significant discrepancies between the aspiration for "optimal medication therapy" and the current state of medication utilization in the United States. Media reports frequently highlight medication errors, adverse drug events, and escalating co-pay costs, all of which impede effective patient medication adherence. Despite being highly accessible and well-trained, pharmacists are frequently underutilized as crucial healthcare professionals. However, they have the potential to play a key role in advancing towards better medication therapy outcomes for patients. Furthermore, pharmacists can function as valuable resources for other healthcare providers and payers, ensuring the secure, suitable, and cost-effective use of medications. Numerous instances exist where pharmacists, operating in diverse settings such as ambulatory care clinics, community health centers, and certain community or food store pharmacies, have actively contributed to enhancing medication therapy outcomes for individuals with diabetes. To comprehend the significant role of pharmacists in managing medications for chronic diseases, this review will delve into current pharmacist education and training and examine successful models for diabetes medication management.

Pharmacist education and training

Pharmacist entry-level education

Since the 1960s, there have been significant transformations in the educational requirements of the pharmacy profession, leading to a notable shift in the emphasis of pharmacy curricula towards a more patient-centered approach and the management of medication therapy. In the late 1990s, a professional mandate mandated the replacement of the Bachelor of Science degree with the Doctor of Pharmacy (Pharm.D.) degree for all pharmacy students graduating and seeking state licensure, as well as for all pharmacy schools seeking accreditation. In the United States, 102 pharmacy schools now offer the Pharm.D. degree as the primary professional qualification, with around 10,000 students graduating with a Pharm.D. degree annually. The Pharm.D. curriculum spans six years and has been extensively revised to create a competency-based learning environment. This environment ensures that pharmacy graduates, some of whom may have completed a previous four-year degree, are well-prepared to contribute to patient care and the profession by collaborating with other healthcare professionals. The foundational courses cover a range of biomedical and pharmaceutical sciences, including anatomy and physiology, pathophysiology, molecular biology, pharmacology, immunology, pharmaceutics, medicinal chemistry, toxicology, pharmacogenomics, and extemporaneous compounding.Clinical courses in the curriculum focus on developing patient-care competencies in pharmacotherapeutics, applied pharmacokinetics, drug literature evaluation, patient assessment and monitoring, and medication patient safety. Additionally, sociobehavioral/administrative courses aim to build pharmacy practice competencies in communication skills, pharmacoeconomics, ethics, law, public health, health informatics, health care systems, drug information, health literacy, cultural competence, pharmacoadherence, and practice management/administration [1].

Postgraduate residency training

Around 15–20% of current Pharm.D. graduates opt to pursue postgraduate pharmacy residency training programs. These programs serve as valuable supplements to one's pharmacy education, offering the chance to acquire advanced knowledge and expertise in delivering patient-centered pharmacy care. Typically spanning one or two years post-Pharm.D., pharmacy residency programs are widespread across the nation, particularly in areas such as ambulatory care, primary care, and community pharmacy, with a specific focus on aiding patients in managing chronic diseases. In 2008, the United States had approximately 2100 pharmacy residency positions, and while numerous programs concentrate on inpatient care, an increasing number are emphasizing ambulatory, primary, and community pharmacy care. Additionally, there are pharmacy fellowship programs dedicated to research in clinical settings [2].

Pharmacy specialties and certifications

The field of pharmacy comprises six specialties that are board-certified: nuclear pharmacy (established in 1978), nutrition support (established in 1988), pharmacotherapy (established in 1988), psychiatric pharmacy (established in 1992), oncology pharmacy (established in 1996), and geriatrics (established in 1997). Pharmacists specializing in pharmacotherapy and geriatrics, through their board-certified expertise, often collaborate with patients, caregivers, and healthcare professionals to navigate intricate drug therapies and polypharmacy, particularly in cases involving diabetes patients. Various certification programs are accessible to professionals from diverse health disciplines, including pharmacists. These certifications cover areas such as diabetes education, anticoagulation therapy, pain management, and asthma education. As per the National Certification Board for Diabetes Educators, there are presently 719 pharmacists who hold the designation of certified diabetes educators (CDEs), constituting 4.5% of all CDEs [3].

Pharmaceutical care

In 1990, Hepler and Strand coined the term "pharmaceutical care" to signify a shift in the emphasis of pharmacy practice. This transition moved away from a focus on products and dispensing towards ensuring optimal drug therapy and patient medication safety. Following the publication of this influential article, there has been an abundance of new practice standards, collaborative agreements with fellow health professionals, and clinical practice literature. These resources collectively outline a patient-centered care model designed to empower pharmacists in guaranteeing the safe and effective drug therapy for individual patients.

Collaborative drug-therapy management

Given the intricacies of contemporary drug therapies and the heightened emphasis on patient medication safety, there is a growing recognition of the need for an interdisciplinary, shared responsibility between pharmacists and physicians. This collaboration aims to enhance patient medication outcomes and ensure the cost-effectiveness of drug therapy regimens. Over 75% of states have enacted legislation or modified state pharmacy practice acts to incorporate a pharmacist's role in a patient's drug therapy management. Collaborative drug-therapy management (CDTM) entails qualified pharmacists, equipped with clinical training and practice experience, working in accordance with a defined protocol alongside one or more physicians. Their responsibilities encompass conducting patient assessments, ordering medication-related laboratory tests, administering medications, and making decisions regarding the selection, initiation, monitoring, and adjustment of medication therapy regimens. The specifics of CDTM agreements vary significantly based on state regulations, practice settings, and the education and training requirements for pharmacists. The qualifications and scope of CDTM responsibilities are ultimately determined by the collaborating healthcare practitioners, taking into account patient needs, the nature of drug therapies, and the context of care settings. This collaborative approach necessitates the development of a protocol that delegates authority to pharmacists under specified circumstances, outlining the functions, procedures, and decision-making criteria for managing medication therapy. The protocol is a mutual agreement between the involved pharmacists and physicians and undergoes review by the appropriate body responsible for quality assurance or improvement. Typically, those engaged in collaborative drug-therapy management have preexisting working relationships and are familiar with the pharmacists' knowledge, clinical skills, and their role in patient-care medication management. The focus of collaborative drug-therapy management is often directed towards handling complex medication regimens or chronic disease medication therapies, such as those for diabetes, hypertension, hyperlipidemia, anticoagulation, or asthma [4].

Pharmacist programs in diabetes management

Diabetes medication-therapy management programs

Some pharmacists in community or hospital settings have integrated remote disease management technology, wherein patients upload blood glucose meter readings weekly via the internet or download readings during pharmacist visits. This enables pharmacists to assess blood glucose levels between physician appointments, offer self-management training, and develop personalized diabetes management plans to optimize medication regimens. For instance, a patient might not see a physician for 3–6 months, yet the pharmacist can monitor blood glucose levels during this period to evaluate the impact of new medications, over-the-counter products, lifestyle changes, or adjustments in diabetes treatment [5].

In food stores with pharmacies, clinical dietitians and pharmacists conduct two-hour educational programs for diabetes patients, guiding them on making informed food and pharmacy choices. These programs include store tours focusing on reading food labels, making healthier food choices, and classes covering understanding diabetes medications, avoiding drug interactions, recognizing symptoms of hyper- and hypoglycemia, and monitoring blood glucose levels [6].

In hospital ambulatory care clinics and physician offices, some pharmacists have established interdisciplinary diabetes-management programs through referrals. Many of these models are affiliated with pharmacy schools as clinical training sites and operate with collaborative drug-therapy management (CDTM) agreements between pharmacists and physicians. Pharmacists collaborate with patients to assess and adjust medication regimens, provide adherence counseling, discuss lifestyle modifications, review device and disease state education, and enroll patients in medication assistance programs if needed. Patients receive a diabetes action plan based on self-management principles, which is reviewed at subsequent meetings or follow-up phone calls to assess progress. A systematic review of 21 outpatient studies with pharmacist interventions for diabetes management demonstrated an overall improvement in HbA1c across diverse settings and study designs. The changes in A1c ranged from a 0.2% increase to a 2.1% decrease. Some studies suggested that pharmacist interventions could reduce long-term costs by improving glycemic control and reducing future diabetes complications [7].

The growing literature supports the pharmacist's role in diabetes care, providing continuity of care by tracking patient progress between physician visits, utilizing clinical expertise to monitor and manage diabetes medication plans, and educating patients on disease, lifestyle, and adherence issues. As of January 2008, new procedural codes have enabled pharmacists to bill for medication therapy management services. Pharmacists in community and primary care settings serve as key resources, working in an interdisciplinary model to enhance medication management for diabetes patients. This aligns with the "medical home" concept, promoting collaborative efforts among healthcare providers to coordinate patient-centered care. In this model, pharmacists focus on managing medications to positively impact health outcomes, reduce overall healthcare system costs, and empower patients and consumers to actively manage their health [8].

Conclusion:

The current state of medication utilization in the United States reveals significant disparities in achieving the goal of "optimal medication therapy." Despite the readiness and expertise of pharmacists, they remain underutilized as essential healthcare professionals. However, by harnessing their clinical knowledge, pharmacists can play a pivotal role in advancing medication therapy outcomes, particularly in leading diabetes management programs within the collaborative framework of the "medical home" model. Through proactive monitoring and management of diabetes medication plans, pharmacists contribute positively to health outcomes, empowering patients to take charge of their well-being. Additionally, pharmacists serve as valuable resources to other healthcare providers and payers, ensuring the safe, appropriate, and cost-effective use of diabetes medications. The evolution of pharmacist education, postgraduate training, specialized certifications, and the adoption of collaborative drug-therapy management highlight their potential impact. As demonstrated by successful diabetes medication management programs, pharmacists can bridge the gap, providing continuity of care, reducing costs, and actively contributing to patient-centered healthcare.

References:

1. American Association of Colleges of Pharmacy. (2008). Academic pharmacy's vital statistics. http://www.aacp.org/Docs/MainNavigation/InstitutionalData/8855_2008.pdf. Accessed September 1, 2008.
2. Medical News Today. (2008). Record number of pharmacy graduates to enter pharmacy residencies. http://www.medicalnewstoday.com/articles/102558.php. Accessed September 1, 2008.
3. National Certification Board for Diabetes Educators. (2008, July 23). Personal communication. Arlington Heights, IL.
4. Hepler, C. D., & Strand, L. M. (1990). Opportunities and responsibilities in pharmaceutical care. *Am J Hosp Pharm*, *47*(3), 533–543.
5. Hammond, R. W., Schwartz, A. H., Campbell, M. J., Remington, T. L., Chuck, S., Blair, M. M., ... Webb, C. E., & American College of Clinical Pharmacy. (2003). Collaborative drug therapy management by pharmacists—2003. *Pharmacotherapy*, *23*(9), 1210–1225.
6. Cranor, C. W., Bunting, B. A., & Christensen, D. B. (2003). The Asheville Project: long-term clinical and economic outcomes of a community pharmacy diabetes care program. *J Am Pharm Assoc (Wash)*, *43*, 173–184.
7. Fera, T., Bluml, B. M., Ellis, W. M., Schaller, C. W., & Garrett, D. G. (2008). The Diabetes Ten City Challenge: interim clinical and humanistic outcomes of a multisite community pharmacy diabetes care program. *J Am Pharm Assoc (2003)*, *48*(2), 181–190.
8. Wubben, D. P., & Vivian, E. M. (2008). Effects of pharmacist outpatient interventions on adults with diabetes mellitus: a systematic overview. *Pharmacotherapy*, *28*(4), 421–436.

SECONDARY METABOLITES SYNTHESIS: A MIRACLE BY THE PLANT

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Introduction:

Plants have been known to offer therapeutic benefits since ancient times. This data has been used in a number of medical systems to support human well-being and a sustainable way of living on Earth. The most valuable plant parts, taken as such, include a multitude of biomolecules with proven medicinal benefits. Plants generate these compounds by a variety of pathways at different phases of development, as well as through interactions with their environment. Secondary metabolites are chemical compounds that are produced as byproducts of primary metabolite through different spatial modifications like hydroxylation, glycosylation, and methylation (Shilpa *et al.*, 2010). These modifications can occur sequentially or simultaneously in different combinations, making secondary metabolites more complex than primary metabolites. Therefore, the number of secondary metabolites varies throughout plant species depending on the environmental factors, age of the plant, place of synthesis, etc. These semi-synthetic chemicals are widely used in many medicinal formulations and are created by plant defense systems (Raja and Sreenivasulu, 2015).

Even in phylogenetically related species, chiefly desirable secondary metabolites are found in extremely small levels and have a restricted distribution. It is difficult to extract and purify these magnificent phytoconstituents because they are synthesized in specialized cell types at distinct developmental stages and are produced in a specific biochemical pathway. Additionally, the site of synthesis and types of compounds produced can vary among plant species. Moreover, some chemicals are created in all tissues, whilst others are synthesized in patterns peculiar to a particular tissue or even a single cell (John and Annadurai, 2015). Approximately a thousand novel compounds are added to the many thousands of compounds from plants that have already been identified. Through the regulation of its biochemical pathways, a single plant can interact with changing environmental circumstances and change its chemical composition throughout time. According to Rao and Ravishankar (2002), these are low molecular-weight chemical molecules that are essential for plants to adapt to their surroundings. Naturally developing plants create and accumulate secondary metabolites in minuscule amounts, which makes their extraction and application prohibitively expensive.

Terpenes (composed only of carbon and hydrogen), phenolics (composed of simple sugars, benzene ring, hydrogen, and oxygen), and chemicals containing nitrogen and/or sulfur are the three chemically different classes into which secondary metabolites are separated (Chinou, 2008). Many chemicals found in terpene families originated from glycolytic intermediates or acetyl-CoA during their production (Gershenzon *et al.,* 1991; Grayson, 1998). There are five main subclasses of terpenes, and the majority of them have medicinal potential.

Generally speaking, plant volatiles such as mono and sesquiterpenes can permeate into the atmosphere if the barrier is lifted. A well-known sesquiterpene is abscisic acid; carotenoids are tetraterpenes with a variety of regulatory functions. Phenolics are aromatic heterogeneous organizations associated with sugar and organic acids. It is classified based on the number and arrangement of carbon atoms as flavonoids and non-flavonoids (Irchhaiya *et al.,* 2015). Usually, phenolic compounds are classified as phenolics with one aromatic ring, with two fragrant jewelry, quinones, and polymers (Kareba *et al.,* 2014). The phenolic organization with one fragrant ring is the simplest kind and with two rings including benzoquinones and xanthones related by means of one carbon atom, stilbene by way of carbon atoms, and flavonoids by using 3 carbon atoms. Coumarin, furanocoumarin, lignin, flavonoids, isoflavonoids and tannins are different important phenolic compounds determined in plant systems and most of those compounds provide protection in opposition to to phytopathogens. Flavonoids are water-soluble pigments divided into anthocyanins, flavones, and flavonols lots of which provide fitness advantages to people. Coumarin, the easy phenolic compound derived from shikimic acid pathway displaying antifungal activity towards soil-borne plant pathogenic fungi, furanocoumarin also an antifungal agent, lignin, a relatively branched polymer of phenylpropanoid organization having mechanical activity, flavonoids, the most important training of plant phenolics generating pigmentation and defense (Kondo *et al.,* 1992) iso-flavonoids, produce development and defense reaction in vegetation and tannins are popular toxin act as feed repellents to animals. Glycosides are very complicated and heterogeneous systems characterised by the attachment of sugar moiety to non-sugar quantities. It's miles categorized based on the character of aglycone, as phenols, quinines, terpeners, and steroids. Sulfur-containing secondary metabolites encompass glutathiones, glucosinolates, phytoalexins, thionins, defensins, and allinin which additionally provide dense against pathogens (Halkier and Gershenzon, 2006). Glutathione is natural sulfur in the soluble fraction of flora offering cell antioxidant pressure reaction (Kang *et al.,* 2007). By focused on xenobiotics and cytotoxins into vacuole, glutathione detoxifies them (Rea *et al.,* 1998). Glucosinolates also are low molecular mass plant glucosides, comprising of nitrogen and sulphur used to increase resistance to the pathogen due to the fact their breakdown products release as volatile protecting substances displaying poisonous or repellent results. The synthesis of phytoalexins in response to fungal or bacteria attacks or other strain that preclude the spreading of contamination in a extensive range of flowers. Defensins, thionins, and lectins are sulphur-rich non-garage plant proteins. These compounds are synthesized and amassed after microbial assault and such allied conditions (van Loon *et al.,* 1994).

Defensins are part of the shielding mechanism of vegetation, and they are extremely dangerous to bugs, animals, and microbes. The defense reaction against microbial contamination is greater with the aid of thionin accumulation. Plants generate lectins, which can be defense proteins that connect to carbohydrates or proteins containing carbohydrates in animal digestive tract epithelium linings and hinder the absorption of nutrients (Peumans and Van Damme, 1995). Alkaloids, cyanogenic glucosides, and non-protein amino acids are examples of nitrogen-containing secondary metabolites that offer human beings with anti-herbivore safety and toxicity. Because of their preferred toxicity and deterrent effect, alkaloids are a extensive circle of relatives of secondary metabolites that comprise nitrogen and act as a defense against microbial infection and herbivorous assault (Harborne, 1988). The cyanogenic glucosides in the plant broke down when it became overwhelmed, giving off unstable poisonous substances, and hence flowers are blanketed from herbivory. Even though non-protein amino acids exist in free forms but act as protecting materials to cover-up pathogenic assaults in plant life without causing any toxicity.

Except, the high fee of current, artificial capsules and bio-incompatibility associated with these capsules make it certain that the plant life will stay the vital source of drugs based totally on their secondary compounds. It is believed that the fundamental use of herbs as the supply of healing dealers, as raw materials food and cosmetics industries will maintain inside the destiny. Those organic parts observed to have no impact on boom and development of the plant, they have got survival function, vital for the communication of the flowers with other organisms (Schafer and Wink, 2009).

Future possibilities

This modern global is asking ahead for herbal drug treatments for primary fitness care because of its lesser facet outcomes. It is very an awful lot indeed that the lively herbal-based totally biomolecules are the use of in contemporary drug therapy. Commercial significance of Secondary metabolites has necessitated its extraction and to investigate viable technological advancement to explore alternative techniques for its manufacturing and extraction. Thus, plant cell tradition technology had been evolved because the maximum convenient and efficient device for analyzing and generating Secondary metabolites. Techniques based on gene manipulation and metabolic engineering are attempted to discover the in-depth productions of those secondary metabolites to meet industrial and public desires (Bourgaud *et al.,* 2001).

References

1. Bourgaud, F., Gravot, A., Milesi, S., & Gontier, E. (2001). Production of plant secondary metabolites: a historical perspective. *Plant Sci, 161*, 839-851.
2. Chinou, I. (2008). Primary and Secondary Metabolites and their Biological Activity. In: Waksmundzka-Hajnos M, Sherma J, Kowalska T (eds), *Thin Layer Chromatography in Phytochemistry,* CRC Press, Boca Raton, pp 59-76.
3. Gershenzon, J., & Croteau, R. (1991). Terpenoids. In: Rosenthal GA, Berenbaum MA (eds), *Herbivores their interaction with secondary plant metabolites, Vol 1,* The Chemical participants, Academic Press, San Diego, pp 165-219.
4. Halkier, B. A., & Gershenzon, J. (2006). Biology and Biochemistry of Glucosinolates. *Ann Rev Plant Biol, 57,* 303-333.
5. Irchhaiya, R., Kumar, A., Yadav, A., Gupta, N., Kumar, S., Gupta, N., ... Gurjar, H. (2015). Metabolites in Plants and its Classification. *World J Pharm Pharm Sci, 4,* 287-305.
6. John, A., & Annadurai, A. (2015). GC-MS screening of active secondary metabolites present in the Cleome gynandra. *Int J Phytopharm Res, 5*, 47-52.
7. Kondo, T., Yoshida, K., Nakagawa, A., Kawai, T., Tamura, H., & Goto, T. (1992). Structural basis of blue-color development in flower petals from Commelina communis. *Nature, 358*, 515-518.
8. Peumans, W. J., & Van Damme, E. J. (1995). Lectins as plant defense proteins. *Plant physiology, 109(2)*, 347.
9. Raja, R., & Sreenivasulu, M. (2015). Medicinal Plants Secondary Metabolites used in Pharmaceutical Importance-An Overview. *World J Pharm Pharm Sci, 4*, 436-447.
10. Rao, S. R., & Ravishankar, G. A. (2002). Plant cell cultures: Chemical factories of secondary metabolites. *Biotechnol Adv, 20*, 101–153.
11. Schafer, H., & Wink, M. (2009). Medicinally important secondary metabolites in recombinant microorganisms or plants: progress in alkaloid biosynthesis. *Biotechnol J, 4,* 1684-1703.
12. Van Loon, L. C., Pierpoint, W. S., Boller, T., & Conejero, V. (1994). Recommendations for naming plant pathogenesis-related proteins. *Plant Molecular Biology Reporter, 12*, 245-264.

SOLAR POWERED RAINWATER HARVESTING SYSTEMS IN INDIA: PRESENT AND FUTURE PERSPECTIVES

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Abstract:

Solar-powered rainwater collection systems are being employed in India to address the country's energy and water deficit demands as these arrangements facilitate the collection and storage of rainwater by utilizing solar energy to power pumps. This integrated strategy provides an environmentally beneficial solution in a nation like India where solar resources are plentiful and water shortage is a major problem. Solar panels, a pump, storage tanks, and a filtration system are usually included in the system. Rainwater is collected from rooftops or other surfaces using a pump that is powered by electricity produced by solar panels. After collection, the water is filtered and kept for later use in home or agricultural irrigation, as well as groundwater replenishment. This creative solution contributes to environmental sustainability by lowering reliance on traditional energy sources and offering a dependable water source in areas with variable rainfall. Since climate change is making India's water problems worse, solar-powered rainwater collection devices may be a vital tool for encouraging sustainable energy practices and guaranteeing water security.

Keywords: Solar-Powered Rainwater Harvesting, Environmental Sustainability, Water Conservation, Sustainable Water Practices.

Introduction:

Rainwater harvesting is an eco-friendly and sustainable method of managing water resources that is essential in tackling the problems associated with water scarcity in many parts of the world. This technique lessens reliance on conventional water sources, such rivers and groundwater, by collecting and storing rainwater during periods of precipitation, so lessening the impact on ecosystems. It provides a decentralized approach that encourages self-sufficiency by enabling communities to satisfy their water demands on their own. Rainwater collection also improves agricultural output, replenishes groundwater, and lessens the impact of water shortages. It is an inexpensive and simple technique that fits with resilience and environmental conservation concepts, which makes it a useful tactic for areas with water scarcity issues.

India has serious problems with water, including shortages, unequal distribution, and declining water quality. Water supplies are under more and more stress due to urbanization, agriculture, and rapid population expansion. Unpredictable monsoons cause water scarcity during dry spells in many areas. Groundwater depletion is a serious issue that is made worse by over-extraction for home and agricultural use. Water quality is further deteriorated by pollution from industrial discharges and insufficient wastewater treatment. These difficulties are made worse by the effects of climate change and an inadequate infrastructure for effective water management. To assure water security for India's expanding population, addressing these challenges calls for an all-encompassing strategy that includes effective conservation techniques, upgraded infrastructure, and sustainable water practices. To maximize the benefits of the plentiful rainfall and provide a decentralized alternative to conventional water sources, rainwater collection is essential. It improves agricultural resilience, replenishes groundwater aquifers, and lessens shortages, particularly in areas with erratic monsoons. To address both shortage and the unequal distribution of water resources, India must establish a robust and sustainable water management system that includes extensive rainwater collection methods.

Integration of solar power into rainwater harvesting systems

Combining solar energy with rainwater collection systems is a creative and sustainable way to solve the problems of energy and water scarcity. Solar panels are used in this integrated system to collect sunlight and produce power. Rainwater collection and distribution pumps are subsequently driven by this renewable energy. Water is drawn from rooftops or collection surfaces by the solar-powered pumps, which enable filtering and storing it for later use. Together, these efforts not only guarantee a steady supply of environmentally beneficial water, but they also lessen the need for traditional energy sources.

This integration is especially helpful in a place like India where there is a shortage of water and plenty of sunlight. Rainwater harvesting systems driven by solar energy reduce carbon emissions linked to conventional energy sources, so promoting environmental sustainability. Additionally, they strengthen the water supply systems' resilience, particularly in areas where unpredictable rainfall is common. The integration of solar electricity into rainwater collecting systems is an attractive approach for sustainable water management because of its twin benefits of alleviating water scarcity and promoting clean energy.

Current status of rainwater harvesting in India

97% of the water on Earth is found in seas, 2% is frozen in the polar caps, and the remaining 1% is freshwater. India makes up 4% of this 1%, whereas the global population is made up of 18% of us. In India, rain is the primary source of water for almost 85% of the cultivated land, either directly or indirectly. Water for drinking, household purposes, and irrigation is provided by seasonal rains. It is essential for growing animal feed and supplies water to cattle. Rainwater harvesting is still not widely used, and there are still obstacles to overcome before it can be considered a sustainable method of managing water resources in India. Fig. 1 shows the water related work done by Govt. of India.

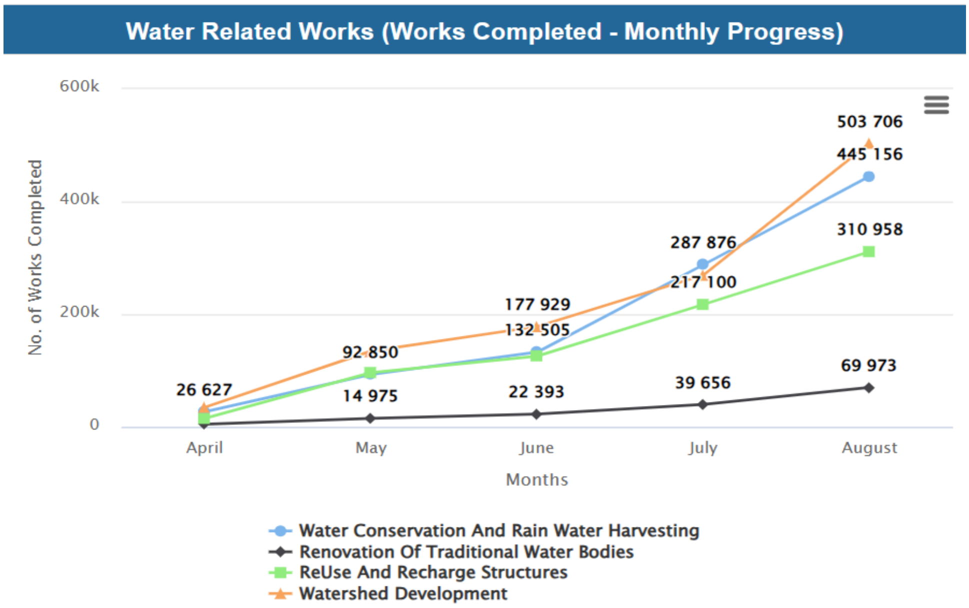

Fig. 1: Water related work done by Govt. of India

[Source: Ministry of Jal Shakti, Govt. of India]

- **Government initiatives:** Rainwater harvesting has been encouraged by several policies and programs that the Indian government has put in place. Rainwater harvesting systems must be installed in new projects according to legislation in many states and cities.
- **Urban and rural adoption:** In urban areas, rainwater collection has become more popular and is frequently mandated for new construction. There has been a wider range of acceptance in rural regions, as some communities have embraced conventional rainwater gathering techniques.
- **Awareness and education:** There have been awareness efforts and educational initiatives to highlight the value of collecting rainwater. However, there is still work to be done to ensure widespread knowledge and execution, and the efficacy of these efforts might vary.
- **Challenges:** Widespread adoption faces obstacles such as inadequate infrastructure, budgetary limitations, and the requirement for greater community involvement. In many instances, there is also a deficiency of knowledge on the advantages of collecting rainwater.
- **Climate variability:** The need of efficient rainwater collection is highlighted by India's varied environment, where certain places experience both intense rains and droughts. Rainwater's consistency as a water supply, however, may be compromised by erratic monsoons in some regions.

Existing rainwater harvesting practices in India

Rainwater harvesting is a crucial practice in India, given the country's dependence on monsoon rains for a significant portion of its water needs. Various traditional and modern rainwater harvesting methods are employed across the country. Fig 2. shows the water conservation and rain water harvesting activities done by India up to November 2023.

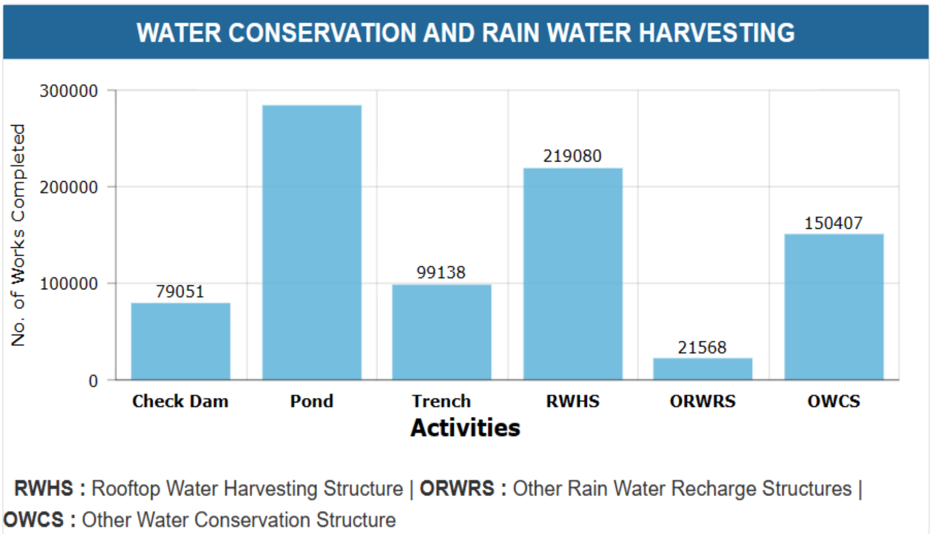

Fig. 2 Water conservation and rain water harvesting activities done by India [Source: Ministry of Jal Shakti, Govt. of India]

In India, the state of rainwater collecting is always changing, and advancements could have taken place. Sustained endeavours in raising awareness, imparting knowledge, and developing infrastructure are essential to the successful and extensive adoption of rainwater collection techniques nationwide. Here are some existing rain water harvesting practices in India:

- **Tankas:** Tankas are traditional underground rainwater storage structures commonly found in the arid and semi-arid regions of Rajasthan. They are designed to store rainwater for domestic use.
- **Khadins:** Khadins are traditional earthen embankments used to capture and store rainwater in arid regions for agricultural purposes.
- **Johads:** Johads are traditional water conservation structures in Rajasthan. These are check dams built across streams to capture rainwater during the monsoon season. They help in recharging groundwater and supporting agriculture.
- **Bamboo drip irrigation:** In some northeastern states of India, bamboo drip irrigation systems are used for rainwater harvesting. These systems involve collecting rainwater in bamboo pipes and directing it to crops for irrigation.
- **Rooftop rainwater harvesting:** Rooftop rainwater harvesting is a widely adopted practice in urban and rural areas. It involves collecting rainwater from rooftops and directing it to storage tanks for domestic use, agriculture, or groundwater recharge.

- **Percolation pits**: Percolation pits are dug in open areas to allow rainwater to percolate into the ground, replenishing the groundwater table. This method is commonly used in both rural and urban settings.
- **Community-based rainwater harvesting:** In some regions, communities come together to implement large-scale rainwater harvesting projects. These projects often involve constructing check dams, percolation tanks, and other structures to store and manage rainwater.
- **School rainwater harvesting:** Some schools in India have incorporated rainwater harvesting systems as part of their infrastructure. This not only helps in water conservation but also serves as an educational tool for students.
- **Artificial recharge structures:** Artificial recharge structures, such as recharge wells and recharge trenches, are used to facilitate the infiltration of rainwater into the ground, thereby replenishing the groundwater.
- **Farm ponds:** Farmers construct small ponds in their fields to capture and store rainwater for agricultural purposes. These ponds also help in recharging groundwater.
- **Government initiatives:** The Indian government has implemented various schemes and initiatives to promote rainwater harvesting. These include financial incentives for individuals and communities adopting rainwater harvesting practices.

These practices play a crucial role in mitigating water scarcity issues and ensuring sustainable water management in different parts of India. However, the success of these initiatives depends on factors such as local geography, climate, and community participation.

Successes and challenges faced in the implementation of traditional rainwater harvesting systems

Traditional rainwater harvesting systems have been used for centuries in various parts of the world to capture and store rainwater for agricultural, domestic, and industrial purposes. While these systems have demonstrated success in many cases, they also face certain challenges. Here are some successes and challenges associated with the implementation of traditional rainwater harvesting systems:

Successes:

- **Sustainability:** Traditional rainwater harvesting systems are often sustainable and environmentally friendly. They utilize natural processes to collect and store water without relying on energy-intensive technologies.
- **Cost-effectiveness:** Many traditional rainwater harvesting methods are cost-effective to implement, using locally available and affordable materials such as stones, sand, and clay.

- **Community involvement:** These systems often involve local communities in their construction and maintenance, fostering a sense of ownership and promoting community resilience.
- **Water quality improvement:** By reducing surface runoff, these systems can improve water quality by preventing soil erosion and filtering out contaminants, leading to cleaner water storage.
- **Adaptability:** Traditional rainwater harvesting systems can be adapted to suit the specific needs and conditions of different regions, making them versatile solutions.

Challenges:

- **Climate variability:** The effectiveness of traditional rainwater harvesting systems can be affected by climate variability, including irregular rainfall patterns and extended dry periods.
- **Limited storage capacity:** Traditional systems often have limited storage capacity, which may not be sufficient during prolonged droughts or in areas with infrequent rainfall.
- **Maintenance issues:** Regular maintenance is crucial for the proper functioning of these systems. Lack of maintenance can lead to siltation, contamination, and structural damage, reducing their efficiency.
- **Lack of technical expertise:** In some cases, communities may lack the technical knowledge and skills required for proper design, construction, and maintenance of rainwater harvesting systems.
- **Land use constraints:** The physical space required for some traditional rainwater harvesting systems, such as surface ponds, may compete with other land uses, limiting their applicability in densely populated or urban areas.
- **Water quality concerns:** Contamination of stored rainwater due to pollution, bird droppings, or other sources can pose health risks if not properly addressed through filtration and water treatment.
- **Policy and regulatory challenges:** Lack of supportive policies and regulations can hinder the widespread adoption of traditional rainwater harvesting systems. In some cases, legal constraints may limit the implementation of these systems.

While traditional rainwater harvesting systems have demonstrated success in many regions, addressing the associated challenges requires a comprehensive approach involving community engagement, technical expertise, and supportive policies. Integrating traditional practices with modern technologies can enhance the resilience and sustainability of rainwater harvesting systems.

Solar power in rainwater harvesting:

Solar power and rainwater harvesting are two sustainable practices that can be integrated to enhance the overall efficiency of water management systems. While they serve different purposes, combining them can contribute to a more sustainable and eco-friendly approach to water supply. Fig. 3 provides a scheme of solar power in rainwater harvesting.

There are some ways in which solar power can be integrated into rainwater harvesting systems:

- **Powering pump systems:** Solar panels can be used to power water pumps that are part of rainwater harvesting systems. These pumps can help in the collection and distribution of rainwater to storage tanks or other areas where it is needed.
- **Data monitoring and control:** Solar-powered sensors and monitoring systems can be employed to track the level of water in storage tanks, the rate of rainwater collection, and other relevant data. This information can help optimize the use of harvested rainwater.
- **Lighting for storage areas:** If the rainwater harvesting system includes storage areas or underground tanks, solar-powered lights can be installed to illuminate these spaces. This ensures safety and facilitates maintenance activities without relying on grid electricity.
- **Solar water purification:** Solar energy can be used to power water purification systems, providing clean and potable water from the harvested rainwater. This is particularly important for areas where water quality may be a concern.
- **Backup power supply:** Solar power can act as a reliable backup power source for critical components of the rainwater harvesting system, ensuring continued operation even during power outages.
- **Educational and community outreach:** Solar panels can be used to power educational displays or community outreach initiatives related to rainwater harvesting. This can include interactive exhibits, informational kiosks, or workshops that promote awareness and understanding of sustainable water practices.
- **Hybrid systems:** Combining solar power with other renewable energy sources, such as wind or hydro power, can create hybrid systems that enhance the reliability and efficiency of rainwater harvesting systems.
- **Green infrastructure:** Integrating solar panels into green infrastructure elements, such as green roofs or solar awnings, can serve a dual purpose by capturing rainwater and generating solar energy simultaneously.
- **Remote monitoring and maintenance:** Solar-powered remote monitoring systems can be established to track the performance of rainwater harvesting systems in real-time. This allows for proactive maintenance and troubleshooting, improving overall system reliability.

- **Off-grid applications:** In areas where access to the electrical grid is limited, off-grid rainwater harvesting systems with solar power can provide a sustainable and independent water supply solution.

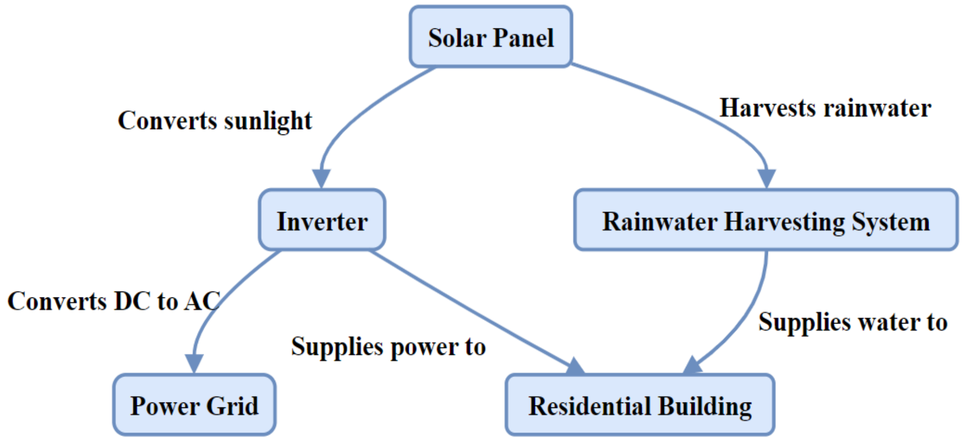

Fig. 3: Scheme of solar power in rainwater harvesting

Technological advances:

There have been few developments in technologies that integrate solar power into rainwater harvesting systems. The currently available techniques are listed below:

- **Solar-powered pumps:** Solar-powered water pumps are used to extract water from the harvested rainwater for distribution or storage. These pumps are directly powered by solar energy, making them more sustainable and reducing the reliance on grid electricity.
- **Solar water heaters:** Solar water heaters can be integrated into rainwater harvesting systems to provide hot water for various purposes, such as domestic use or heating for industrial processes. These systems use solar energy to heat the water stored in tanks.
- **Solar-powered filtration systems:** Solar energy can be used to power water filtration systems that ensure the collected rainwater is safe for consumption. These systems may include UV purification, reverse osmosis, or other advanced filtration technologies.
- **Solar-powered monitoring systems:** Solar panels can be used to power monitoring systems that track the water level, quality, and other parameters in rainwater harvesting systems. This information can be crucial for optimizing the system's efficiency.
- **Solar-powered sensors and IoT devices:** Internet of Things (IoT) devices and sensors powered by solar energy can be deployed in rainwater harvesting systems to monitor and control various aspects, such as water flow, tank levels, and system performance.
- **Solar-powered desalination systems:** In regions where, freshwater scarcity is a concern, solar-powered desalination systems can be integrated into rainwater harvesting setups to convert brackish or seawater into freshwater using solar energy.

- **Solar water purification:** Solar stills and other solar water purification technologies can be employed to harness the sun's energy for purifying rainwater, making it safe for consumption or other uses.
- **Solar-powered backup systems:** Solar power can be used to provide backup electricity for pumps and other essential components of rainwater harvesting systems. This ensures that the system can continue to operate even during power outages.

Government policies and incentives:

Supportive government policies and incentives can play a crucial role in the widespread adoption of solar rainwater harvesting. Governments have encouraged the installation of such systems through subsidies, tax incentives, and regulations promoting sustainable water and energy practices. Few of the policies are listed below:

- **Atal Mission for Rejuvenation and Urban Transformation (AMRUT):** The creation of basic urban infrastructure, particularly access to tap connections and water supply for every home in 500 cities, is the main goal of the Atal Mission for Rejuvenation and Urban Transformation (AMRUT), which was initiated by the Indian government in 2015. ULBs and the State may undertake projects in the water supply sector pertaining to the creation, expansion, or repair of water supply systems; revitalization of water bodies for water supply; rainwater collection and recharging of ground water, among other things.
- **Jal Shakti Abhiyan**: To address both rural and urban regions nationwide, Jal Shakti Abhiyan-I (JSA-I) and "Jal Shakti Abhiyan: Catch the Rain" (JSA: CTR) (Fig.4) were introduced. The third and fourth JSAs in the series, "Jal Shakti Abhiyan: Catch the Rain" (JSA: CTR) -2022 and -2023, were introduced to cover every block in every district (rural and urban) throughout the nation. One of the main focuses of the program is rainwater gathering. States and Union Territories (UTs) have been recommended to actively engage in JSA: CTR 2023 and to implement rain harvesting initiatives in accordance with JSA: CTR.
- **Pradhan Mantri Krishi Sinchayee Yojana (WDC-PMKSY):** Rainwater harvesting is one of the activities included in the Natural Resource Management (NRM) component of the Pradhan Mantri Krishi Sinchayee Yojana (WDC-PMKSY) Watershed Development Component.
- **Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS):** Water harvesting and conservation are two of the tasks included by the natural resource management (NRM) component of the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS).
- **Model Building Bye Laws (MBBL)**: Rainwater harvesting is covered under the Model Building Bye Laws (MBBL) 2016 that the Ministry of Housing and Urban Affairs sent to

all states and territories. Except for Sikkim, Lakshadweep, and Mizoram, all States and Union Territories have ratified the MBBL-2016 rainwater harvesting regulations thus far.

Jal Shakti Abhiyan: Catch The Rain

Intervention Wise Progress Report

Status From : 04-03-2023 to 20-11-2023

S.N.	Jal Shakti Abhiyan	Water Conservation and Rain Water Harvesting Structures		Renovation of Traditional Water Bodies		Reuse and Recharge Structures	Watershed Development	Total Water Related Works		Intensive Afforestation	Training Programmes/ Kisan Melas
		Rural	Urban	Rural	Urban			Rural	Urban		
1.A	Total Nos. of Work Completed	6,98,814	0	1,40,076	438			20,23,937	438		
		6,98,814		1,40,514		4,59,309	7,25,738	20,24,375		6,41,15,284	52,809
1.B	Total Nos. of Works Ongoing	3,52,947		1,11,223		1,16,704	4,92,979	10,73,853		5,34,774	
2	Total of Completed and Ongoing Works	10,51,761		2,51,737		5,76,013	12,18,717	30,98,228		6,46,50,058	
3	Expenditure in Rs Crores*	6,132		3,107		224	5,360	14,823		1,499	
4	Total Expenditure Including Water related works and Afforestation (In Rs Crores)*									16,322	

* Expenditure is given only for the works carried out by DoRD under MGNREGS

Fig. 4: Jal Shakti Abhiyan Progress Report [Source: Ministry of Jal Shakti, Govt. of India]

- **Mission Amrit Sarovar**: To preserve water for future generations, the Mission Amrit Sarovar was inaugurated on April 24, 2022, National Panchayati Raj Day, as part of the celebration of Azadi ka Amrit Mahotsav. The mission is to revitalize and develop seventy-five water bodies in each of the nation's districts.
- In addition to boosting ground water recharge and reviving lost irrigation potential, the Surface Minor Irrigation (SMI) and Repair, Renovation & Restoration (RRR) of Water Bodies schemes aim to increase the cultivable area under guaranteed irrigation through the enhancement and restoration of water bodies.

Future perspectives:

The integration of solar power with rainwater harvesting systems represents an innovative and sustainable approach to addressing water and energy challenges. Looking into the future, several perspectives and trends can be considered for solar rainwater harvesting:

- **Technological advancements:** Ongoing advancements in solar technology, including more efficient solar panels and energy storage solutions, are likely to enhance the performance and reliability of solar-powered rainwater harvesting systems. Improved efficiency can lead to increased energy generation and more effective water utilization.
- **Smart and integrated systems:** Future systems may become more intelligent and integrated. Smart technologies, such as sensors and automated controls, can optimize the

operation of rainwater harvesting systems by adjusting parameters based on weather forecasts, water demand, and energy availability.

- **Decentralized water and energy solutions:** The trend toward decentralized water and energy solutions may continue to grow. Solar-powered rainwater harvesting systems can provide localized and off-grid solutions, especially in rural or remote areas where centralized infrastructure is challenging.
- **Urban applications and green infrastructure:** In urban areas, there could be an increased emphasis on integrating solar-powered rainwater harvesting into green infrastructure projects. Rooftop gardens, permeable pavements, and other eco-friendly urban designs may incorporate such systems to enhance sustainability.
- **Community and agricultural applications:** Community-based and agricultural applications of solar rainwater harvesting may expand. These systems can provide reliable water sources for communities and support sustainable agriculture practices, reducing dependence on conventional energy sources and water supplies.
- **Research and innovation:** Ongoing research and innovation in the field of water management and renewable energy are likely to yield new technologies and approaches for solar rainwater harvesting. Collaboration between research institutions, industry, and government bodies can drive progress in this area.
- **Climate resilience and adaptation:** Solar rainwater harvesting systems may play a role in climate resilience and adaptation strategies. As climate change leads to more extreme weather events, including droughts and intense rainfall, these systems can help communities adapt to changing water availability patterns.
- **Public awareness and education:** Increasing public awareness of water scarcity and the benefits of sustainable practices can drive the adoption of solar rainwater harvesting at the individual and community levels. Education campaigns and outreach efforts can play a vital role in promoting the understanding and acceptance of these systems.

Conclusion:

The integration of solar power with rainwater harvesting systems can lead to more resilient, self-sufficient, and environmentally friendly water management practices, especially in regions where water scarcity is a concern. This synergistic approach maximizes the utilization of renewable resources, and promoting efficiency. By combining clean energy generation with responsible water management, this integrated system not only reduces environmental impact but also fosters community self-sufficiency, cost savings, and adaptability to diverse climatic conditions. Embracing this holistic approach holds the promise of a greener and more resilient future for communities worldwide.

References:

1. Water Crisis in India: The World's Largest Groundwater User. (n.d.). Retrieved from https://www.teriin.org/article/water-crisis-india-worlds-largest-groundwater-user
2. Chakraborti, R. K., Kaur, J., & Kaur, H. (2019). Water Shortage Challenges and a Way Forward in India. *Journal - American Water Works Association, 111*(5), 42–49. https://doi.org/10.1002/awwa.1289
3. Dupraz, C., Marrou, H., Talbot, G., Dufour, L., Nogier, A., & Ferard, Y. (2011). Combining solar photovoltaic panels and food crops for optimising land use: Towards new agrivoltaic schemes. *Renewable Energy, 36*(10), 2725–2732. https://doi.org/10.1016/j.renene.2011.03.005
4. Lancaster, B. (2014). *Rainwater harvesting for drylands and beyond. Volume 1, Guiding principles to welcome rain into your life and landscape.* Rainsource Press.
5. Jal Shakti Abhiyan. (n.d.). Retrieved November 20, 2023, from https://jsactr.mowr.gov.in
6. Chakkaravarthy, D. N. (2019). Water Scarcity- Challenging the Future. *International Journal of Agriculture Environment and Biotechnology, 12*(3). https://doi.org/10.30954/0974-1712.08.2019.2
7. Sanewe, A. J., & Backeberg, G. R. (2012). Overview of research on rainwater harvesting and conservation by the water research commission. *Irrigation and Drainage, 61*, 1–6. https://doi.org/10.1002/ird.1691
8. Kaya, M. (2020). Evaluation of the Existing Solar Energy and Rainwater Potential in the Total Roof Area of Buildings: Izmit District Example. *Advances in Materials Science and Engineering, 2020*, 1–16. https://doi.org/10.1155/2020/8167402
9. Helmreich, B., & Horn, H. (2009). Opportunities in rainwater harvesting. *Desalination, 248*(1-3), 118–124. https://doi.org/10.1016/j.desal.2008.05.046
10. Dobrowsky, P. H., Carstens, M., De Villiers, J., Cloete, T. E., & Khan, W. (2015). Efficiency of a closed-coupled solar pasteurization system in treating roof harvested rainwater. *Science of the Total Environment, 536*, 206–214. https://doi.org/10.1016/j.scitotenv.2015.06.126
11. Amin, M. T., & Han, M. Y. (2009). Roof-harvested rainwater for potable purposes: Application of solar collector disinfection (SOCO-DIS). *Water Research, 43*(20), 5225–5235. https://doi.org/10.1016/j.watres.2009.08.041
12. Kumar, M., Ghosh, S., Patel, A., Sundar, S., & R. Ravindranath. (2006). Rainwater harvesting in India: some critical issues for basin planning and research. *Land Use and Water Resources Research, 6*, 1–17. https://doi.org/10.22004/ag.econ.47964

13. Stout, D. T., Walsh, T. C., & Burian, S. J. (2015). Ecosystem services from rainwater harvesting in India. *Urban Water Journal, 14*(6), 561–573. https://doi.org/10.1080/1573062x.2015.1049280
14. Van Meter, K. J., Steiff, M., McLaughlin, D. L., & Basu, N. B. (2016). The socioecohydrology of rainwater harvesting in India: understanding water storage and release dynamics across spatial scales. *Hydrology and Earth System Sciences, 20*(7), 2629–2647. https://doi.org/10.5194/hess-20-2629-2016
15. Jagannath Rekha. (2002). Rainwater Harvesting in India. *Artha Journal of Social Sciences, 1*(1), 49–56. https://doi.org/10.12724/ajss.1.4
16. Mwenge Kahinda, J., & Taigbenu, A. E. (2011). Rainwater harvesting in South Africa: Challenges and opportunities. *Physics and Chemistry of the Earth, Parts A/B/C, 36*(14-15), 968–976. https://doi.org/10.1016/j.pce.2011.08.011
17. Li, R., Shi, Y., Alsaedi, M., Wu, M., Shi, L., & Wang, P. (2018). Hybrid Hydrogel with High Water Vapor Harvesting Capacity for Deployable Solar-Driven Atmospheric Water Generator. *Environmental Science & Technology, 52*(19), 11367–11377. https://doi.org/10.1021/acs.est.8b02852
18. Mzirai, O. B., & Tumbo, S. D. (2010). Macro-catchment rainwater harvesting systems: challenges and opportunities to access runoff. *Journal of Animal and Plant Sciences, 7*(2), 789–800.
19. New Water Security Plan. (n.d.). Retrieved from https://www.pib.gov.in/PressReleasePage.aspx?PRID=1739097
20. Nathan, M. (2021, March 19). India's water crisis: The seen and unseen. *Down to Earth.* Retrieved from https://www.downtoearth.org.in/blog/water/india-s-water-crisis-the-seen-and-unseen-76049
21. National Water Policy Central Water Commission, New Delhi. (n.d.). Retrieved from http://cwc.gov.in/sites/default/files/nwauser/nwp-lectnote6.pdf
22. Govt. of India. (2009). Background note for consultation meeting with Policymakers on review of National Water Policy. Ministry of Water Resources, pp. 50. http://jalshakti-dowr.gov.in/sites/default/files/background_note_NWP2002717577543_1.pdf

NARRATIVE REVIEW OF PHARMACOLOGICAL POTENTIAL AND MEDICINAL USES OF *MIKANIA* SPECIES

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Abstract:

Out of the 450 species of Mikania that have been identified, 55 of them are capable of producing over 300 different chemical compounds, including terpenes and derivatives. A few of these compounds were identified as being of exceptionally high pharmacological interest due to their behavior due to their extensive usage as herbal remedies. Additionally, the previously acknowledged other actions were not yet experienced. Once fresh research is approved, it may describe other stimulating characteristics of the molecules already taken from this species. One of the 430 species in the Asteraceae family is Mikania. Less than 10% of these varieties have, however, been studied. These include *M. cordata, M. laevigata* Schultz Bip. ex Baker, and *M. glomerata* Spring, all of which are thought to have therapeutic use. Additionally, these herbs have proven use in the treatment of gastrointestinal problems, rheumatism, and the flu.Their extract, as well as the pure isolated chemical, demonstrated a variety of pharmacological effects, including those that were anti-inflammatory, respiratory tract illnesses, antiulcer, anti-diarrheal, antispasmodic, and antibacterial.

Keywords: Mikania, Phytochemistry, Pharmacological Activities, Toxicity Studies

Introduction:

Mikania is a species of about 450 classes of plants in the tribe Eupatorieae within the relations Asteraceae. People have look into regulatory it with herbicides. However, less than 12% of 450 variety of Mikania have been investigate [1,2]. These are mainly found in Brazil, Argentina, Paraguay, India, Uruguay, Sao Paulo and Rio Grande region. The members of this genus are mainly twinners and linans; climbs over shrubs and trees. Thereare many similarities occurs among them in the morphology, organoleptic characters and medicinal uses [3]. Although these three species found its place in Brazilian Pharmacopoeia and in some monographs [4,5], none have described the entire chemistry and pharmacology of these significant therapeutic plants.

Therefore, we intended to accumulate an up-to-date and comprehensive review of *M. cordata, M. laevigata* Schultz Bip. ex Baker and *Mikania glomerata* that cover its conventional and folk therapeutic uses, phytochemistry, and pharmacology and toxicity efficiency.

Ethnomedicinal / traditional uses

Primarily in Brazil did the Mikania species find its position for customary purposes. In Brazil, these Mikania species are referred to as "guaco" often. To treat respiratory tract conditions including cough, pleurisy bronchitis, and asthma, the guaco plant is frequently used as an extract or syrup. Additionally, it established a center for the care of gastrointestinal problems, rheumatism, and the flu. [6,7,8].

Phytochemistry

Terpenoids, flavonoids, volatile oils, carbohydrate, and acid content of these plants is frequently recorded. Friedelin, deoxymikanolide, scandenolide, fumaric acid, -pienene, -pienene, -thujene, germacrene D, glucose, fructose, and other minor compounds are reported to be present in *M. cordata* [9,10,11]. Coumarin, derivatives of kaurenoic acid, lupeol, lupeol acetate, campesterol, caryophyllene oxide, sabinene, -sitosterol, spathulenol, and germacrene D were the most important contents in the shell of Mikania glomerata, along with a few other minor components [12,13]. Additionally, *M. laevigata* Schultz Bip. ex Baker is abundant in compounds like coumarin, germacrene D, spathulenol, myrcene, kaurenoic acid, grandifloric acid, syring aldehyde, and others [14].

Pharmacology

Several researchers have reported the different pharmacological actions of these three plants belonging to genus Mikania in vitro and in vivo model. Dissimilar parts of these plants have been established to exhibit several activities including anti-inflammatory, antiulcer, antidiarrhoeal, antispasmodic, and antimicrobial behavior. These have been described in superior detail as follows.

Anti-inflammatory activity

The Methanolic portion of *Mikania glomerata* extract was found to inhibit carrageenin and mediator induced oedema especially due to reserve of protein exudation, increased peritoneal vessel permeability and leucocyte relocation in inciting condition. The extract also resulted the inhibition of sodium-furate induced experimental gout [15]. It found to be effective in inhibition of PAF-induced pleural neutrophil migration useful in immunogenic inflammation [16]. When *M. laevigata* Schultz Bip. ex Baker decoction of leaves was investigated foranti-inflammatory activity in rat paw oedema and pleurisy models, it was found that the leaf decoction (200 mg/kg) inhibited oedema by 81.56% in rat paw oedema model while in pleurisy model the leaf decoction (400 mg/kg) inhibited leucocyte movement to pleural exudate by 28.26% [17].

Antiulcer activity

The Methanolic portion of *M. cordata* root extract was investigated for antiulcer activity in acetylsalicylic acid, serotonin and indomethacin induced ulcers in investigational rats and guinea pigs. It showed the significant protective action in gastric lesion in all these experimental models along with enhancement of acetic acid induced chronic gastric lesion [18]. The methanolic extract of *M. cordata* roots (50-150 mg/kg) prevented water immersion stress- (ED50=95.1 mg/kg), ethanol- (ED50=109.7 mg/kg), aspirin- (ED50=125.5 mg/kg) and phenylbutazone-(ED50=136.2 mg/kg) induced gastric ulcers and increased mucus secretion. This antiulcer behavior might be due to inflection of defensive factor through an enhancement of gastric cytoprotection [19]. When the alkaloidal fraction of *M. cordata* investigated for antiulcer activity against diclofenac sodium-induced gastrointestinal lesion in rats, it was found that the alkaloid rich extract (50 mg/kg) increased the stomach and duodenum pH, decreased ulcer index ofstomach and duodenum without showing any symptoms of tissue damage. These results were found to be comparable or more potent than ranitidine hydrochloride [20,21,22].

Antidiarrhoeal activity

Mikania glomerata has been use in Brazilian habitual drug to treat gastrointestinal disorder. In order to determine its effect, in one experiment, the aqueous extract of leaves of *Mikania glomerata* assayed for the propulsive actions of the intestinal contents in mice. It found to have significant antidiarrhoeal action, as that of loperamide, by inhibiting intestinal motility [23].

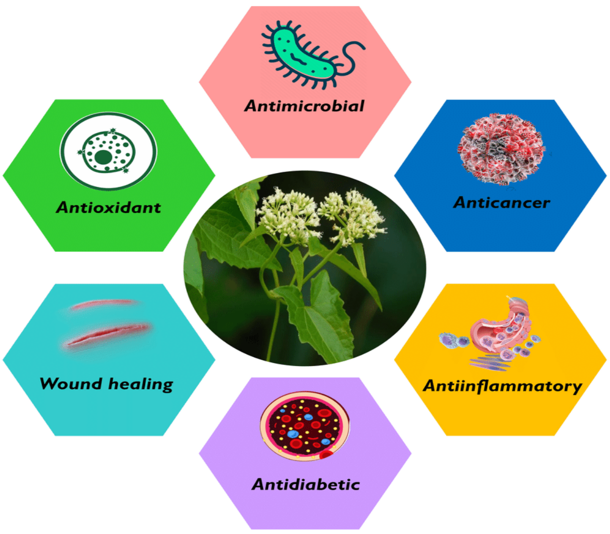

Fig. 1: Pharmacological Potential of Mikania species

Antispasmodic activity

The ethanolic and hydro-ethanolic extracts of *Mikania glomerata* prepared by percolation and reflux; were investigated for antispasmodic action on rat jejunum and guinea pig ileum elicted by acetyl choline (Ach) and histamine (Hist). These extracts were found as mixed antagonist. The ethanolic extracts obtain by percolation or reflux were more effective than hydro-ethanolic extracts (IC_{50}=0.082 and 0.103 mg/ml correspondingly for Hist and Ach). While, the hydro-ethanolic extracts obtained by percolation and reflux were found to have weakest activity (IC_{50}=0.324 and 3.594 mg/ml respectively for Hist and Ach). However, the main constituent coumarin was originate to have no role in this movement [24].

Antimicrobial and antifungal activity

The antibacterial potential of plant extracts was studied. The hydroalcoholic extract of *Mikania glomerata* exhibited antibacterial action against S. faecium (MIC=0.1 mg/ml), whereas *M. laevigata* Schultz Bip. ex Baker exhibited inhibition against S. aureus (MIC=0.04 mg/ml), S. faecium (MIC=0.35 mg/ml), and B. subtilis (MIC=0.09 mg/ml) [25]. In a different investigation, the ethanolic, hexane, and ethyl acetate fractions of *Mikania glomerata* and *M. laevigata* Schultz Bip. ex Baker extracts were tested for antibacterial efficacy on the growth and cell adhesion of mutans streptococci. Both plant extracts' hexane fractions limit microbial growth (MIC=12.5-400 g/ml and MBS=25-400 g/ml) and adhesion to a glass surface[26],[27].

Effect on bronchi

Mikania glomerata and *M. laevigata* Schultz Bip. ex Baker has been use in Brazilian folk drug for the action of respiratory tract diseases. In order to decide its place, in one study, the ethanol: water (70:30) extract (100 mg/kg) of leaves of both these plants were investigated for its effect in pulmonary inflammation cause by acute coal dust coverage in rats. It was found that LDH activity and cell count decreased by *M. laevigata* Schultz Bip. ex Baker extract, whereas *Mikania glomerata* extract only decreased the cell count increased during coal-dust exposure in rats. Both extracts also found to diminish lung inflammatory infiltration induce by coal dust while other parameters like myeloperoxidase and TBARS levels were found to be unchanged [28]. The aqueous and hydro-alcoholic extracts and dichloromethane fraction of *Mikania glomerata* leaves upon investigation for its effect on isolated respiratory and vascular smooth muscle [29,30]; It also showed a small vasodilatation on isolated mesenteric vascular bed and on the remote rat aorta along with important relaxation of the oedema induce by Bothrops jararaca venoms in mice [31].

Analgesic and antipyretic activity

M. cordata crude extract and its methanolic extract were investigated for analgesic and antipyretic activity on rats. It showed that the crude extract (1-3 g/kg) and a sesquiterpene dilactone- deoxymikanolide (10 mg/kg) had a promising analgesic activity [9], while methanolic extract showed a significant antipyretic activity [15].

Antiallergic activity

The methanolic fraction of *Mikania glomerata* extract was evaluated for antiallergic action on oval albumin-induced allergic pleurisy. It was found to show significant decrease in plasma exudation as well as neutrophil and eosinophil infiltration [16].

Antistress activity

Methanolic extract of *M. cordata* roots upon evaluation for its antistress activity in albino mice; showed that at dose of 50-150 mg/kg, it amplified the survival time of swimming in mice, enhanced swimming performance, prevented stress induce adrenal function changes, milk-induced leucocytosis, stress-induced gastric ulceration [32]. These effects were found due to the decreased in level of Ad, NA, DA and 5-HT along with noticeable inhibition of brain MAO and stimulation of SDH activities in brain and in liver [33].

Antimutagenic potential

Aqueous extract of *M. laevigata* Schultz Bip. ex Baker was tested for the presence of mutagenic action in the Salmonella/microsome assay and was found to be negative; however, it did exhibit a high percentage of inhibition of mutagenesis induced by mutagens 2AF in the presence of exogenous metabolism (S9 fraction), for frame shift (TA98) and base pair substitution (TA100) lesion. Additionally, it demonstrated the suppression of SAZ mutations without exogenous metabolism. A synergistic impact was also shown in frameshift mutation. These outcomes were discovered, nonetheless, most likely as a result of the interaction between the extract's many active principles and genetic material[34].

Drug detoxifying potential

M. cordata proved a significant role in hepatic biotransformation system. Methanolic roots extract (50-150 mg/kg) was found to have no or little effect on microsomal cytochrome P- 450, cytochrome b5 contents and NADPH cytochrome c reductase; It increased the level of microsomal uridine diphosphoglucuronyl transferase, microsomal uridine diphosphoglucose dehydrogenase while reduced the level of nicotinamide adenine dinucleotide (phosphate): quinine reductase and cytosolic glutathione S-transferase. These results showed the potential of *M. cordata* extract for the biotransformation of harmful chemical substances [35].

Liver tissue repairing activity

Researchers discovered that *M. cordata* root extract may mitigate the harmful effects of CCl4 by testing it for tissue healing activities in mice exposed to the chemical. The level of hepatic microsomal RNA (42.2%) and cytochrome P-450 content (70.2%) affected by CCl4 were considerably improved by *M. cordata* root extract (150 mg/kg). The research supports the restoration of protein synthesis as well as the activation of the hepatic reticuloendothelial system's defensive mechanism [36]. Additionally, it affected the liver tissue's lipid peroxidation process. At a dose of 10 mg/kg, it was shown to decrease the level of lipid peroxide in liver homogenate (7.8%), however at a dose of 150 mg/kg, it became (68.7%). Additionally, it reduced the levels of the enzymes SGOT (15.6%) and SGPT (13.4%) [37].

Effect on fatty acid profile

Arachidonic acid (ARA) and docosahexanoic acid (DHA) levels in the lung and liver cells of mice presenting the Balb-C isogenic allergic pneumonitis were shown to be distinct in the *M. laevigata* Schultz Bip. ex Baker aqueous extract. Only the DHA levels in the liver were changed; there were no appreciable variations in ARA synthesis. Additional research revealed that the liver's production of DHA was enhanced by the aqueous extract, coumarines, and O-coumarinic acid (P 0.05) [14].

Toxicity Study

Mikania species have been used in Brazil for many years for the treatment of various diseases. In order to determine its safety, in one study the "guaco" syrup was tested for its toxicity showed that the LD_{50} dose of guaco syrup was very high (10 g/kg) in rats; while upto 300 mg/kg it neither produce disturbances in haematological or biochemical parameters nor toxicity in hepatic, renal or pancreatic system [30]. In another study it was found to be safe in terms of reproductive system and on appearance of external organ [38].

Conclusion:

In this study, we have made an effort to compile information on the medicinal plants *M. cordata*, *M. laevigata* Schultz Bip. ex Baker, and *M. glomerata*, which are utilized as traditional medicines in Brazil, India, and other parts of the world. Terpenoids, flavonoids, volatile oils, carbohydrates, acids, and many other compounds were found, according to a review of the literature. According to an early study from experimental tests, it considerably reduces the symptoms of liver, lung, and gastrointestinal system disorders. It is required to carryout pinpoint study related to such type of diseases. This review will definitely help the researchers as well as practitioners, dealing with these plants.

References:

1. Nunez, C. V., Amendola, M. C., Lago, J. H. G., & Roque, N. F. (2004). Diterpene acids from *Mikania* sp. nov (Asteraceae). *Biochemical Systematics and Ecology*, *32*, 233-237.
2. Gasparetto, J. C., Campos, F. R., Budel, J. M., & Pontarolo, R. (2010). *M. glomerata* Spreng. e *M. laevigata* Schultz Bip. ex Baker Sch. Bip. ex Baker, Asteraceae: estudos agronomicos, geneticos, morfoanatomicos, quimicos, farmacologicos, toxicologicos e uso nos programas de fitoterapia do Brasil. *Brazilian Journal of Pharmacognosy, 20*, 627-640.
3. Colares, M., Muguerza, A., Rosella María, A., & Consolini, Alicia E. (2013). Antispasmodic effects of *Mikania micrantha* Kunth and dual gastrointestinal effect of *Mikania cordifolia* (L.F.) Willd (asteraceae) on isolated rat thin intestine. *Pharmacology on Line, 2*, 1-11.
4. Sastri, B. N. (2003). *A Dictionary of Indian Raw Materials & Industrial Products*. *The Wealth of India, CSIR, New Delhi, India, VI (L-M)*, 376.

5. Pal, S., Bhattacharya, S., & Chaudhuri, A. K. N. (2006). The effect of *M. cordata* (Burm) B.L. Robins root extract in gastro-duodenal ulcer models in rats and guinea pigs. *Phytotherapy Research, 20*(4), 180-182.
6. Silva, L. S., Brumano, L., Stringheta, P. C., Oliveira, P. M. A., Dias, L. O. M., et al. (2012). Preparation of Dry Extract of *M. glomerata* Sprengel (Guaco) and Determination of Its Coumarin Levels by Spectrophotometry and HPLC-UV. *Molecules, 17*, 10344-10354.
7. Napimoga, M. H., & Yatsuda, R. (2010). Scientific evidence for *Mikania laevigata* and *Mikania glomerata* as a pharmacological tool. *Journal of Pharm. Pharmacol, 62*, 809–820.
8. Amaral, M. P. H., Vieira, F. P., Leite, M. N., Amaral, L. H., Pinheiro, L. C., Fonseca, B. G., Pereira, M. C. S., & Varejao, E. V. (2009). Coumarin content of guaco syrup stored at different temperatures. *Brazilian Journal of Pharmacognosy*, *19*, 607–611.
9. Rufatto, L. C., Gower, A., Schwambach, J., & Moura, S. (2012). Genus *Mikania*: chemical composition and phytotherapeutical activity. *Brazilian Journal of Pharmacognosy, 22*(6), 1384-1403.
10. Bedi, G., Tonzibo, Z. F., Guessan, T. Y., & Chalchat, J. C. (2003). Chemical constituents of the essential oil of *M. cordata* (Burm.f.). *Journal of Essential Oil Research, 15*(3), 198-199.
11. Mazzorana, D. M., Nicolau, V., Moreira, J., Amaral, P. A., & Andrade, V. M. (2013). Influence of *Mikania laevigata* Extract over the Genotoxicity Induced by Alkylating Agents. *ISRN Toxicology*, 1-7.
12. Rehder, V. L. G., Sartoratto, A., & Rodrigues, M. V. N. (2006). Essential oil composition from leaves, inflorescences and seeds of *M. laevigata Schultz Bip. ex Baker* and *M. glomerata Sprengel*. *Revista Brasileira de Plantas Medicinais, Botucatu, 8*, 116-118.
13. Pedroso, A. P. D., Santos, S. C., Steil, A. A., Deschamps, S. F., Barison, A., Campos, F., et al. (2008). Isolation of syringaldehyde from *Mikania laeivigata* medicinal extract and its influence on the fatty acid profile on mice. *Brazilian Journal of Pharmacognosy, 18*(1), 63-69.
14. Bhattacharya, S., Pal, S., & Nagchaudhuri, A. K. (2006). Pharmacological studies of the anti-inflammatory profile of *M. cordata* (Burm) B.L. Robinson root extract in rodents. *Phytotherapy Research, 6*(5), 255-260.
15. Fierro, I. M., Silva, A. C. B., Lopez, C. D. S., Moura, R. S. D., & Barja-Fidalao, C. (1999). Studies on the anti-allergic activity of *Mikania glomerata*. *Journal of Ethnopharmacology, 66*(1), 19-24.

16. Suyenaga, E. S., Reche, E., Fariar, F. M., Schapoval, E. E. S., Chaves, C. G. M., & Henriques, A. T. (2002). Anti-inflammatory investigation of some species of *Mikania*. *Phytotherapy Research, 16*(6), 519-523.
17. Pal, S., Bhattacharya, S., & Chaudhuri, A. K. N. (2006). The effect of *M. cordata* (Burm) B.L. Robins. root extract in gastro-duodenal ulcer models in rats and guinea pigs. *Phytotherapy Research, 2*(4), 180-182.
18. Selvakumar, P. (2012). Phytochemical screening and antioxidant activity of red flowered *Mirabilis jalapa* leaf in different solvents. *International Journal of Pharm Bio Sci, 3 Suppl 4*, 440–446.
19. Paul, R. K., Jabbar, A., & Rashid, M. A. (2000). Antiulcer activity of *M. cordata*. *Fitoterapia, 71*(6), 701-703.
20. Mosaddik, M. A., & Alam, K. M. (2000). The anti-ulcerogenic effect of an alkaloidal fraction from *M. cordata* on diclofenac sodium-induced gastrointestinal lesion in rats. *Journal of Pharmacy and Pharmacology, 52*(9), 1157-1162.
21. Paul, R. K., Jabbar, A., & Rashid, M. A. (2000). Antiulcer activity of *M. cordata*. *Fitoterapia, 71*(6), 701-703.
22. Bighetti, A. E., Antonio, M. A., Kohn, L. K., Rehder, V. L., Foglio, M. A., Possenti, A., et al. (2005). Antiulcerogenic activity of crude hydroalcoholic extract and coumarin isolated from *Mikania laevigata* Schultz Bip. *Phytomedicine, 12*(1-2), 72-77.
23. Salgado, H. R. N., Roncari, A. F. F., & Moreira, R. R. D. (2005). Antidiarrhoeal effects of *M. glomerata* Spreng. (Asteraceae) leaf extract in mice. *Brazilian Journal of Pharmacology, 15*(3), 205-208.
24. Aboy, A. L., Ortega, G. G., Petrovick, P. R., Langeloh, A., & Bassani, V. L. (2002). Antispasmodic activity of leaf extracts of *M. glomerata* Sprengel (guaco). *Acta Pharmaceutica Bonaerense, 21*(3), 185-191.
25. Duarte, M. C. T., Figueira, G. M., Pereira, B., Magulhaes, P. M., & Delarmelina, C. (2004). Atividade antimicrobiana de extratos hidroalcolicos de especies da colecao de plantas medicinais CPQBA/UNICAMP. *Revista Brasileira de Farmacognosia, 14*(1), 06-08.
26. Yatsuda, R., Rosalen, P. L., Cury, J. A., Murata, R. M., Rehder, V. L. G., Melo, L. V., et al. (2005). Effects of *Mikania* genus plants on growth and cell adherence of mutans streptococci. *Journal of Ethnopharmacology, 97*(2), 183-189.
27. Begum, J., Yusuf, M., Chowdhury, J. V., Khan, S., & Anwar, M. N. (2007). Antifungal activity of forty higher plants against phytopathogenic fungi. *Bangladesh Journal of Microbiology, 24*(1), 76-78.

28. Selvakumar, P. (2022). Phytochemical and Pharmacological Profile Review of *Bryophyllum Pinnatum*. *Biomedical and Biotechnology Research Journal (BBRJ), 6*(3), 295-301. DOI: 10.4103/bbrj.bbrj_126_22.
29. Freitas, T. P., Silveira, P. C., Rocha, L. G., Rezin, G. T., Rocha, J., Citadini-Zanette, V., et al. (2008). Effects of *M. glomerata* Spreng. and *M. laevigata* Schultz Bip. ex Baker (Asteraceae) extracts on pulmonary inflammation and oxidative stress caused by acute coal dust exposure. *Journal of Medicinal Food, 11*(4), 761-766.
30. Graça, C., Freitas, C. S., Baggio, C. H., Paulo, R. D., & Morques, M. C. A. (2007). *Mikania laevigata* syrup does not induce side effects on the reproductive system of male Wistar rats. *Journal of Ethnopharmacology, 111*(1), 29-32.
31. Santos, S. C., Krueger, C. L., Steil, A. A., Kreuger, M. R., Bivatti, M. W., & Junior, A. W. (2006). LC characterisation of *Guaco* medicinal extracts, *Mikania laevigata* and *Mikania glomerata* and their effects on allergic pneumonitis. *Planta Medica, 72*, 679-684.
32. Moura, S., Costa, S. S., Jansen, J. M., Silva, C. A., Lopez, C. S., Bernardo-Filho, M., et al. (2006). Bronchodilator activity of *M. glomerata* Sprengel on human bronchi and guinea-pig trachea. *Journal of Pharmacy and Pharmacology, 54*(2), 249-256.
33. Bishayee, A., & Chatterjee, M. (1994). Antistress potential of *M. cordata* root extract in mice. *Pharmaceutical Biology, 32*(2), 126-134.
34. Bishayee, A. A., & Chatterjee, M. (1995). Mechanism of anti-stress activity of *M. cordata* root extract in albino mice. *Pharmaceutical Biology, 33*(3), 215-221.
35. Fernandes, J. B. F., & Vargas, V. M. F. (2003). Mutagenic and antimutagenic potential of the medicinal plants of *M. laevigata* Schultz Bip. ex Baker and *C. Xanthocarpa*. *Phytotherapy Research, 17*(3), 269-273.
36. Bishayee, A., & Chatterjee, M. (1994). Anticarcinogenic biological response of *M. cordata*: reflections in hepatic biotransformation systems. *Cancer Letters, 81*(2), 193-200.
37. Mandal, P. K., Bishayee, A., Chatterjee, M., & Mukherjee, J. R. (2006). *M. cordata* root extract in the inhibition of lipid peroxidation and reduction of enzyme leakage in mice with carbon tetrachloride-induced liver damage. *Phytotherapy Research, 6*(4), 227-229.

SOLID POLYMER SUPPORTED REAGENTS: OXIDATION OF SUBSTITUTED AROMATIC SECONDARY ALCOHOLS

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Abstract:

Polymer supported reagents have found many applications in recent years. Scientists in research laboratories of agrochemical and pharmaceutical industries now routinely utilize these compounds to prepare ensembles of small organic molecules for screening. This review is aimed to highlight some of the most important applications of these promising materials in organic synthesis. Furthermore, an extensive listing of polymeric reagents that were recently used in organic synthesis is included [1-3].

Chemical kinetics is a branch of chemistry which deals with rate of reaction. A detail study of chemical kinetic along with other no kinetic study will enable us to understand thoroughly mechanism of reactions. There are some reactions which takes place very fast, within fraction of second (upto femto second level). Some reactions are extremely slow for example rusting of iron. In between these two extreme ends, there are reactions which take reasonable time for completion. These reactions can be studied conveniently with suitable methods. There are several researchers who contributed in the field of chemical kinetics. Ludwig Ferdinand Wilhelmy, Wilhelm Ostwald, C F Wenzel, Louis Jacques The nard, Pierre Eugene Marcelin Berthelot, Leon Pean de Saint-Gilles, Peter Waage and Harcourt etc. had made pioneering work in the field of chemical kinetics [4-5]. The aim of present review article is to review various oxidizing agents used to study the kinetics of oxidation process in general and to study the oxidation of substituted aromatic secondary alcohols. In this research work we determine rate of reaction using aromatic substituted alcohols by using Solid polymer supported reagents with help of oxidation mechanism.

Keywords: Polymeric Reagent, Solid-Supported Reagent, Oxidation, Alocohols.

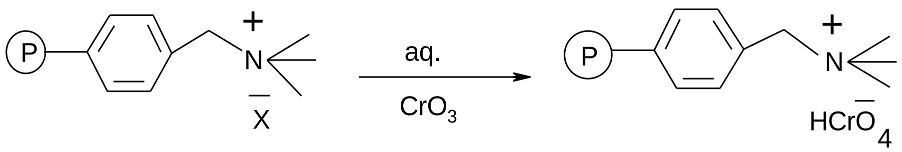
Introduction:

The use of polymer-supported species in both syntheses and separations is steadily increasing and the applications in industry continue to grow [6] Medicinal chemists in the pharmaceutical industry now routinely utilize polymer-supported reagents to prepare ensembles of small organic molecules [7]. Using polymeric materials as supports, solid supported reagents or scavengers have a great influence in organic synthesis, work-up, and purification of the products.

Until Merrifield introduced the concept of solid phase peptide synthesis in 1963 all chemistry was performed in solution-phase. In 1962, *Merrifield* utilized a functionalized and nitrated styrene-divinylbenzene co-polymer for synthesizing a tetra peptide [8]. This polymer was reacted with an amino acid with its amino group protected by a carbobenzoxy group. For deprotecting the amino group of the product, utilized a HBr=HO*Ac* mixture. For chain extension, the product was reacted with another carbobenzoxy-protected amino acid and at the end of the reaction, the polymer linkage was cleaved by saponification. The manipulations required for the synthesis of a polypeptide chain consist simply of pumping the proper solvents or reagents into and out of the vessel containing the polymer in the proper sequence and timing. It was obvious to *Merrifield* that the simplicity of the steps involved in this process could be automated. The construction an apparatus which performed all these operations automatically [9-14]. The ease of solid phase synthesis (SPS) compared with the labor and time to produce a tetra peptide by conventional solution approaches was sufficient to attract considerable attention of the scientists.

Preparation of supported oxidizing agent [15]

The supported oxidizing agent was prepared by reported method. The Chromate forms of Dowex-2 containing a quaternary ammonium group [10 x 10^{-3} kg] was stirred with a saturated solution of periodates [5 x 10^{-3} dm^3] in water [30 x10^{-3} dm^3] for 30 min at room temperature using a magnetic stirrer. The Chromate ion was readily displaced and Chromate form of resin was obtained in 60 min. The resin was successively rinsed with water, acetone and THF and finally dried in vaccum at 323 K for 7h. The dried form of the resin was stored and used throughout the kinetic study.



[X = Cl] Polymer supported oxidizing agent

Determination of capacity of polymeric reagent [16]

The capacity of Chromate form of Dowex-2 polymeric reagents was determined by iodometrically. The capacity of the chromate form of resin were 2.11 and 2.06 eq/L and used for kinetic study throughout work. The loading was also determined by elemental nitrogen analysis and were found to be 1.45 and 1.79 eq/L.

Method of kinetics [17]

The reaction mixture for the kinetic run was prepared by mixing alcohol, oxidant and solvent. The reaction was carried out either constant stirring using magnetic stirrer and at a constant temperature 318 ±1 K. At different time interval, the reaction mixture was withdrawn using a micropipette. The aliquot thus withdrawn was taken in a stoppered test tube containing 5 x 10^{-3} dm^3 of 1, 4-dioxane and subjected to spectral analysis. The absorbance of the product formed was measured using SL 159 UV-visible spectrophotometer. Duplicate kinetic runs showed that the rate constants were reproducible to within ±1 %.

Results and Discussion [18-19]:

The influence of concentration of alcohol change on reaction rate

Table 1:- Study rate of reaction for change in concentration of alcohol

Alcohols	50 mg	60 mg	70 mg	80 mg
	$k \times 10^{-4}$ min^{-1}			
1-Phenylethanol	1.33	1.66	1.73	2.00
4-Methylphenylethanol	1.33	1.60	2.00	1.33
4-Methoxyphenylethanol	1.33	1.40	1.55	1.66
4-Flurophenylethanol	1.66	2.97	2.33	2.40

The influence of polymeric reagent change on reaction rate

Table 2: Study rate of reaction for change in concentration of polymeric reagent

Alcohols	50 mg	60 mg	70 mg	80 mg
	$k \times 10^{-4}$ min^{-1}			
1-Phenylethanol	1.33	1.40.	2.66	2.73
4-Methylphenylethanol	1.66	1.69	2.00	2.06
4-Methoxyphenylethanol	1.66	2.00	2.05	2.13
4-Flurophenylethanol	2.00	2.00	2.66	2.73

It is evident from the information from above table that,

1. The graphically calculated 'k' values at different time intervals remain nearly constant.
2. The Absorbance versus time plots consistently exhibit linear trends passing through the origin.
3. The average 'k' value, when considering all kinetic runs with varying polymeric reagent weights for each type of alcohol, also remains constant.

The influence of concentration of solvent on reaction rate

Table 3: Study of rate of solvent change on reaction Rate

Alcohols	Dielectric Constant	C_6H_{12}	CCl_4	1,4 -Dioxane	$CHCl_3$
		$k \times 10^{-4}$ min^{-1}			
1-Phenylethanol	2.0	1.30	1.33	2.00	2.06
4-Methylphenylethanol	2.2	2.00	1.40	1.66	1.88
4-Methoxyphenylethanol	2.2	1.33	1.46	2.00	1.33
4-Flurophenylethanol	4.8	1.38	2.00	2.34	2.66

The Influence of Change in Temperature on Reaction Rate

The activation energy (Ea) analysis reveals a different trend: The activation energy for para-substituted 1-Phenyl ethanol follows a specific order, indicating.

1-Phenylethanol >4-Methylphenylethanol >4-Methoxyphenylethanol > 4-Florophenylethanol

Table 4: The Influence of temperature change on reaction rate

Alcohols	40ºC	45ºC	50ºC	55ºC
	$k \times 10^{-4}$ min^{-1}			
1-Phenylethanol	1.73	1.83	3.33	3.21
4-Methylphenylethanol	1.33	1.66	2.00	2.66
4-Methoxyphenylethanol	1.28	1.41	1.66	2.33
4-Flurophenylethanol	2.00	2.32	2.66	3.33

Table 5: Temperature coefficient of P-substituted alcohols

Sr. No.	Alcohols	Temperature coefficient
I	1-Phenylethanol	1.45
II	4-Methylphenylethanol	1.53
III	4-Methoxyphenylethanol	1.70
IV	4-Flurophenylethanol	1.43

The reasonable values of activation enthalpy ($\Delta H^{\#}$) and activation entropy ($\Delta S^{\#}$) observed in this study provide valuable insights into the nature of electron transfer processes involved. These values fall within a range that is typically positive for reactions involving electron transfers.

Table 6: Study of Energy of activation of P-Substituted alcohols

Sr. No.	Alcohols	E_a Kcal mol^{-1}
I	1-Phenylethanol	12.40
II	4-Methylphenylethanol	12.60
III	4-Methoxyphenylethanol	12.90
IV	4-Flurophenylethanol	11.40

Frequency factor

The combination of a low frequency factor (A) and negative activation entropy further reinforces our earlier assessment of the reaction. The consistency in the free energy of activation ($\Delta G^{\#}$) across all oxidation reactions is a noteworthy observation. This consistency strongly indicates that a similar mechanism likely governs all of these reactions. The near-identical $\Delta G^{\#}$ values imply that, despite potential variations in reactants or reaction conditions, the overall energy barrier that must be overcome to reach the transition state remains remarkably constant. This suggests a common set of chemical pathways and interactions, regardless of the specific reactants involved.

Table 7: Frequency factor for P-Substituted alcohols

Sr. No.	Alcohols	Frequency Factor × 10^{-5} min^{1}
I	1-Phenylethanol	3.96
II	4-Methylphenylethanol	5.00
III	4-Methoxyphenylethanol	6.28
IV	4-Flurophenylethanol	3.15

Enthalpy of activation of alcohols

Table 8: Enthalpy of activation of P-substituted alcohols

Sr. No.	Alcohols	$\Delta H^{\#}$ Kcal mol^{-1}
I	1-Phenylethanol	6.530
II	4-Methylphenylethanol	5.720
III	4-Methoxyphenylethanol	9.530
IV	4-Flurophenylethanol	6.420

The negative values of the activation entropy ($\Delta S^{\#}$) in each case serve as compelling evidence supporting the assertion that the rate-determining step entails the association of molecules, accompanied by a restriction in their freedom of motion. This implies that the transition state exhibits a higher degree of orderliness compared to the initial reactant molecules.

Table 9: Entropy of activation for P-Substituted alcohols

Sr. No.	Alcohols	$\Delta S^{\#}$ e.u
I	1-Phenylethanol	-54.58
II	4-Methylphenylethanol	-52.90
III	4-Methoxyphenylethanol	-46.30
IV	4-Flurophenylethanol	-54.80

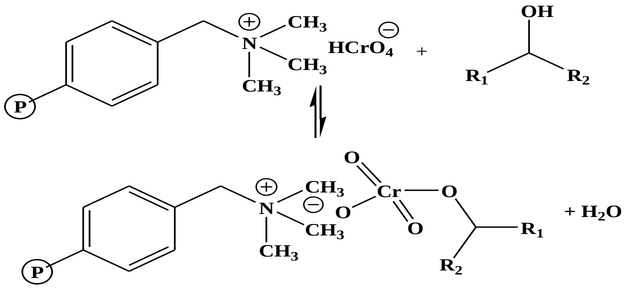
Table 10: Free energy of activation of P-Substituted alcohols

Sr. No.	Alcohols	ΔG# Kcal.mol-1
I	1-Phenylethanol	24.18
II	4-Methylphenylethanol	24.27
III	4-Methoxyphenylethanol	24.36
IV	4-Flurophenylethanol	24.05

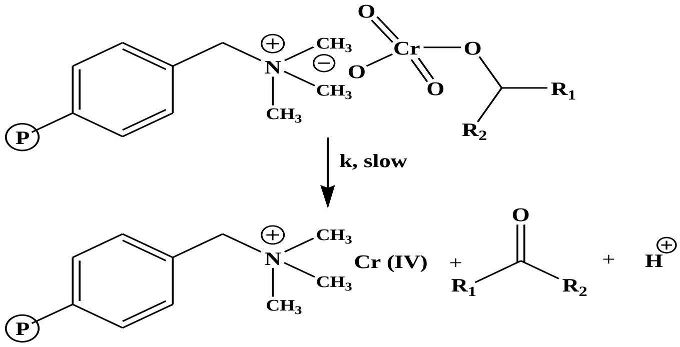
Based on the obtained experimental results, which indicate a zero-order reaction for the oxidation of substituted 1-Phenylethanol, a reasonable mechanistic proposal can be put forth.

Scheme of mechanism

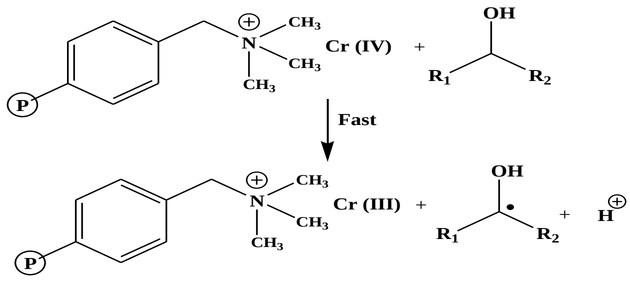
1] The preliminary step in the mechanism involves the formation of an ester



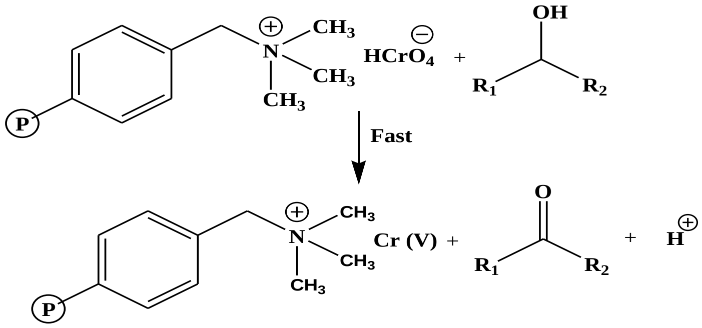
2] In the subsequent step, the formed ester will undergo decomposition, yielding a ketone. This process leads to the formation of the intermediate chromium (IV) in the second, which is also the slower, step.



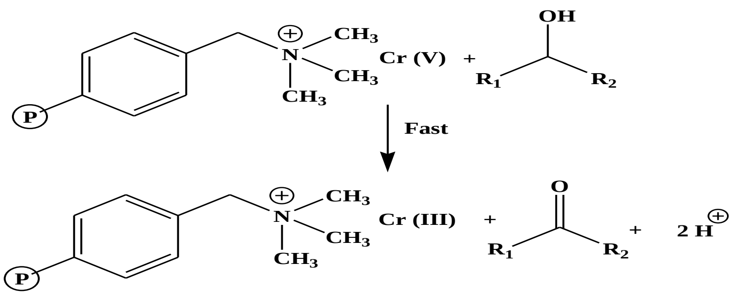
3] The intermediate Chromium (IV) undergoes a reaction with another alcohol, resulting in the formation of free radical. This free radical formation was substantiated by observing the polymerization of acrylonitrile within the reaction mixture as well as by ESR spectrum.



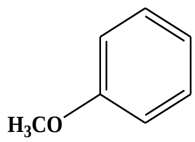
4] The free radical will counter with a second oxidant position in the polymeric reagent in a fast step leading to the creation of chromium (V).



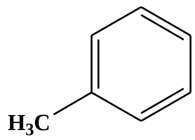
5] Transition chromium (V) in the last step reacts with alcohol to produce ketone. The test for formation of chromium (IV) and chromium (V) by their characteristic induced oxidation of iodine and manganese (II) were not successful, probably due to heterogeneity of the reaction mixture.



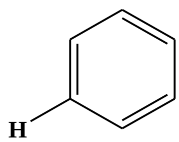
Where R_2 = $-CH_3$ and R_1 =



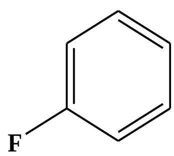
4-Methoxyacetophenone



4-Methylacetophenone



Acetophenone



4-Fluoroacetophenone

In accordance with above Scheme, we anticipate a second-order rate law due to the initial solid-phase ester formation step. Assuming this equilibrium does not significantly influence the overall reaction rate, we observe a zero-order dependence on the rate constant 'k' for the subsequent slower step, where in the reaction corresponding ketone product is generated.

Acknowledgemnt:

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References:

1. Sherrington, D. C., & Hodge, P. (1988). *Syntheses and Separations using Functional Polymers*. John Wiley & Sons.
2. Ley, S. V., Baxendale, I. R., Bream, R. N., Jackson, P. S., Leach, A. G., Longbottom, D. A., Nesi, M., Scott, J. S., Storer, R. I., & Taylor, S. J. (2000). J Chem Soc Perkin Trans 1 23: 3815.
3. Buchmeiser, M. R. (Ed.). (2003). *Polymeric Materials in Organic Synthesis and Catalysis*. Wiley-VCH.
4. Drewry, D. H., Coe, D. M., & Poon, S. (1999). Med Res Rev, 19, 97.
5. Kirschning, A., Monenschein, H., & Wittenberg, R. (2001). Angew Chem Int Ed, 40, 650.
6. Ley, S. V., Baxendale, I. R., Brusotti, G., Caldarelli, M., Massi, A., & Nesi, M. (2002). IL Farmaco, 57, 321.
7. Chesney, A. (1999). *Green Chemistry*, 209.
8. Cano, M., & Balasubramanian, S. (2003). *Drugs of the Futures*, 28, 659.
9. Kirschning, A., Monenschein, H., & Wittenberg, R. (2000). Chem Eur J, 6, 4445.
10. Reader, J. C. (2004). *Current Topics in Medicinal Chemistry*, 4, 671.
11. Marshall, G. R. (2003). J Peptide Sci, 9, 534.
12. Merrifield, R. B. (1963). J Am Chem Soc, 85, 2149.
13. Merrifield, R. B., & Stewart, J. M. (1965). *Nature*, 207, 522.
14. Merrifield, R. B. (1965). *Science*, 150, 178.
15. Sonawane, V. Y., & Hilage, N. P. (2008). *J. Indian Coun. Chem.*, 25(2), 122.
16. Sonawane, V. Y., & Hilage, N. P. (2009). *Orient. J. Chem.*, 25(2).
17. Sonawane, V. Y. (2018). *IOSR. JAC.*, 11, 36-39.
18. Sonawane, V. Y. (2020). *JETER*, 07(4), 162-164.
19. Magar, C. V. (2021). *IJRES*, 9(9), 67-70.

YAKOV PERELMAN: A MATHEMATICAL VISIONARY AND HIS ENDURING LEGACY

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Abstract:

Yakov Isidorovich Perelman (1882-1942) was a prominent Russian mathematician, writer, and educator whose works have left an indelible mark on the world of mathematics and science education. In this research article, we delve into the life, achievements, and lasting impact of Yakov Perelman. Through an examination of his contributions to mathematical literature and educational philosophy, we shed light on his role in promoting mathematical understanding among both students and the general public. We also explore the enduring influence of Perelman's works and their continued relevance in contemporary mathematics education.

Keywords: Mathematician, Educator, Legacy, Author.

Introduction:

Yakov Perelman was a visionary mathematician who dedicated his life to promoting mathematical knowledge and encouraging critical thinking among students and readers of all ages. His commitment to making complex mathematical concepts accessible to the general public resulted in a series of popular science books that have become classics in the field of mathematics education. This research article aims to honor Perelman's contributions and explore their impact on the world of mathematics.

Early life and education:

Perelman was born in 1882 in Bialystok, Russia (now in Poland), and displayed an early aptitude for mathematics. He pursued higher education at the University of Kharkov, where he excelled in mathematics and physics, earning his doctorate in 1909. Yakov Isidorovich Perelman was a distinguished Russian mathematician, educator, and author, known for his contributions to popular science and mathematics education. He was born on December 4, 1882, in Bialystok, which was then part of the Russian Empire (now in Poland). Perelman displayed a remarkable aptitude for mathematics from a young age, setting the stage for a future dedicated to promoting mathematical knowledge and inspiring generations of learners.

Contributions to mathematical literature:

Perelman's most notable contributions lie in his authorship of a series of books that present mathematical concepts in an engaging and accessible manner. His works, including "Mathematics Can Be Fun" and "Physics for Entertainment," have been translated into multiple languages and continue to captivate readers worldwide. These books explore a wide range of topics, from basic arithmetic and geometry to advanced physics and astronomy, appealing to both young students and adult enthusiasts.

Yakov Perelman, a renowned Russian mathematician and author, wrote several popular science books that aimed to make mathematics and science accessible and engaging to a wide audience. Here's a short summary of some of his most notable works:

1. "Mathematics Can Be Fun" (originally published in 1913): In this classic book, Perelman presents a collection of intriguing mathematical puzzles, problems, and paradoxes designed to captivate readers of all ages. Through playful and imaginative examples, he demonstrates that mathematics can be enjoyable, inspiring curiosity and critical thinking.
2. "Physics for Entertainment" (originally published in 1913 as "Physics for Entertainment – Book for Amateurs"): With a focus on physics, this book explores fascinating scientific phenomena and concepts through entertaining anecdotes and real-life situations. Perelman's engaging storytelling style brings complex physics principles within reach of non-specialists, making science both entertaining and enlightening.
3. "Figures for Fun: Stories and Conundrums" (originally published in 1952): In this collection, Perelman presents a variety of mathematical and geometrical problems that challenge readers' logic and reasoning skills. The book features intriguing puzzles, curious shapes, and mind-bending scenarios, encouraging readers to explore the playful side of mathematics.
4. "Arithmetic for Entertainment" (originally published in 1916): Targeted at a younger audience, this book introduces fundamental arithmetic concepts in an enjoyable and interactive manner. Perelman's creative approach makes learning arithmetic an enjoyable adventure, fostering a positive attitude towards mathematics in young readers.
5. "Algebra Can Be Fun" (originally published in 1934): In this work, Perelman makes algebraic concepts accessible and interesting through relatable examples and problem-solving exercises. The book is designed to help readers develop a solid foundation in algebra while emphasizing its practical applications.

6. "Geometry for Entertainment" (originally published in 1939): Through captivating geometrical problems and explanations, Perelman demonstrates the beauty and elegance of geometry. The book engages readers in exploring geometric shapes, transformations, and the principles behind them, encouraging a deeper appreciation for the subject.
7. "Lively Mathematics: Elementary Science" (originally published in 1959)
8. "Mechanics for Entertainment" (originally published in 1945)
9. "Mathematics: A Collection of Articles and Problems" (originally published in 1947)
10. "Trigonometry for Entertainment" (originally published in 1935)

These works by Yakov Perelman have become timeless classics in popular science and mathematics education. They continue to inspire and educate readers, both young and old, making complex mathematical and scientific concepts enjoyable and comprehensible for all. Perelman's dedication to promoting the joy of learning has left a lasting impact on mathematics education worldwide.

Popularizing mathematics education:

Perelman's writing style, characterized by clear explanations, captivating examples, and a sense of wonder, played a pivotal role in popularizing mathematics education. His ability to simplify complex ideas without compromising their essence made his books invaluable resources for educators seeking to engage students with the beauty of mathematics.

Even decades after his passing, Perelman's works remain relevant in modern mathematics education. Educators continue to draw inspiration from his approach to teaching and strive to emulate his passion for making mathematics accessible to all. His books are frequently recommended as supplementary reading in classrooms and serve as a bridge between formal textbooks and real-world applications. While his works were influential, it's important to note that Perelman's life was tragically cut short when he fell victim to political repression during the Stalinist era, leading to his arrest and eventual death in 1942. Despite this, his contributions to popularizing science endure through his writings.

Conclusion:

Yakov Perelman's legacy as a mathematical visionary endures through his enduring works that continue to inspire and educate generations of readers. His commitment to promoting the joy of learning mathematics has left an indelible impact on the field of mathematics education. As we celebrate his contributions, we recognize the lasting influence of this remarkable mathematician and advocate for the importance of fostering curiosity and enthusiasm for mathematics among learners of all ages.

References:

1. Wikipedia. (2019). Yakov Perelman. Retrieved from https://en.wikipedia.org/wiki/Yakov_Perelman
2. Krynzhina, M. D. (2021). *The Language of Modern Popular Science Media*.
3. Pavlova, M., & Shabanova, M. (2020). Students make interactive exhibition "Experimental Mathematics" for the Museum of Entertaining Sciences. *Mathematics Teaching Research Journal*, *12*(1), 58-69.
4. Ross, H. E. (1974). The British Interplanetary Society's Astronautical Studies 1937-39, First Steps Towards Space. *pp 209-216*.
5. Harvey, B. (2007). *Russian Planetary Exploration: History, Development, Legacy and Prospects*. Springer.
6. Kordemsky, B. A. (1992). *The Moscow Puzzles: 359 Mathematical Recreations*. Dover Publication.

CRISPER CAS9 TECHNOLOGY: THE FUTURE OF PRECISION HEALTH

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Abstract:

Genome edition can lead to a change physical trait of an organism. CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats. CRISPR/Cas9 system allows adding, altering, and deleting the genomic code in organisms. Cas9 protein has six domains. It is the most developed and widely used tool for current genome editing. It has been rapidly promoted and applied in the generation of animal models; gene function research; multiplexed mutations; chromosome rearrangements etc. It has certain limitations. This article focuses on the discovery, mechanism, applications, and limitations of CRISPR/Cas 9 gene editing.

Keywords: CRISPR/Cas9, genome editing, mutations.

Introduction:

Like every year, the 2020s made history when the Nobel in chemistry was announced. It was awarded to women scientists Jennifer Doudna and Emmanuelle Charpentier. They honored Noble for the "Development of a method of genome editing". It can lead to the emergence of novel biological applications. All human dreams may come true when this technology is utilized for curing inherited diseases.

In this article, we will discuss the discovery of gene technology's sharpest tool that is CRISPR/Cas9, it's concept, applications, and its limitations.

Origin of gene therapy:

The introduction of gene therapy into the clinic provided hope for thousands of patients with genetic diseases and limited treatment options. Initially, gene therapy utilized viral vector delivery of therapeutic transgenes for cancer treatment.[7]

Tragic setbacks for gene therapy [7]:

Jesse Gelsinger, an 18-year-old with a mild form of the genetic disease ornithine transcarbamylase (OTC) deficiency, participated in a clinical trial. This trial was related to delivering a non-mutated OTC gene to the liver through a hepatic artery injection of the recombinant adenoviral vector housing the therapeutic gene. Unfortunately, Jesse passed away 4 days after treatment. The adenovirus vector triggered a much stronger immune response in Jesse than it had in other patients, causing a chain of multiple organ failures that ultimately led to his death. At the time of the trial, adenoviral vectors were considered reasonably safe.[7]

CRISPR/Cas 9 and gene therapy[7]:

Gene therapy is the strategy to provide therapeutic benefits. It includes modifying genes via disruption, correction, or replacement. It has witnessed both early successes and tragic failures in a clinical setting.

Genome editing is a technique that leads scientists to change the DNA of many organisms such as plants, bacteria, and animals. Genome edition can lead to change physical traits of an organism.

What exactly CRISPR/Cas9 is?:

CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats.[7] It is part of bacteria's immunological system that helps them to recognize threatening viruses. When bacteria sense to hide out the virus, bacteria produce RNAs which are translated into proteins. This also contains the Cas gene which is used to produce enzymes like Cas-9. This Cas-9 enzyme is used to cleave the DNA of a virus that has entered during infection.

CRISPR/Cas9 system allows for adding, altering, and deleting the genomic code in living beings as we do the addition, altering, and deletion of words in the computer. CRISPR are pieces of DNA that bacteria snip from viruses that once attacked them.

Surgery, radiation therapy, and chemotherapy are still the main treatment options for pancreatic cancer, but there is now a considerable effort in identifying better treatment strategies for pancreatic cancer, such as targeted therapy, immune therapy, and potentially CRISPR/Cas9-directed gene therapy.[8]

History of CRISPR/Cas9:

CRISPRs were first discovered in Archae by Francisco Mojica at the University of Alicante, Spain.

CRISPR repetitive sequences were first observed by Ishino et.al in 1987. They identified highly conserved nucleotide sequences with 14 bp dyad symmetry at 30 ends flanking region of alkaline phosphatase gene in *E. coli*.

The function and biological importance of CRISPR sequences were not fully understood until 2007 when Barrangou et al. exposed Streptococcus thermophilus to phage and sequenced the resultant phage-resistant variants. Analysis of the variant DNA revealed that the bacteria had gained new CRISPR spacers that were derived from the phage genome.[8,10]

The identification of CRISPR sequences in bacterial genomes led to the identification of a set of homologous genes referred to as CRISPR and associated (Cas) genes that together comprise the CRISPR locus.

Subsequent work by Jinek et. al(2012) proved that an endonuclease can be directed to cleave target DNA. From this discovery CRISPR/Cas9 technology has rapidly evolved, leading to incredible progress in research and clinical applications.

Compared to the other gene-editing technologies, such as meganucleases (MNs), zinc finger nucleases (ZFNs), and transcription activator-like effector nucleases (TALENs), CRISPR/Cas9 technology has lower cost, higher efficiency, and is less complex in its application [8]

CRISPR/Cas9 for gene editing:

Emmanuelle Charpentier (Director at Max Plank Institute for Infection Biology, Berlin) studied Streptococcus pyogenes, the bacteria that is associated with a range of illnesses like pharyngitis, scarlet fever, and tonsillitis. During this study, she discovered a previously unknown molecule tracrRNA. Her work showed that tracrRNA is part of bacteria's ancient immune system. Dr. Charpentier published her discovery in 2011.

During the same year, she initiated collaboration with biochemist Jennifer Doudna (Now a Professor at the University of California, Berkeley). They both succeeded in the creation of bacterial genetic scissors in vitro. They simplified the scissors' molecular components. In the significant experiment, they reprogrammed genetic scissors in their natural form, scissor recognizes DNA from viruses but Doudna and Charpentier proved that they could be controlled so that they can be cut at a predetermined site and rewrite the sequence that we want to insert at the cut site.

Mechanistic overview of CRISPR/Cas9-mediated genome editing [9]

The key step in editing an organism's genome is the selective targeting of a specific sequence of DNA. Two biological macromolecules, the Cas9 protein, and guide RNA. These molecules interact to form a complex that can identify target sequences with high selectivity.

The Cas9 protein is responsible for locating and cleaving target DNA, both in natural and artificial CRISPR/Cas systems.

The Cas9 protein has six domains, REC I, REC II, Bridge Helix, PAM Interacting, HNH, and RuvC (Fig.1)[1,3,4, 5]

REC I domain:

Largest domain and responsible for binding guide RNA[2]

REC II domain:

The role of the REC II domain is not yet well understood.[2]

PAM (protospacer adjacent motif) domain:

The interacting domain confers PAM specificity and is responsible for initiating binding to target DNA

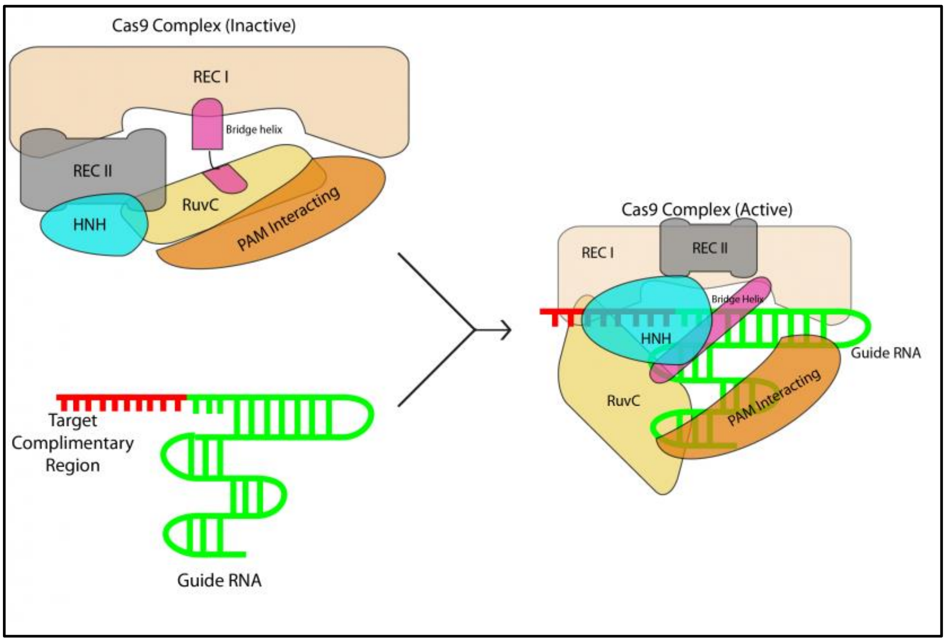

Fig. 1: Image credit: Cavanagh & Garrity, "CRISPR Mechanism", CRISPR/Cas9, Tufts University, 2014.

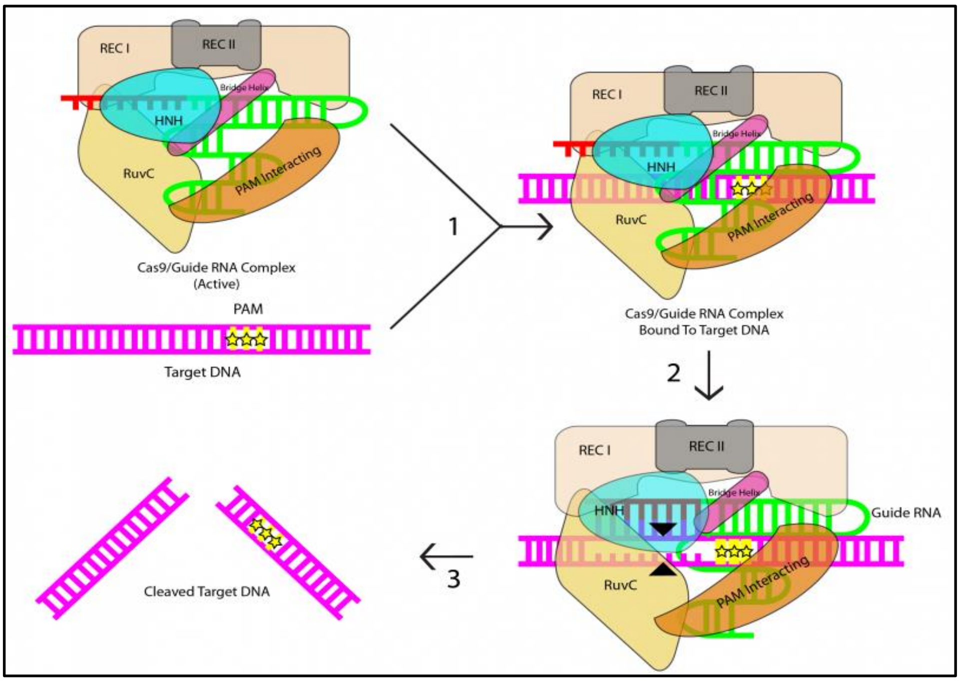

Fig. 2: Image credit: Cavanagh & Garrity, "CRISPR Mechanism", CRISPR/Cas9, Tufts University, 2014.

HNH and RuvC domains:

Nuclease domains that cut single-stranded DNA.

They are highly homologous to HNH and RuvC domains found in other proteins

The Cas9 protein remains inactive in the absence of guide RNA[3]. In engineered CRISPR systems, guide RNA is comprised of a single strand of RNA that forms a T-shape comprised of one tetraloop and two or three stem-loops [3,5] (Figure 2). The guide RNA is engineered in such a way that it should have a 5′ end that is complimentary to the target DNA sequence.

This artificial guide RNA binds to the Cas9 protein and, upon binding, induces a conformational change in the protein. The conformational change converts the inactive protein into its active form (Fig. 1) The mechanism of the conformational change is not completely understood, but Jinek and colleagues hypothesize that steric interactions or weak binding between protein side chains and RNA bases may induce the change [3].

Once the Cas9 protein is activated, it searches for target DNA by binding with sequences that match its protospacer adjacent motif (PAM) sequence (Sternberg et al. 2014). A PAM is a two- or three-base sequence located within one nucleotide downstream of the region complementary to the guide RNA. When the Cas9 protein finds a potential target sequence with the appropriate PAM, the protein will melt the bases immediately upstream of the PAM and pair them with the complementary region on the guide RNA (Sternberg et al. 2014). If the complementary region and the target region pair properly, the RuvC and HNH nuclease domains will cut the target DNA after the third nucleotide base upstream of the PAM (Anders et al. 2014)[9]

Applications:

CRISPR/Cas9 technology has been rapidly promoted and applied in the generation of animal models, gene function research, multiplexed mutations, and chromosome rearrangements.

Cancer immunotherapy:

The first CRISPR Phase 1 clinical trial in the US opened in 2018 with the intent to use CRISPR/Cas9 to edit autologous T cells for cancer immunotherapy against several cancers with relapsed tumors. These include multiple myeloma, melanoma, and synovial sarcoma. This trial was approved by the United States Food and Drug Administration (FDA) after careful consideration of the risk-to-benefit ratios.[7]

CRISPR Cas12-based assay:

Recently, a CRISPR Cas12-based assay named SARS-CoV-2 DETECTR was developed for the detection of COVID-19 with a short turnaround time of about 40 min and a 95% reported accuracy. This method is easy to apply and has been used in a wide variety of experimental models such as cell lines, laboratory animals, plants, and human clinical trials.[6]

CRISPR/Cas9 in other diseases:

The CRISPR/Cas9 system has been applied in cellular and animal models to study and search for treatments for different neurological disorders, such as Parkinson's disease.

CRISPR/Cas9 in disease models:

The CRISPR/Cas9 system has an extraordinary therapeutic potential for treating different diseases in which the genetic cause of dysfunction is known.[6]

Apart from pancreatic cancer research, it is also used in other cancer settings to further understanding of disease progression, identify mechanisms of drug resistance, and uncover potential therapeutic vulnerabilities.

Limitations:

In addition to technical limitations, CRISPR/Cas9, like traditional gene therapy, still raises concerns about immunogenic toxicity

Human subjects in their study possessed pre-existing anti-Cas9 antibodies against the most commonly used bacterial orthologs, SaCas9 and SpCas9 .[7]

While viral vectors continue to be essential for current gene therapy, the concerns and limitations of viral-mediated gene editions have broadened the diversity of gene-editing approaches being considered. The discovery and repurposing of nucleases for programmable gene editing made this possible, beginning with the development of various methods and most recently, the CRISPR/Cas system. Of the CRISPR/Cas systems, CRISPR/Cas9 is the most developed and widely used tool for current genome editing.[7]

Having studied both the applications and limitations of CRISPR technology it can be concluded that it should be the better option for precision medicine in the future. But as a coin has two sides, how we will use this technology will take time to watch.

References:

1. Le Rhun, A., Escalera-Maurer, A., Bratovič, M., & Charpentier, E. (2019). CRISPR-Cas in *Streptococcus pyogenes*. *RNA Biology, 16*(4), 380–389. https://doi.org/10.1080/15476286.2019.1582974
2. Gupta, D., Bhattacharjee, O., Mandal, D., Sen, M. K., Dey, D., Dasgupta, A., Kazi, T. A., Gupta, R., Sinharoy, S., Acharya, K., Chattopadhyay, D., Ravichandiran, V., Roy, S., & Ghosh, D. (2019). CRISPR-Cas9 system: A new-fangled dawn in gene editing. *Life Sciences, 232*, 116636. https://doi.org/10.1016/j.lfs.2019.116636
3. Jinek, M., Jiang, F., Taylor, D. W., Sternberg, S. H., Kaya, E., Ma, E., Anders, C., Hauer, M., Zhou, K., Lin, S., Kaplan, M., Iavarone, A. T., Charpentier, E., Nogales, E., & Doudna, J. A. (2014). Structures of Cas9 Endonucleases Reveal RNA-Mediated Conformational Activation. *Science*, *343*(6176). https://doi.org/10.1126/science.1247997
4. Jinek, M., Chylinski, K., Fonfara, I., Hauer, M., Doudna, J. A., & Charpentier, E. (2012). A Programmable Dual-RNA–Guided DNA Endonuclease in Adaptive Bacterial Immunity. *Science, 337*(6096), 816–821. https://doi.org/10.1126/science.1225829
5. Nishimasu, H., Ran, F., Hsu, P., Konermann, S., Shehata, S., Dohmae, N., Ishitani, R., Zhang, F., & Nureki, O. (2014). Crystal Structure of Cas9 in Complex with Guide RNA and Target DNA. *Cell*, *156*(5), 935–949. https://doi.org/10.1016/j.cell.2014.02.001

6. Rodriguez Rodriguez, D., Ramirez Solis, R., Garza Elizondo, M., Garza Rodriguez, M., & Barrera Saldana, H. (2019). Genome editing: A perspective on the application of CRISPR/Cas9 to study human diseases (Review). *International Journal of Molecular Medicine*. https://doi.org/10.3892/ijmm.2019.4112
7. Uddin, F., Rudin, C. M., & Sen, T. (2020). CRISPR Gene Therapy: Applications, Limitations, and Implications for the Future. *Frontiers in Oncology, 10*. https://doi.org/10.3389/fonc.2020.01387
8. What Is CRISPR: The Ultimate Guide To CRISPR Mechanisms, Applications, Methods & More. (n.d.). https://www.synthego.com/learn/crispr. Retrieved from https://www.synthego.com/learn/crispr
9. https://sites.tufts.edu/crispr
10. Yang, H., Bailey, P., & Pilarsky, C. (2019). CRISPR Cas9 in Pancreatic Cancer Research. *Frontiers in Cell and Developmental Biology*, *7*. https://doi.org/10.3389/fcell.2019.00239
11. Foresight, S. (n.d.). Mihalis Kritikos | Epthinktank | European Parliament. *Epthinktank*. https://epthinktank.eu/tag/mihalis-kritikos/

ARTIFICIAL INTELLIGENCE: REVOLUTIONIZING OUR EVERYDAY EXISTENCE

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Abstract:

Artificial intelligence (AI) has emerged as a transformative force in modern society, profoundly impacting and reshaping various aspects of daily life This paper explores the history of AI and extensive integration of AI technologies in various sectors such as healthcare, education, communications, travel, and entertainment. By exploring the current landscape, we aim to elucidate the profound impact of AI on everyday activities, social structures, and personal experiences. By understanding the implications and challenges associated with the widespread adoption of AI, we can take a closer look at the evolving relationship between humans and intelligent machines

Keywords: History of Artificial Intelligence, Education, entertainment, Transportation, Deeppfake technology

Introduction:

"The emergence of Artificial Intelligence has transformed our world; as intelligent machines have become ever-present in shaping our daily experiences. From machine learning to natural language processing and robotics, AI technologies have revolutionized multiple aspects of our lives, presenting both unique opportunities and challenges. With this in mind, the objectives of this research are to delve deeper into:

a) The evolution of AI in the past and its impact on society.

b) The current state of AI integration in our daily lives.

c) The far-reaching effects of AI on various sectors, including healthcare, education, communication, transportation, and entertainment.

d) The societal implications and ethical considerations that come with the widespread adoption of AI.

e) Potential challenges and futuristic advancements at the intersection of AI and our daily routines."

History of AI

The captivating journey of Artificial Intelligence (AI) is a tale rife with revolutionary ideas, progressive innovations, and ever-evolving aspirations. Artificial intelligence (AI) originated in the ancient world, when attempts were made to create mechanical devices that simulated sentient behaviour. However, formal acceptance of AI as an area of research did not come until the middle of the 20th century. The phrase "Artificial Intelligence", first used during the illustrious 1956 Dartmouth Conference, which is credited with this significant milestone. The prestigious workshop, spearheaded by visionaries such as John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon, is widely regarded as the defining moment of AI's emergence as an academic discipline.

Alan Turing is a well-known British mathematician who made a major effect on the formation of artificial intelligence theory. He developed the ground-breaking "Turing Test" during 1950s to gauge how well a machine might mimic human intelligence. Today, this concept holds significant weight in conversations surrounding AI. In its early years (1950s-1960s), AI research predominantly revolved around symbolic or rule-based systems. The foremost goal was to design systems that had the ability to control symbols to solve complex problems. It was a popular period in the subject for knowledgeable systems and other rationality-driven techniques.

The idea of machine learning started to catch on in the 1950s and 1970s. This was demonstrated by Frank Rosenblatt's work, which in 1957 produced the perceptron, a crude neural network. However, the field had a pause known as the "AI Winter," during which funding and interest in AI research reduced due to numerous budget-related challenges and the limits of the Perceptron. Over the 1970s and 80s, the invention of expert systems emerge as the primary focus of AI research. In an effort to imitate human skill in specialised fields, these systems applied knowledge-based strategies to solve certain issues. Rules and knowledge representations were used to accomplish this.

Research on neural networks became more prevalent in the 1980s and 1990s due to development of algorithmic backpropagation and an improved grasp of neural networks. Consequently, notable advancements were achieved in domains like as speech recognition, pattern recognition, and further AI applications. But AI did not really take off until the twenty-first century. The main strategy was the advancements in machine learning, especially in deep learning. Large-scale data availability and enhanced computing power contributed to this, resulting in advances in image identification, natural language processing, and other AI domains.

Artificial Intelligence (AI) has gained widespread usage across multiple areas, including healthcare, banking, transportation, and entertainment. Particularly noteworthy has been the emergence of virtual assistants, smart devices, and driverless cars. But as AI is used more and more, worries about job displacement, ethics, prejudice, and transparency are becoming more and more pressing. AI's ethical ramifications, particularly those pertaining to privacy and accountability, are hot subjects these days.

Numerous industries, including healthcare, banking, transportation, and entertainment, have seen a rise in the use of AI and robotics in practical applications. Particularly, the development of virtual assistants, smart devices, and driverless cars has drawn a lot of interest. Simultaneously, debates concerning the moral implications and societal fallout have been triggered by the swift adoption of AI technologies. A greater focus has been placed on issues of ethics, bias, transparency, and employment displacement. AI's wide-ranging effects, especially in terms of privacy and responsibility, have spurred a lot of discussion.

The field of artificial intelligence is always changing; at the moment, research is concentrated on subjects like explainable AI, natural language comprehension, and reinforcement learning. Developments in transdisciplinary teams and quantum computing are also significantly influencing how AI will develop in the future.The journey of AI is a captivating tale, characterized by cycles of excitement, doubt, and advancements. As AI techniques continue to progress, their influence on society, the economy, and everyday life deepens, bringing about new possibilities and obstacles for the years ahead.

The current stage of AI

a. AI in medical field

The currently, artificial intelligence in healthcare is remarkable. With the implementation of AI-driven diagnostic tools and treatment recommendations, there has been a significant transformation in the healthcare services. Disease detection and management have become more precise and efficient, ultimately leading to better patient outcomes. Furthermore, wearable AI integration enables real-time health tracking and remote monitoring. This advanced technology enables proactive healthcare interventions and personalized treatment plans, enhancing the overall quality of care. This allows for more targeted and effective interventions, especially in areas such as oncology.

AI algorithms analyse medical images (such as X-rays, MRIs, and CT scans) to help diagnose and diagnose diseases. For example, AI in radiology can detect abnormalities and help radiologists make faster and more accurate diagnoses. AI accelerates drug discovery by analysing large data sets to identify potential drugs and predict their efficacy. This reduces the time and cost of bringing new drugs to market.

AI-driven decision assistance platforms help healthcare professionals make evidence-based recommendations for treatment options. These systems integrate patient information with the latest medical research to improve decision-making. NLP algorithms process and analyze raw data from clinics, medical literature, and other sources. This helps generate valuable insights, improve documentation, and support data-driven decision making. AI makes it easier to continuously care for patients who do not have access to traditional health care. Wearable devices and AI-embedded sensors can monitor vital signs, detect abnormalities, and alert healthcare providers to potential problems. The AI system analyzes patient`s data to predict disease progression, relapse risk, and potential complications. This information assists health care providers in prompt intervention and resource allocation. These systems can analyze data in real time, providing insights and improving operational efficiency. AI-powered virtual assistants provide information, answer questions and assist in medical management. These virtual health agents can provide support to patients and healthcare professionals, strengthen communication and administer treatment regimens. AI improves medical imaging, reduces the necessity of manual scanning, and helps diagnose diseases like cancer earlier. This increases the accuracy and efficiency of analysis. Algorithms help detect fraud in health care claims and optimize payment processes, reduce financial losses and uplift the overall efficiency of health care systems.

b. AI in education

With the aid of AI, receive a distinctive and personalised education. Through careful analysis of your learning patterns, AI algorithms curate educational materials specific to your needs, catering to your unique learning style. Don't struggle with difficult concepts, you are guided by AI-powered tutoring systems that offer personalised learning routes and real-time feedback.

Intelligence (AI) is transforming the education industry with new tools and solutions that enhance learning experiences, facilitate personalized learning and streamline business processes. There are many ways AI is being used in education AI systems examine data on each student's performance individually and customise learning experiences and materials based on learning preferences, learning styles, and areas of strength and weakness. This method will ensure that each student receives a personalized and customized learning journey.

- **Smart presentation design:** The AI-powered tutoring system delivers real-time feedback and guides to students, providing personalized support for understanding complex concepts. These programs adapt to each student’s pace and progress, encouraging customized learning experience.
- **Grading and self-assessment:** AI simplifies the grading process by automatic analysis of assignments. This provides quality information and interacting with students rather than spending a significant amount of time on routine grading.
- **Language resources for writing:** AI-powered tools equipped with natural language processing (NLP) help students improve their writing skills. These tools suggest grammar and style, and help develop strong communication skills.
- **Smart submissions:** AI algorithms analyse educational data to make recommendations and deliver appropriate resources to students and teachers. This ensures that the content is aligned with course requirements and individual learning objectives.

- **Predicting assessment for student success:** AI analyzes historical student data to identify potential learning challenges, dropouts, or areas where additional support may be needed. This approach allows institutions to intervene early and support student success.
- **Gamification and learning processes:** AI helps create gamified educational platforms that engage students through interactive and immersive experiences. These sessions make learning more enjoyable and can improve student motivation. Virtual and Augmented Reality in Education: AI, combined with virtual and augmented reality technologies, enhances the immersive learning experience. Students may be required to analyze historical events, conduct virtual experiments, or create simulations that provide a useful perspective on complex issues.
- **Adaptive Learning Management System (LMS):** AI-powered LMS platforms adapt to each student's unique needs, recommending appropriate lessons, materials and learning strategies. This process facilitates effective course management and enhances the overall learning experience.
- **Business strategies:** AI scheduling, resource allocation and communication, enabling teachers to focus teaching. This can increase efficiency and reduce administrative burden.
- **The faces they see to go:** Some educational institutions are using AI-powered facial recognition techniques to automate attendance tracking, providing business processes associated with student attendance tracking has been weakened While the integration of AI into education brings some benefits, it also raises concerns about data privacy, ethical considerations, and the possibility of algorithmic decision-making bias.

c. AI in communication

The way we connect with one other has been completely transformed by the introduction of AI into communication. AI-powered solutions such as chatbots and language translation have successfully closed the cultural divide by means of Natural Language Processing, enabling smooth real-time communication. AI algorithms can also comprehend and analyse user preferences, this results in personalised content curation in social media and recommendation systems. This has a big effect on conversations on social media and the entire internet.

- **Natural Language Processing (NLP):** NLP enables machines to understand, interpret and process human language. AI applications in networking are using NLP for chatbots, virtual assistants, and language translation services to increase the efficiency of information interactions.
- **Chatbots and virtual assistants:** AI-powered chatbots and virtual assistants provide immediate, automatic responses to user queries. It is used to manage routine interactions in customer service, web support, and communication systems, improving responsiveness and productivity.

- **Language translation:** AI facilitates language translation by overcoming language barriers in global communication. Advanced translation tools powered by AI algorithms are capable of providing more accurate and contextual translations, making cross-language communication even easier. AI-powered speech recognition systems convert spoken speech into text, enabling hands-free communication. Applications include voice-activated virtual assistants, transcription services, and voice-controlled interfaces on devices.
- **Automated information processing:** AI algorithms can create things like news reports, reports, and social media posts. This has implications for content marketing, social media management, and other communication efforts simply by creating content-based content.
- **Emotional analysis:** AI analyzes text data to identify the emotions behind messages, comments, or thoughts. Sentiment analysis helps organizations understand public opinion, measure customer satisfaction, and respond effectively to feedback.
- **Personal recommendations:** AI algorithms analyze user behavior, preferences and interactions to provide personalized content recommendations. It is widely used in content streaming services, news platforms and social media to enhance user engagement.
- **Enhanced email communication:** AI is used in email communications to increase productivity. This includes automatic email planning, filtering and prioritization based on user preferences and past interactions.
- **Conversation workers on social media:** Social media platforms integrate AI-powered conversational services that allow users to engage in real-time conversations. These representatives can answer questions, provide information, and facilitate discussions on a variety of topics.
- **Voice biometrics authentication:** AI is used for voice biometrics to enhance security in networks. Voice authentication systems analyze unique voice characteristics to ensure users are heard, providing additional security.
- **Emotional AI:** AI technology can analyze facial expressions, tone of voice, and other cues to measure emotional states during interactions. This can be used for sentiment analysis, improving customer service interactions, and user experiences.
- **Video conferencing AI:** Video conferencing platforms incorporate AI features such as background blurring, noise cancellation and automated transcription services. These improvements make virtual meetings both better and more efficient.

d. AI in transportation

The future of transportation is being re-imagined with the rise of AI-powered autonomous vehicles. These cutting-edge vehicles are set to revolutionize the way we commute, promising increased safety, efficiency, and accessibility. In addition to the ground-breaking capabilities of autonomous vehicles, AI is also being utilized in traffic management systems. Utilizing predictive analytics, AI algorithms can optimize traffic flow, reducing congestion and improving the overall transportation infrastructure. But the benefits of AI in transportation don't end there. With the help of sensors and IoT devices, AI is being employed for predictive maintenance of vehicles and roadways. By collecting and analyzing data on the condition of vehicles and infrastructure, AI algorithms can identify potential maintenance issues before they become major problems. This proactive approach not only prevents breakdowns but also ensures the overall reliability of our transportation systems. With AI technology at the forefront, the future of transportation is indeed in good hands.

The combination of AI and modes of transportation has revolutionized the progress of smart transportation systems. From buses and trains to bicycles, AI has played a crucial role in optimizing routes, schedules, and ticketing, resulting in a seamless and efficient journey for commuters. Real-time data is utilized by AI-driven navigation systems to provide the fastest and most efficient routes, considering factors such as traffic congestion, accidents, and road closures. Not only does this benefit daily commuters, but the logistics and supply chain industry also benefits from AI's optimization capabilities. From route planning and warehouse operations to inventory management, AI has improved efficiency in this sector. The potential for autonomous delivery vehicles and drones equipped with AI is being explored to further enhance the last-mile delivery process.

By seamlessly integrating artificial intelligence technology, advancements in transportation safety have significantly improved. Through the interpretation of data collected from sensors, AI enables collision avoidance systems, lane departure warnings, and adaptive cruise control, effectively taking corrective actions to avoid mishaps. Moreover, AI has also played an essential role in reducing the environmental impact of transportation. Through the implementation of electric and autonomous vehicles, optimizing traffic flow, and efficient route planning, AI has successfully helped decrease fuel consumption and emissions, promoting sustainability within the transportation sector. Furthermore, AI mechanisms have been instrumental in ensuring regulatory compliance in the sector of transportation. From monitoring driver behavior for adherence to safety regulations to analyzing vehicle emissions and managing compliance with transportation laws and standards, AI has played a crucial part in maintaining strict regulatory standards.

e. AI in entertainment

AI has taken the world of entertainment by storm, revolutionizing the way content is created. From music and art to literature, AI-generated content has created new horizons and disrupted traditional beliefs about artistic expression. These advancements have allowed for more diverse and innovative content, stretching the bounds of conventional thinking. Additionally, AI algorithms play a pivotal role in shaping our entertainment experiences by providing personalized content recommendations on streaming platforms. These recommendations influence our desires and impact our media consumption patterns, further solidifying the presence of AI in the entertainment industry.

- **Contents creation:** AI algorithms are used in content creation for tasks such as screenwriting, video editing and music composition. Generative models like OpenAI's GPT-3 can help creators by creating text-based input prompts.
- **Suggestion framework:** AI-powered recommendation systems analyze users' behaviors, preferences and looks to identify personalized products. Platforms like Netflix, Spotify, and YouTube use these programs to increase user engagement and satisfaction.
- **Personal advertising:** AI algorithms analyze user data to deliver targeted and personalized ads. This not only improves the effectiveness of relevant ads, but also enhances user experiences by providing personalized content.
- **Virtual Reality and Augmented Reality (VR/AR):** AI is contributing to immersive experiences in virtual and augmented reality. AI algorithms improve graphics, simulate realistic environments, and provide interactive features in VR/AR contexts.
- **Content management:** AI is used to process content on online platforms to identify and filter inappropriate or offensive content. This helps users to have a safer and more enjoyable online environment.
- **Characters and CGI:** AI is used in character animation and computer generated imagery (CGI) to create more realistic and vivid characters. AI-powered modeling tools can create life-like movements and facial expressions.
- **Composition and production:** AI technology helps compose songs, helping artists create original songs or remix existing ones. AI-powered instruments can analyze song patterns and create songs that match specific genres or songs.
- **Games:** AI plays an important role in the gaming industry, empowering non-player character (NPC) characters, creating dynamic environments, and enhancing game graphics AI algorithms can tailor the game based on the user and by his own will.
- **Sports news:** AI is used in sports broadcasting for services such as automatic camera tracking, instant replay analysis and real-time statistical generation. This makes all fans of the sport look good.
- **User guide:** AI-powered interactive storytelling platforms let users engage with the storytelling process in unique ways. These platforms use AI algorithms to filter information based on user choices, creating personalized and interactive experiences.

- **Speech and voice introduction:** AI technology enables accurate speech and voice recognition in entertainment. Voice control features on smart devices and virtual assistants allow users to better interact with entertainment content.
- **Deepfake technology:** Deeppfake technology, which uses AI to create realistic video or audio content that raises ethical concerns, has been used in the entertainment industry for special effects, as well as virtual reality in film and television
- **Dynamic pricing of tickets:** AI-powered dynamic pricing models are being used in the entertainment industry, adjusting ticket prices based on factors such as demand, time and availability to optimize revenue

f. Social consequences and the ethical problems

Bias in artificial intelligence algorithms has sparked worries about fair and equal access and treatment, prompting continuous efforts to tackle these concerns. Automating tasks with AI technology brings attention to the problem of job displacement and necessitates the development of plans for employment retraining and adjustment.

Future Applications of AI in Daily Life:

Artificial intelligence (AI) has enormous potential to change how we live our everyday lives. With ongoing innovations in artificial intelligence, we may anticipate smooth AI integration across a range of applications, revolutionizing our daily activities. From increasing efficiency and convenience to personalization, the possibilities are endless. Let's take a look at some potential scenarios that could become a reality in the Future Applications of AI in our day-to-day lives. The creation of individualized virtual assistants is among the most promising opportunities. These AI-driven assistants will have a thorough knowledge of our preferences, habits, and surroundings. They will be proactively assisting us with daily tasks, making customized suggestions, efficiently managing our schedules, and even predicting our needs by analysing our past behaviour. In the realm of healthcare and well-being, AI is poised to assume a pivotal role, offering finely-tuned treatment plans that take into account unique genetic makeup, lifestyle, and health information. With the aid of AI algorithms, wearable technology and sensors will continuously track vital health metrics, allowing for early detection of health concerns and proactive intervention.

In the arena of education and learning, AI's effects will be just as revolutionary. Powered by AI, educational tools will open up new avenues for learning, as adaptive learning platforms dynamically tailor content to individual progress and preferred learning styles. In addition, virtual tutors and AI assistants will provide tailored guidance and support to students, revolutionizing the educational experience.

By combining AI with IoT devices, smart homes will become even more advanced and tailored to individual preferences. From lighting and temperature control to entertainment options, AI algorithms will ensure a seamless and adjustable home environment. Similarly, Artificial Intelligence Integrated autonomous vehicles will revolutionize transportation. With AI guiding the way, commutes will be more productive as people can work, unwind, or engage in other activities while on the go. Furthermore, AI-powered traffic management systems will optimize traffic flow, resulting in less congestion and shorter travel times. As technology continues to rapidly progress, the world of Augmented and Virtual Reality (AR/VR) is set to take an even bigger leap forward. These experiences will become even more tailored and engaging with the incorporation of AI, transporting consumers to realistic and interactive virtual worlds. Not only in the realm of gaming, but also in education, virtual tourism, and remote collaboration, the potential for sophisticated and seamless interactions with AI-enhanced AR/VR is limitless.

Furthermore, AI fundamentally transform how we communicate with technology, expanding beyond typical commands and responses. With the growth of Emotional AI and the advancement of Human-Computer Interaction, machines will develop greater insight of human emotions and thereby improve their ability to understand and respond to our needs. A more organic and sympathetic connection will result from this integration between humans and machines, enhancing our daily interactions and streamlining our use of devices and applications.

The arrival of AI-generated content creation will revolutionize artistic expression and storytelling across multiple mediums such as art, music, literature, and video. Working alongside human creators, advanced AI tools will break traditional boundaries and bring forth innovative and captivating content. As AI increasing widely, Transparency and ethical considerations will also become more crucial.

In the coming years, we can expect humans and AI to work together in close collaboration rather than in competition. Intelligent machines will enhance our capabilities, not replace them. This cooperation will result in synergistic efforts that combine the unique strengths of both parties. While these possibilities give us a glimpse into the potential future of AI, it's crucial to approach these advancements with caution and reflection on ethical, privacy, and security concerns. As AI technologies continue to progress, responsible development and deployment will play a vital role in ensuring that these innovations benefit society as a whole. Let's embrace this partnership between humans and AI with mindfulness and foresight for the greater good.

Challenges of AI

The realm of Artificial Intelligence (AI) unquestionably grapples with a range of obstacles encompassing technical, moral, and societal dimensions. These are some of the key challenges that accompany AI:

When it comes to AI, there is a pressing concern about bias and fairness. It's possible for AI systems to unconsciously continue biases found in the data they were trained on.

Consequently, addressing and ensuring fairness in AI algorithms is no small feat, especially in crucial areas like hiring, finance, and criminal justice. Delving into the concepts of ability and interpretability: The rise of cutting-edge AI models, especially deep neural networks, has brought about a challenge - their intricate workings often remain hidden in the realm of "black boxes," leaving us perplexed about their decision-making processes. To instill trust and promote ethical implementation of AI, promoting transparency and interpretability is of utmost importance.

The issue of data privacy is a crucial consideration when it comes to AI systems, as they rely heavily on large amounts of data for training purposes. This raises concerns about protecting individuals' privacy while still utilizing data to advance AI technology. Striking this balance is no easy task and requires robust regulations and practices. Additionally, the security of AI systems is also a major concern, as malicious actors can manipulate inputs to deceive the system. To prevent exploitation and unauthorized access, ensuring the security of both AI models and the data they process is essential.

However, keeping up with the rapid evolution of AI technology can prove challenging for regulatory frameworks. The development and implementation of appropriate regulations to govern the ethical use of AI poses a significant challenge for policymakers. The lack of standardized practices in developing AI poses significant challenges to achieving interoperability and collaboration. To ensure responsible AI practices, it is crucial to establish industry-wide standards for ethics, safety, and performance.

Additionally, the implementation of AI automation has the potential to displace jobs in various industries. This highlights the importance of preparing the workforce for a shifting job landscape and implementing strategies for reskilling and upskilling. However, the ethical implications of determining what tasks AI systems should perform cannot be overlooked. Complex questions surrounding responsibility, accountability, and moral implications must be carefully considered when making decisions about the role of AI.

AI models, although proficient in specific tasks, often struggle with applying their knowledge to unforeseen situations, hindering their overall effectiveness. Creating versatile AI that can adapt to various scenarios continues to be a longstanding obstacle. Additionally, the energy-intensive nature of training and utilizing advanced AI models have notable environmental consequences. It is imperative to prioritize the development of more efficient algorithms and infrastructure to minimize the ecological impact of AI technologies.

Integrating AI into diverse fields and promoting successful teamwork between humans and AI systems poses a significant test. It is vital to strike a seamless balance between automation and human participation to unlock the true potential of AI. Meeting this challenge demands a multi-faceted approach, involving experts from multiple fields such as research, policy-making, ethics, and industry. Open communication and cooperative efforts are crucial in navigating the intricacies and ensuring the ethical advancement and implementation of AI.

Conclusion:

AI is becoming increasingly prevalent in everyday activities, leaving an undeniable impact on areas such as healthcare, education, communication, transportation, and entertainment. While this presents ground breaking opportunities, it also poses significant societal, ethical, and economic dilemmas that must be carefully considered and proactively addressed. By understanding these complexities, society can navigate the ever-evolving AI landscape and utilize its potential for the greater good. The proliferation of advanced AI technologies, including quantum and neuromorphic computing, brings both possibilities and challenges for the integration of intelligent systems into daily life. Therefore, establishing strong ethical frameworks is crucial in guiding the responsible advancement and implementation of AI.

References:

1. Russell, S., & Norvig, P. (1995). *Artificial Intelligence: A Modern Approach*. Publisher.
2. Tegmark, M. (2017). *Life 3.0: Being Human in the Age of Artificial Intelligence*. Publisher.
3. Lee, R. S. T. (2020). *Artificial Intelligence in Daily Life*. Publisher.
4. Emiliani, P. L., & Stephanidis, C. (2005). Universal access to ambient intelligence environments: Opportunities and challenges for people with disabilities. *IBM Systems Journal, 44*(3), 605–619. https://doi.org/10.1147/sj.443.0605
5. Duarte, E. F., Merkle, L. E., & Baranauskas, M. C. C. (2019). The interface between interactive art and human-computer interaction: Exploring dialogue genres and evaluative practices. *Journal of Interactive Systems, 10*(2), 20–34. https://doi.org/10.5753/jis.2019.551
6. Cook, D. J., Youngblood, M., Heierman, E. O., Gopalratnam, K., Rao, S., Litvin, A., & Khawaja, F. (2003). Mavhome: An agent-based smart home. In *Proceedings of the first IEEE International Conference on Pervasive Computing and Communications* (pp. 521–524). IEEE. https://doi.org/10.1109/PERCOM.2003.1192783
7. Augusto, J. C., & McCullagh, P. (2007). Ambient intelligence: Concepts and applications. *Computer Science and Information Systems, 4*(1), 1–27. https://doi.org/10.2298/CSIS0701001A.

UNLOCKING PETase AND MHETase UNIQUE STRUCTURAL FEATURES FOR EFFICIENT PLASTIC DEGRADATION AND SUSTAINABLE BIOREMEDIATION STRATEGIES

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Abstract:

Plastic, including PET (polyethylene terephthalate) is one of the abundantly producing synthetic polymer. It is a one of the synthetic polymers which is widely used in daily life in modern society, but huge amount of PET waste can cause Serious environmental problems and its accumulation become a global problem as been a non-degradable pollutant. Very recently a novel bacterial strain is discovered known as *Ideonella sakaiensis* that produces many unique enzyme, PETase (polyethylene terephthalate hydrolase) and MHETase- mono (2- hydroxyethyl terephthalic acid hydrolase, which permit bacteria to utilise PET as their energy source (sole source of carbon). The enzyme PETase show hydrolytic activity and substrate PETase. Here, we focus on unique structural features of PETase enzyme and chemical degradation of PET with the help of enzyme PETase and summarize some recent developments in the crystallographic analysis of PETase. In comparison to similar enzymes, PETase have an additional disulfide bond and elongated loop (beta8-alpha6). In particular, the W156 wobbling is closely related to attachment of product and substrate. Enzyme potential as molecular tool that can be important for the development of sustainable bioremediation strategies and catalytic activity to degrade PET.

Introduction:

Plastic is a material which contains an essential constituent of organic substance of large molecular weight. It is a polymer of long carbon moieties. Carbon atoms are attached to each other via a linkage. Plastics are a wide range of synthetic or semi-synthetic materials accoutrements that use polymers as a main component. Their malleability makes it attainable for plastics to be moulded, extruded, or pressed into hard things of various geometry (Wei *et al.*, 2022). This is troubling as utmost waxy forms, resembling as polyethylene terephthalate (PET), formed from polymerized terephthalic acid (TPA) and ethylene glycol (EG) monomers, are non-biodegradable environmental impurities. These two enzymes are part of the special and unique enzyme network system linked or identified in a recent discovered bacterium termed as *Ideonella sakaiensis* (Mori, 2020).

PET is a veritably common type of plastic extensively employed for single- usage plastic bottles, bags, pouches, straws, film, packing 'peanuts' and many fibres in clothing. PET is also called Plastic 1, denoting it is one of, if not the, utmost generally used plastics, and despite its capability to be reclaimed up to ten times (in the case of plastic bottles) and formerly or doubly for polyester apparel, it is a major contributor to waste plastic and plastic in the deep ocean.

Two enzymes polyethylene terephthalate hydrolase (PET hydrolase or PETase) and mono(2hydroxyethyl) terephthalic acid hydrolase (MHETase) as implicit moldable degrading vehicle (Wei *et al.,* 2022).

The usual path to operate mechanical, thermal, and chemical-grounded treatments to break PET waste remains cost-prohibitive and could potentially deliver poisonous toxic secondary impurities (Wei *et al.,* 2022) (Mori, 2020). Therefore, better remediation styles must be developed to deal with plastic contaminants in pelagic and terrestrial environments. Enzymatic treatments could be a presumptive avenue to overcome plastic adulterants in conditions under which enzymes serves without chemicals. The detection of PET hydrolases, along with added modification of the enzymes, has highly aided efforts to enrich their capability to reduce the ester bond of PET. Hence, this emphasizes PET-degrading microbial hydrolases and their donation to easing environmental microplastics. Information on the molecular and degrading mechanisms of PET is also highlighted here, which might be applicable in the coming rational engineering of PET-hydrolyzing enzymes (Mori, 2020).

***Ideonella sakaiensis*: General characteristics**

It is a bacterial strain from the microbial population growing in a PET recycling centre in Sakai city, Japan, that utilizes PET as its direct carbon source. the bacteria as a gram-negative, aerobic bacillus relating a unipolar flagellum, non-pigmented, circular, concentrated margined colonies. colonies. The bacterium exhibits extreme sensitivity towards the slightest increase in temperature or salinity but suitable to tolerate mildly acidic (pH 5.5) or alkaline (pH 9.0) conditions with optimal growth observed at neutral pH (Mori, 2020; Khairul *et al.*, 2022).

In general, the effects of warmth, light, air and water are the most meaningful factors in the declination of plastic polymers. The major chemical changes are oxidation and sequence cleavage, leading to a reduction in the molecular weight and degree of polymerization of the polymer. The depolymerisation recycling process starts with the very first step where plastic waste products are sorted and prepared for processing (Guard, 2020; Khairul *et al.,* 2022). The depolymerisation procedure– frequently referred to as chemo lysis or solvolysis – uses different blend of chemistry, detergent, solvents and heat to break down polymers into monomers.

PETase

I.skaiensis belong to the family of cutinases in this bacteria PETase is detected and identical to other members of the family such as TfCut2(PDB-4CG1), Tacut(PDB-3VlS), and SvCut(PDB-4WFJ). The substrate binding site of the PETase contains an alpha-beta-hydrolase folds contain a twisted nine strands beta sheet flanked by Disqus x helices, catalytic traid is composed by ser- His-Asp residues. Recently reported that catalytic domain of PETase contain Gly-X1-ser-X2_Gly also known as lipase box. Inspite of higher degree of similarity between the crystal structure of the enzyme PETase and other phylogenetically similar cutinases, the catalytic activity is much higher than other members of cutinase family. Molecular simulation and High crystallography study of the enzyme complexes the substrate analog or substrate which shows the important amino acid site attaching to the substrate binding site of PETase. These amino acids have an unequal degree of inflexibility to active site of the PETase enzyme improving its catalytic effectiveness. Trp156(W156) is one of the amino acids located just above the active site domain, only in case of PETase it saves in all identical cutinases and exhibit infexibility. His get substitute with ser in 187 position is accumulated by ser in PETase is important determinant for the enzyme substrate interaction between the PET molecules and enzyme PETase. Bulkier molecules like PET can occupy substrate binding site of PETase because W156 wobbling allow elasticity or expand the active site where substrate bind. The substrate binding site of all enzyme which belong to cutinases family are stabilised by C terminal sulfhydryl bond joining the beta9- alpha6 loop of its alpha-beta hydroxylase fold however sulfhydryl bond is present in PETase which holds the beta7-alpha5 and beta8-alpha6 loop together. Second sulfhydryl bond in PETase Play and important role in holding two catalytic amino acid- His242 and Asp177 which are close to each other stabilising catalytic traid. Beta6-alpha8 in enzyme PETase have three dimensional amino acids which promotes for better accumulation of bulkier substrate molecules like PET (Maity *et al.*, 2021).

Crystal structure of PETase from *I. sakaiensis*

As compare to cutinases, PETase have broader substrate binding site. PETase enzyme have a wider active site due to which this enzyme PETase bind to huge substrate like PET. The residues which make the active site are preserve or semipreserve in enzyme PETase and other similar enzymes. Some different factors other than different types of amino acid may subsidies to change the active site of PETase. W156 Play crucial role in hole substrate this term as “W156 wobbling” means that W156 is preserved in all the similar enzyme but display many conformations. Mainly in PETase. Wobbling plays a crucial role in catalytic reaction: purtative secondary active site cleft get narrower due to two mutations occur in an adjacent region this result enzyme display a greater ability in diminishing PETase enzyme crystallinity. More aromatic interaction was occurred because of addition of Phe residue and PET through molecular inducement, so due to this the active site contact were increased. These outcomes put different binding modes which may occur outside the catalytic center. W156 is preserved in all the similar enzymes but show more than one conformation mainly in PETase.

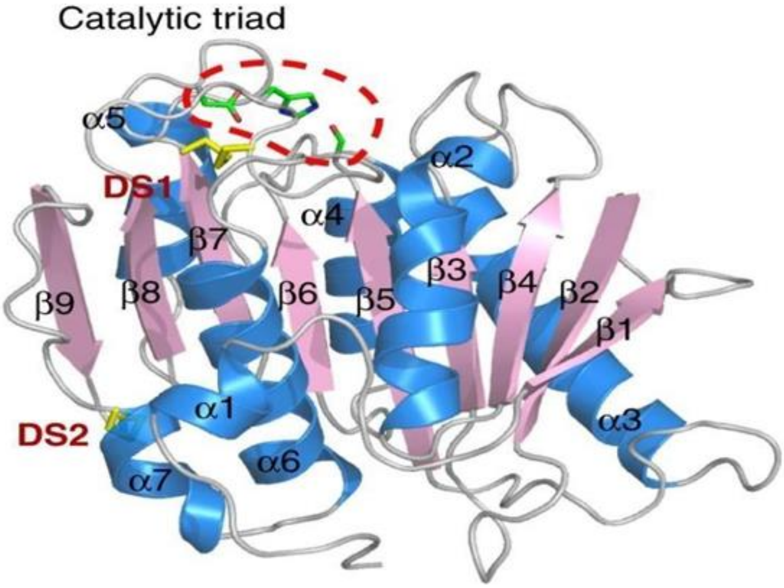

Fig. 1: PETase structure presented as carton model. The catalytic triad and disulfide bridges are shown as stick models (Han *et al.*, 2017)

PETase contain two disulfide bridges but the enzymes which are homologous to PETase contain only one. DS2 link last helix and C terminal loop are preserve in all structure which are homologous to enzyme PETase. PETase- specific DS1 is present adjacent to active site and link the beta7-alpha5 and beta8-alpha6 loop that contain D177 (catalytic acid) and H208 (catalytic base). DS1 play important role in PETase activity. Under experiment such as breaking PET bond condition and mutagenesis show that decrease in enzyme activity due to reduction of DS1 depletion of DS2 may influence the distance among the D177 and H208 residues and thus substrate binding integrity is compromise. DS1 is important to keep the elongated Loop and catalytic traid in their functional region. Another interesting phenomenon, W156 play crucial role in active site. In the apoform different conformation are seen denoted as A, B, and C conformer. W156 is preserved between PETase and other PETase hydrolysing homologous enzyme, but equal Trp in the other structure maintain the c conformation. The amino acid encompassing W156 indicated that His replace S185 in PETase. Trp in the C confirmation is stack and restrict by the His and Trp side chain, were as small spaces for W156 rotation is yeild by small ser residue which allow the addition of a conformation and B conformer. S185 H active residue shown by the mutagenesis experiment. In crystal structure of S185H variant was found that W156 aquire a single conformation. When W156 is acquire S185 than only substrate analog is bind to complex structure. S185 H important residue in PETase that provides W156 with flexibility and active site binding may be different from Wild type PETase.

Complex structure of PETase with substrate and product analogs:

With the help of x-ray crystallography structure of PET hydrolsis enzyme. A complex structure of PET is not easily degraded 1-(2-hydroxyethyl)4-methyl terephthalate (HEMET) it is a complex structure of substrate and pNP of PET (Product analog) expose the substrate binding mode. To achieve complex structure R103G was introduce in addition to non-active mutation S131A otherwise the substrate binding site may be get occupied by the guanidine group of R103 of adjacent protein molecule.

HEMHET contain ester bond moiety and consider a substrate analog. Carboxyl group lies adjacent to A131 in complex structure promote nucleophilic attack by S131 in the wild-type enzyme. The carbonyl O atom is surrounded by H- bond distance of putative oxyaninon hole which is formed by main chain NH group of Y158 and M132 Hydrophobic interaction provide by 1179 and M132. W156 indole ring appear to give face to face (T- stacking) force to HEMT aromatic moiety. Structurally similar to pNP, TPA is consider an analog of a leaving product of PETase. pNP attach to the same site as 1-(2-hydroxyethyl)4-methyl terephthalate (HEMET) and associated with W156, M132 and 1179 through hydrophobic bonds. pNP is rotated about 36° and shift away from cataytic core by ~2.3A°. The benzene ring is face to face (π-stacked) by W156 indole ring. Based on the complicated structure, W156 must be in B conformation to permit ligand binding, implying that other PET- hydrolysing enzyme the equal Trp in a conformation does not accommodate substrate list. In this context S185 which allows W156 wobbling is a major point of PETase. This structure observance is further supported by mutagenesis. Experiment, a S188H mutant exhibits significantly less exertion in hydrolysing PET. Indispensable binding modes may exist but the mode of PETase is supposedly the most favorable for PET hydrolsis as it exhibits superior catalytic activity.

The different binding design of (HEMET) and pNP is also interesting because it implies that the attach substrate proceeds with a structural difference after the ester bond break. PETase form a superficial gap where W156. Maintain different conformation through hydrophobic interaction PET bind to substrate binding site, with the carbonyl group place in the calaytic center with its Oatom facing the oxyaninon hole. W156 should be in B conformation to give a face to face (T-stacking) force to the Trp moiety of PET. Then canonical hydrolytic reaction take place with acyl- enzyme intermediate molecules to break the ester bond. Broader planar surface for due to benzoic acid group the broader planar surface is prove to strong face to face (π-stacking) interaction with W156. The product is rotated and pure away and free from active center.

PETase and MHETase as an effective biodegradation tool

Ideonella sakaiensis has the ability to produce two enzymes that work in sync to break down polyethylene terephthalate (PET) into its constituent monomers. The PETase enzyme from *I. sakaiensis* is responsible for breaking down PET, resulting in soluble byproducts. One of these byproducts is mono(2-hydroxyethyl) terephthalate (MHET) and bis (hydroxyethyl) terephthalate (BHET), which is further broken down into terephthalic acid and ethylene glycol by the enzyme MHETase specific to MHET (Fig 1). It has been previously reported that various types of hydrolases such as esterases, lipases, and cutinases can break down PET. Among these, cutinases, a type of serine hydrolase, have been studied for their PET-degrading capabilities. Researchers have examined the catalytic mechanism of cutinase by analyzing complex structures involving inhibitors and natural substrate analogs like cutin and triglyceride. However, since PET has distinct chemical properties compared to the substrates of cutinase, there is a lack of clear understanding regarding how PET binds to the enzyme and the specific mechanism through which PET is broken down (Han *et al.*, 2017).

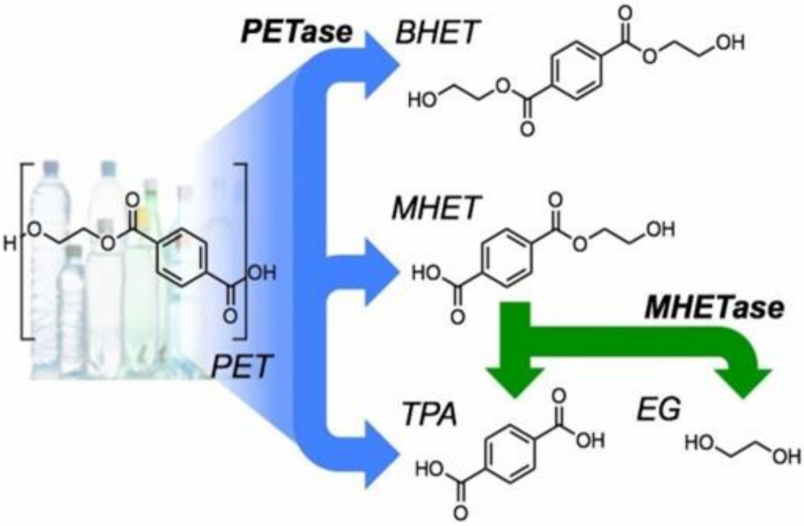

Fig. 2: PETase catalyzes the depolymerization of PET to bis(2-hydroxyethyl)-TPA (BHET), MHET, and TPA. MHETase converts MHET to TPA and EG (Austin *et al.*, 2018).

Several cutinases exhibiting the capability to biodegrade PET have been identified. These include cutinases from various sources such as *Humicola insolens* (HiC), *Thermobifida fusca* (TfCut2), a compost derived from leaf branches (LCC), as well as the enzymes PETase and MHETase from *Ideonella sakaiensis* (Tournier *et al.*, 2020). The biodegradation of the polymer is influenced by various factors including its shape, dimensions, and the presence of diverse additives like chlorine atoms or benzene rings. The degradability of polymer decreases with increase in its molecular weight. The challenges in breaking down plastics are attributed to their elevated hydrophobic nature, crystalline structure, robust chemical bonds, and substantial molecular weight.

Cutinases can hydrolyse both ester bonds found in aliphatic and aromatic polyesters, hence it has wide range of supplication in biodegradation of plastic polymers. PETase is specialized in breaking down ester bonds found exclusively in aromatic polyesters (Austin *et al.*, 2018). Enzymes engaged in the degradation of PET are categorized as esterases and fall under the subclass of α/β-hydrolases, characterized by a catalytic triad (Ser-His-Asp). The hydrolysis of ester bonds occurs through the serine oxygen launching a nucleophilic attack on the carbonyl carbon within the ester bond. This process involves the stabilization of the positively charged histidine residue by the negatively charged aspartate, establishing a charge transfer network that facilitates the nucleophilic attack by serine (Han *et al.*, 2017). In the effort to optimize PETase, researchers have employed rational protein engineering technique which involves comparing PETase with a desirable enzyme, then crafting and assessing mutant versions of PETase with specific structural traits. Within this approach, one team of researchers focused on elevating the thermal stability of PETase, thermal stability is an important characteristic as biocatalysis of PET degradation is easier at higher temperatures. Another approach to improve PETase involved engineering of mutants that can degrade crystalline PET which is found in variety of plastic bottles.

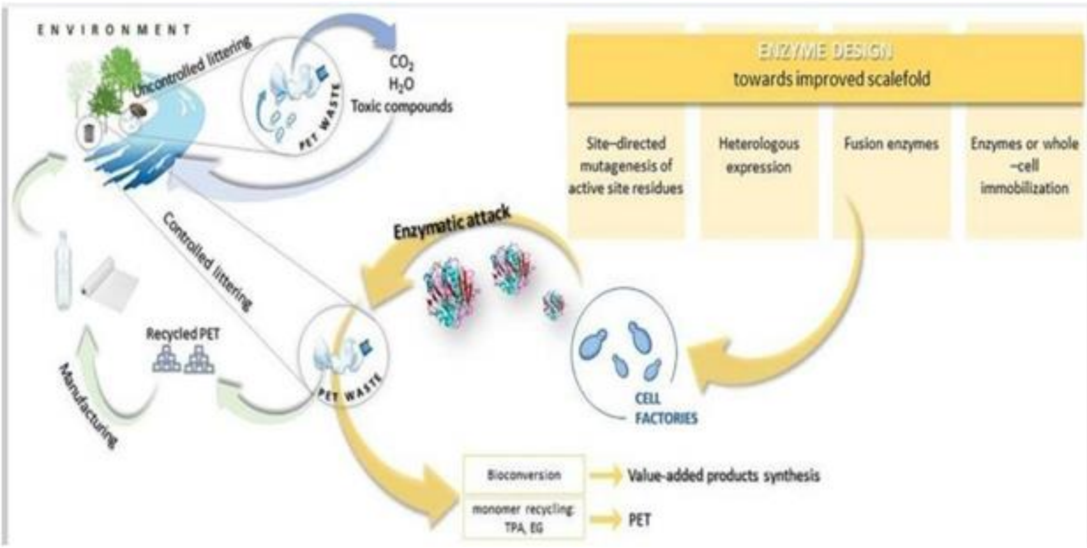

Fig. 3: Scheme of plastic circulation in the natural environment and the possibilities of the plastic circular economy (Urbanek *et al.*, 2021)

Apart from properties of enzyme, structure of the enzyme also plays an important role in enzymatic degradation. Particularly crucial are the regions situated on the enzyme's surface, outside its active site, as well as the binding modules. These elements play a vital role not only in engaging with the polymer but also in facilitating the hydrolysis process. For example, (Liu *et al.*, 2018) proposed in their research that the significance of the broad substrate-binding pocket in PETase is essential for PET hydrolysis. It is important to emphasize that mutations are commonly employed to generate additional room within the active sites, allowing accommodation of sizable and inaccessible polymer particles, as well as to construct a substrate-binding site that is more hydrophobic.

The MHETase discovery occurred at a similar time as PETases, but it is not well studied as compared to PETase despite the fact, that they both are cooperatively involved in degradation of PET by *Ideonella sakaiensis*. In terms of its structure, MHETase is categorized as an α/β hydrolase and stands out for its notable substrate specificity. The domain arrangement of MHETase is similar to those in feruloyl esterase however, it deviates by existing as a monomer instead of a dimeric structure (Sagong et al. in 2020). MHETase functions optimally at a temperature of 45°C and exhibits a broad pH activity range spanning from 6.5 to 9.0 (Palm et al. in 2019). Like other hydrolases, MHETase operates through a nucleophilic attack orchestrated by serine upon the carbonyl carbon. During the initial stages of exploring MHETase's precise structure, an early instance of mutagenesis was conducted in which a modification was done an amino acid within the enzyme's active site generating a number of mutants to identify the key amino acid involved in enzyme activity. Through their investigation, they unveiled that a pivotal amino acid, Phe495, played a crucial role in binding the substrate. Substituting Phe495 with alanine (A) led to the creation of the protein variant F495A. Analyses of this mutant's catalytic attributes demonstrated that its turnover rate in comparison to the original enzyme was diminished by over two-fold, measuring around 5 s-1 (Palm et al. in 2019). MHETases are quite specific to MHET and high-resolution crystallographic analysis showed that substrate-binding crevice within MHETase is shielded by a phenylalanine (Phe424) residue. The inclusion of such bigger amino acids imposes limitations on the ability of the catalytic groove to accommodate larger molecules, such as BHET. This hypothesis was tested using site directed mutagenesis to replace the Phe424 residue with smaller amino acids like Asp, His, Val, and Glu. This led to a noteworthy enhancement in the catalysis of BHET. The outcomes of the experiments involving the selective substitution of Phe424 with these smaller amino acid residues consistently exhibited an expansion of the substrate-binding crevice, consequently amplifying the catalytic efficiency for BHET (Sagong *et al.,* 2020).

Discussion:

With the mounting concern over plastic pollution, the enzymatic degradation of polyethylene terephthalate (PET) has emerged as a promising solution. The increasing global plastic pollution crisis has fueled the search for innovative solutions to tackle plastic waste accumulation (Acero *et al.,* 2011). Polyethylene terephthalate (PET) is one of the most common plastics used in packaging and textiles, contributing significantly to this problem. Enzymatic degradation of PET holds promises as an eco-friendly approach to address this issue. One key enzyme in this context is MHETase, which plays a crucial role in the PET degradation process. This discussion explores the mechanism and efficiency of MHETase as a potential solution to plastic waste management (Austin *et al.,* 2018). Two key enzymes, PETase and MHETase, have garnered attention for their potential roles in PET degradation. This discussion explores the advantages and disadvantages of these enzymes and envisions their future applications in addressing the plastic waste crisis.

Advantages and future perspectives:

- Broad substrate specificity for diverse application: PETase's ability to hydrolyse various PETlike compounds expands its potential beyond traditional PET degradation. This versatility opens doors for its utilization in creating bio-based materials, such as bioplastics, offering a sustainable alternative to conventional plastics (D Chow & Streit., 2020).
- Biodegradation of Amorphous PET: PETase's capability to break down amorphous PET, often used in textiles, is a significant advantage. This property could lead to innovative methods for recycling PET-based textiles, reducing the environmental impact of the fashion and textile industry (Fecker *et al.*, 2018).
- Synthesis of value-added products: Future applications might involve harnessing PETase to produce valuable monomers, such as terephthalic acid, which can be used as precursors for the synthesis of various chemicals, polymers, and even biofuels (Khairul *et al.*, 2022).
- Lower catalytic efficiency: PETase's comparative lower efficiency necessitates synergistic approaches, such as combining it with MHETase, to achieve optimal PET degradation rates for practical applications.
- Risk of non-specific degradation: PETase's broad substrate specificity raises concerns about potential non-specific degradation of unintended materials. Careful engineering and testing are required to ensure its safe application (Khairul *et al.*, 2022).
- Efficient PET hydrolysis: MHETase's proficient cleavage of MHET into terephthalic acid and ethylene glycol provides a key step in the PET degradation pathway. This efficiency is valuable for enhancing the overall process.
- Targeted enzyme engineering: Future prospects involve engineering MHETase to improve its thermal stability and catalytic efficiency, making it more suitable for large-scale industrial applications (Mori, 2020).
- Limited substrate range: MHETase's specificity restricts its application to PET and related intermediates. Future research could explore ways to broaden its substrate specificity for versatility (Hobdey *et al.*, 2021).
- Thermal stability challenges: Addressing MHETase's susceptibility to thermal denaturation is crucial for its practical use in industrial settings, where elevated temperatures might be encountered.

- Combined enzyme approaches: The synergistic utilization of PETase and MHETase holds immense potential. Combining their strengths could lead to optimized PET degradation processes with enhanced efficiency.
- Expanded applications: Beyond PET degradation, these enzymes might play pivotal roles in creating sustainable materials, contributing to the circular economy through recycling and valorisation of plastic waste (Fecker *et al.,* 2018).
- Regulatory consideration: As these enzymes move towards practical applications, regulatory frameworks must be established to ensure their safe and responsible use, considering potential environmental, health, and societal implications.
- Public awareness and education: Raising public awareness about these enzymes' capabilities and limitations is essential for fostering acceptance and understanding of the role they play in plastic waste management (Sulaiman *et al.,* 2014).

The future application of PETase and MHETase in plastic waste management hinges on harnessing their respective advantages while addressing their limitations. These enzymes, when used strategically and responsibly, could be vital tools in mitigating the plastic pollution crisis and transitioning towards a more sustainable and eco-friendly future (Tournier *et al.,* 2020).

References:

1. Han, X., Liu, W., Huang, J. W., Ma, J., Zheng, Y., Ko, T. P., Xu, L., Cheng, Y. S., Chen, C. C., & Guo, R. T. (2017). Structural insight into catalytic mechanism of PET hydrolase. *Nature communications, 8*(1), 2106.
2. Tournier, V., Topham, C. M., Gilles, A., David, B., Folgoas, C., Moya-Leclair, E., Kamionka, E., Desrousseaux, M. L., Texier, H., Gavalda, S., Cot, M., Guémard, E., Dalibey, M., Nomme, J., Cioci, G., Barbe, S., Chateau, M., André, I., Duquesne, S., & Marty, A. (2020). An engineered PET depolymerase to break down and recycle plastic bottles. *Nature, 580*(7802), 216–219.
3. Liu, B., He, L., Wang, L., Li, T., Li, C., Liu, H., Luo, Y., & Bao, R. (2018). Protein Crystallography and Site-Direct Mutagenesis Analysis of the Poly(ethylene terephthalate) Hydrolase PETase from Ideonella sakaiensis. *Chembiochem : a European journal of chemical biology, 19*(14), 1471–1475.
4. Palm, G. J., Reisky, L., Böttcher, D., Müller, H., Michels, E. A. P., Walczak, M. C., Berndt, L., Weiss, M. S., Bornscheuer, U. T., & Weber, G. (2019). Structure of the plastic-degrading Ideonella sakaiensis MHETase bound to a substrate. *Nature communications, 10*(1), 1717.
5. Sagong, H. Y., Seo, H., Kim, T., Son, H. F., Joo, S., Lee, S. H., Kim, S., Woo, J. S., Hwang, S. Y., & Kim, K. J. (2020). Decomposition of the PET Film by MHETase Using Exo-PETase Function. *ACS Catalysis, 10*(8), 4805-4812.

6. Acero, H., Ribitsch, D., & Steinkellner. (2011). Enzymatic surface hydrolysis of PET: effect of structural diversity on kinetic properties of cutinases from Thermobifida. *Macromolecules, 44 (12)*, 4632-4640.
7. Austin, H. P., Allen, M. D., Donohoe, B. S., Rorrer, N. A., Kearns, F. L., Silveira, R. L., Pollard, B. C., Dominick, G., Duman, R., El Omari, K., Mykhaylyk, V., Wagner, A., Michener, W. E., Amore, A., Skaf, M. S., Crowley, M. F., Thorne, A. W., Johnson, C. W., Woodcock, H. L., McGeehan, J. E., … Beckham, G. T. (2018). Characterization and engineering of a plastic-degrading aromatic polyesterase. *Proceedings of the National Academy of Sciences of the United States of America, 115*(19), E4350– E4357.
8. Danso, D., Schmeisser, C., Chow, J., Zimmermann, W., Wei, R., Leggewie, C., Li, X., Hazen, T., & Streit, W. R. (2018). New Insights into the Function and Global Distribution of Polyethylene Terephthalate (PET)-Degrading Bacteria and Enzymes in Marine and Terrestrial Metagenomes. *Applied and environmental microbiology, 84*(8), e02773-17.
9. Fecker, T., Galaz-Davison, P., Engelberger, F., Narui, Y., Sotomayor, M., Parra, L. P., & Ramírez-Sarmiento, C. A. (2018). Active Site Flexibility as a Hallmark for Efficient PET Degradation by I. sakaiensis PETase. *Biophysical journal, 114*(6), 1302–1312.
10. Guard, L. (2020, December 2020). https://www.chm.bris.ac.uk/. Retrieved from https://www.chm.bris.ac.uk/.
11. Temporiti, M. E. E., Nicola, L., Nielsen, E., & Tosi, S. (2022). Fungal Enzymes Involved in Plastics Biodegradation. *Microorganisms, 10*(6), 1180.
12. Mori, T. (2020). Enzymatic studies on aromatic prenyltransferases. *J Nat Med. 2020*.
13. Khairul Anuar, N. F. S., Huyop, F., Ur-Rehman, G., Abdullah, F., Normi, Y. M., Sabullah, M. K., & Abdul Wahab, R. (2022). An Overview into Polyethylene Terephthalate (PET) Hydrolases and Efforts in Tailoring Enzymes for Improved Plastic Degradation. *International journal of molecular sciences, 23*(20), 12644.
14. Numoto, N., Kamiya, N., Bekker, G. J., Yamagami, Y., Inaba, S., Ishii, K., Uchiyama, S., Kawai, F., Ito, N., & Oda, M. (2018). Structural Dynamics of the PET-Degrading Cutinase-like Enzyme from Saccharomonospora viridis AHK190 in Substrate-Bound States Elucidates the Ca2+-Driven Catalytic Cycle. *Biochemistry, 57*(36), 5289–5300.
15. Tournier, V., Topham, C. M., Gilles, A., David, B., Folgoas, C., Moya-Leclair, E., Kamionka, E., Desrousseaux, M. L., Texier, H., Gavalda, S., Cot, M., Guémard, E., Dalibey, M., Nomme, J., Cioci, G., Barbe, S., Chateau, M., André, I., Duquesne, S., & Marty, A. (2020). An engineered PET depolymerase to break down and recycle plastic bottles. *Nature, 580*(7802), 216–219.

16. Wei, R., von Haugwitz, G., Pfaff, L., Mican, J., Badenhorst, C. P. S., Liu, W., Weber, G., Austin, H. P., Bednar, D., Damborsky, J., & Bornscheuer, U. T. (2022). MechanismBased Design of Efficient PET Hydrolases. *ACS catalysis, 12*(6), 3382– 3396.
17. Yoshida, S., Hiraga, K., Takehana, T., Taniguchi, I., Yamaji, H., Maeda, Y., Toyohara, K., Miyamoto, K., Kimura, Y., & Oda, K. (2016). A bacterium that degrades and assimilates poly(ethylene terephthalate). *Science (New York, N.Y.), 351*(6278), 1196– 1199.
18. R. Wei, H. Gerlis von and P. Lara, "Mechanism-Based Design of Efficient PET Hydrolases," in *ACS CatalysisVolume 12, Issue 6*, American Chemical Society, 2022, pp. 3382 - 3396.
19. Khairul Anuar, N. F. S., Huyop, F., Ur-Rehman, G., Abdullah, F., Normi, Y. M., Sabullah, M. K., & Abdul Wahab, R. (2022). An Overview into Polyethylene Terephthalate (PET) Hydrolases and Efforts in Tailoring Enzymes for Improved Plastic Degradation. *International journal of molecular sciences, 23*(20), 12644.
20. Maity, W., Maity, S., Bera, S., & Roy, A. (2021). Emerging Roles of PETase and MHETase in the Biodegradation of Plastic Wastes. *Applied biochemistry and biotechnology, 193*(8), 2699–2716.
21. Chen, C. C., Han, X., Ko, T. P., Liu, W., & Guo, R. T. (2018). Structural studies reveal the molecular mechanism of PETase. *The FEBS journal, 285*(20), 3717–3723.
22. Joo, S., Cho, I. J., Seo, H., Son, H. F., Sagong, H. Y., Shin, T. J., Choi, S. Y., Lee, S. Y., & Kim, K. J. (2018). Structural insight into molecular mechanism of poly(ethylene terephthalate) degradation. *Nature communications, 9*(1), 382.
23. Hachisuka, S. I., Nishii, T., & Yoshida, S. (2021). Development of a Targeted Gene Disruption System in the Poly(Ethylene Terephthalate)-Degrading Bacterium Ideonella sakaiensis and Its Applications to PETase and MHETase Genes. *Applied and environmental microbiology, 87*(18), e0002021.
24. Zurier, H. S., & Goddard, J. M. (2022). Directed Immobilization of PETase on Mesoporous Silica Enables Sustained Depolymerase Activity in Synthetic Wastewater Conditions. *ACS applied bio materials*, 10.1021/acsabm.2c00700. Advance online publication.
25. Kim, J. W., Park, S. B., Tran, Q. G., Cho, D. H., Choi, D. Y., Lee, Y. J., & Kim, H. S. (2020). Functional expression of polyethylene terephthalate-degrading enzyme (PETase) in green microalgae. *Microbial cell factories, 19*(1), 97.
26. Zurier, H. S., & Goddard, J. M. (2023). A high-throughput expression and screening platform for applications-driven PETase engineering. *Biotechnology and bioengineering, 120*(4), 1000–1014.

27. Guo, X., Jiang, Y., Xie, D., & Zhou, Y. (2023). Computational investigation on the binding modes of PET polymer to PETase. *Journal of biomolecular structure & dynamics*, 1–8. Advance online publication.
28. Graf, L. G., Michels, E. A. P., Yew, Y., Liu, W., Palm, G. J., & Weber, G. (2021). Structural analysis of PET-degrading enzymes PETase and MHETase from Ideonella sakaiensis. *Methods in enzymology, 648*, 337–356.
29. Erickson, E., Shakespeare, T. J., Bratti, F., Buss, B. L., Graham, R., Hawkins, M. A., König, G., Michener, W. E., Miscall, J., Ramirez, K. J., Rorrer, N. A., Zahn, M., Pickford, A. R., McGeehan, J. E., & Beckham, G. T. (2022). Comparative Performance of PETase as a Function of Reaction Conditions, Substrate Properties, and Product Accumulation. *ChemSusChem*, *15*(1), e202101932.
30. Sevilla, M. E., Garcia, M. D., Perez-Castillo, Y., Armijos-Jaramillo, V., Casado, S., Vizuete, K., Debut, A., & Cerda-Mejía, L. (2023). Degradation of PET Bottles by an Engineered Ideonella sakaiensis PETase.

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