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CURRENT PERSPECTIVE IN PHYSICAL AND MATERIAL SCIENCE RESEARCH

Editors:
Dr. Jitendra Pal Singh
Dr. Sudha Pal
Dr. Atanu Nag
Prof. Y. K. Sharma

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Current Perspective in Physical and Material Science Research

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Editors

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PREFACE

In today's fast-growing world; Science, Technology and Innovation have always played a driving role in the advancement of human civilization and transformation of societies. With the constant evolution of societies, new trends in scientific advancement and technological exploration materialize, offering ground-breaking solutions to the challenges of modern times. Research in physical science and material science holds incomparable significance for the scientific and technological development in the global perspective.

This book, Current Perspectives in Physical and Material Science Research, highlights some of the most innovative advancements that reflect the transformation physical science and material science researchers to collaborate under one roof in order to advance the development of current physical and material scientific research. This book brings together prominent academic scientists, researchers, and research scholars of physical and material sciences to discuss and share their knowledge and research findings on different areas of physical and material science. Our aim is to provide a great platform for the basic and advanced outstanding research from the most fundamental theoretical and practical works in the relevant field.

The chapters in this book cover a diverse range of fields, each contributing to the relevant theme of scientific innovation. Whether it's general and interdisciplinary Physics, metamaterials and nanomaterials or atmospheric sciences; the research presented in this book demonstrates how unique approaches are reshaping the background of recent physical science and material science research.

We anticipate this book serves as a resource for academicians, practitioners, and educators to present and debate the latest discoveries, trends, concerns, practical difficulties, solutions in their domains to adopt innovative approaches in their own work. By embracing the spirit of innovation, we can collectively bring new possibilities to construct a brighter, more sophisticated future for physical science and material science researchers..

- Editors

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L-ORNITHINE MONOHYDROCHLORIDE DOPED HIPPURIC ACID SINGLE CRYSTALS FOR NLO APPLICATIONS

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Abstract:

In the current study, L-ornithine mono hydrochloride added Hippuric acid LOMHA single crystals are synthesized successfully by utilizing slow evaporation solution technique (SEST). The obtained crystals are belonging to the orthorhombic system confirmed by single crystal X-ray diffraction technique (SXRD). The crystalline nature and purity of LOMHA crystal was confirmed by powder XRD pattern. The chemical composition is resolved by the Fourier transform infrared (FTIR) spectroscopy and energy dispersive X-ray analysis. The UV-Visible spectroscopic study showed that the lower cut-off wavelength was found to be 227.82 nm it indicated the good transmission of crystal. The dielectric study emphasizes that the LOMHA crystal is good in the applicability for NLO device applications. The grown crystals showed improvement in the thermal stability upon doping of LOMHA. SHG efficiency of HA is increased relatively upon the inclusion of LOM. These results favor the competency of LOM doped HA crystal in various NLO and laser assisted applications.

Keywords: Slow Evaporation Method, XRD, FTIR, UV-Visible, Dielectric Constant, SHG.

1. Introduction:

In the development of device fabrication, nonlinear optical (NLO) crystals are much concentrating materials in various industries viz., the optoelectronic and photonic fields, and fiber optical communication industry [1]. The symmetrical or regular arrangement of atoms in crystalline lattice point is called crystal. The crystals are used in many of places in our everyday life, chemical industries, food industries, purification technique, etc. In recent year science association of nonlinear optics developed in many applications [2]. The crystals it produced the nonlinear optical effect from electricity, magnetic field and strain field is called NLO crystals. The NLO crystal is formed in any kind of materials like Organic, inorganic and semiorganic crystals are used in the nonlinear optics [3]. Nonlinear optical (NLO) crystals are becoming more and more important materials in a variety of industries, including the photonic, fiber optic, and electronic sectors, as device production advances [4]. The intention is that these NLO materials regular periodic collections of atoms in their crystals allow them to have high levels of light transmission and the capacity to convert frequencies [5]. This indicates less light dispersion. NLO (Non Linear Optical) crystals have been the subject matter of theoretical and experimental scrutinization during the past 20 years. L-ornithine mono hydrochloride amino acids due to their significant impact as a dopant in improving the optical, thermal, mechanical, and SHG efficiency of hippuric acid crystals parameters that are crucial for NLO applications [6]. In the LOM molecule, the or nithine and chloride have cations and anion, respectively [7]. Due to LOM's zwitter ionic nature and significant dipole moment, it could be a useful dopant to improve the crystals performance of hippuric acid. The NLO crystal of L-ornithine mono hydrochloride added Hippuric acid LOMHA single crystal is grown and its characterization investigations are single crystal XRD, Powder XRD, FTIR, UV-visible, Dielectric constant, TGA/DTA and SHG.

2. Experimental procedure

The L-ornithine monohydrochloride added Hippuric acid LOMHA single crystal was prepared by slow evaporation method. The calculated amount of main solvent Hippuric Acid was added into the beaker which containing acetone according to the solubility and stirred for 3 h. On the other side the calculated amount of dopant solvent LOM was added into the beaker which containing distilled water according to the solubility and stirred for 5 h. In order to obtain a homogeneous mixture, both solutions were mixed while being continuously stirred with a magnetic stirrer for 4 h. The LOM doped HA transparent solution was filtered with good quality filter paper. The good quality of LOMHA crystals obtained 37 days is shown Fig.1.

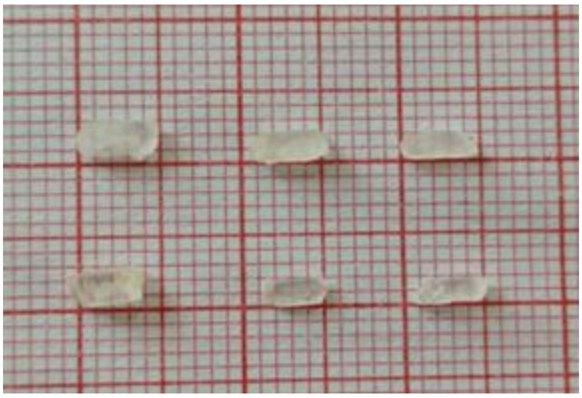

Fig. 1: Grown single crystal of LOMHA

3. Characterization studies

3.1. Single crystal XRD

Single-crystal X-ray Diffraction is a non-destructive analytical technique which provides detailed information about the internal lattice of crystalline substances, including unit cell dimensions, bond-lengths, bond-angles, and details of site-ordering [8]. The final cell constants of a = 8.8828(3) Å, b = 9.1173(3) Å, c = 10.5829(4) Å, volume = 857.08(5) $Å^3$, are based upon the refinement of the XYZ-centroids of 4036 reflections above 20 σ(I) with 5.898° $< 2\theta < 56.15°$. Data were corrected for absorption effects using the Multi-Scan method. The ratio of minimum to maximum apparent transmission was 0.781. The calculated minimum and maximum transmission coefficients (based on crystal size) are 0.9180 and 0.9330.

Table 1: Structure refinement data

Identification code	HLO_03_22022024
Chemical formula	$C_9H_7NO_3$
Formula weight	177.16 g/mol
Temperature	296(2) K
Wavelength	0.71073 Å
Crystal size	0.666 x 0.760 x 0.824 mm
Crystal system	Orthorhombic
Space group	$P_{21\ 21\ 21}$
Unit cell dimensions	a = 8.8828(3) Å
	b = 9.1173(3) Å
	c = 10.5829(4) Å
Volume	857.08(5) Å^3
Z	4
Density (calculated)	1.373 g/cm^3
Absorption coefficient	0.105 mm^{-1}
F(000)	368

3.2. Powder X-ray diffraction analysis

The powder X-ray diffraction is investigated and given crystallinity and analysis the lattice parameter [9]. L-Ornithine monohydrochloride doped Hippuric Acid crystal grown in acetone (LOMHA) was examined at a wide angle of 5^o to 60^o using a powder X-ray diffractometer. Fig. 2. represents the X-ray Diffraction for the sample LOMHA. LOMHA represents the diffraction peaks for the sample LOMHA are 12.96°, 16.22°, 16.69°, 19.31°, 19.91°, 21.69°, 23.38°, 27.91°, 28.80°, 30.46°, 31.60°, 32.70°, 34.61°, 35.33°, 40.45° and 43.84° corresponding to hkl values of (011), (111), (020), (120), (002), (012), (211), (202), (131), (310), (103), (-311), (041), (410) and (051) this crystalline planes confirms the orthorhombic crystal structure orientation with space group $P_{21\ 21\ 21}$ which are referred from the JCPDS card no. (00-030-1748). Powder X-ray diffraction analysis was used to examine the crystalline quality and their cell dimensions. A Rigaku X-ray diffractometer with a Cukα radiation source (1.5406 Å) was utilized for this purpose. Using Bruker SHELXTL Software Package, the growing crystals lattice parameter values were computed and the peaks were indexed.

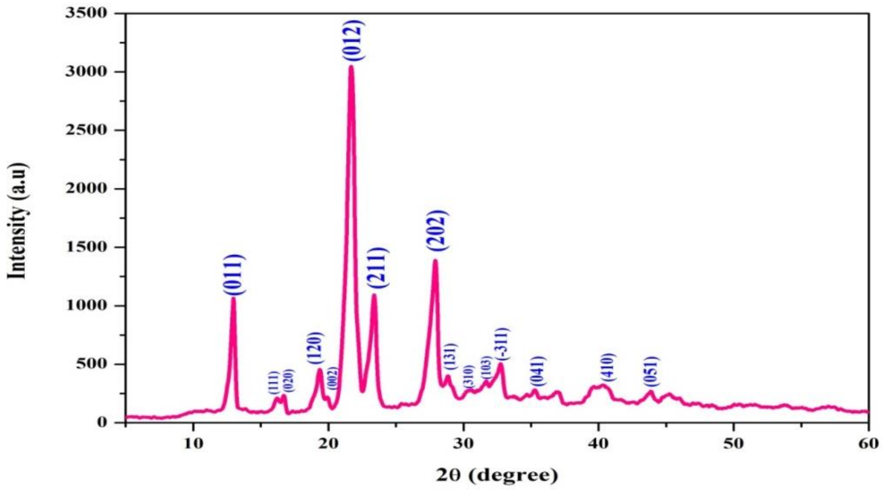

Fig. 2: Powder XRD pattern of LOMHA

3.3. Fourier Transform Infrared (FT-IR) Analysis

The FT-IR of the L-Ornthine monohydrochloride doped Hippuric acid, recorded between 500 and 4000 cm^{-1} using KBr pellet Elmer RXI FTIR spectrometer, is displayed in Fig.3. Analysis was conducted to determine the molecular structure and chemical bonding of the material. For N-H stretching, the bond (alkyne group) at 3342 cm^{-1} is designated [10]. The frequency for C-N stretching is 3060 cm^{-1}. At 2691 cm^{-1} and 2478 cm^{-1}, the distinctive stretching vibrations of CH_2 stretching take place. The peak for C=O stretching is located at 1749 cm^{-1}. At 1553 cm^{-1}, the N-C-N asymmetric stretching vibration was seen. Asymmetric stretching vibration with C=S verified for 1403 cm^{-1} in doped crystal. The N-C-S symmetric bending is shown by the absorption band at 658 cm^{-1}. The cause of the frequency 723 cm^{-1} is symmetric stretching with C=S. The presence of dopant in the crystal is verified by FT-IR.

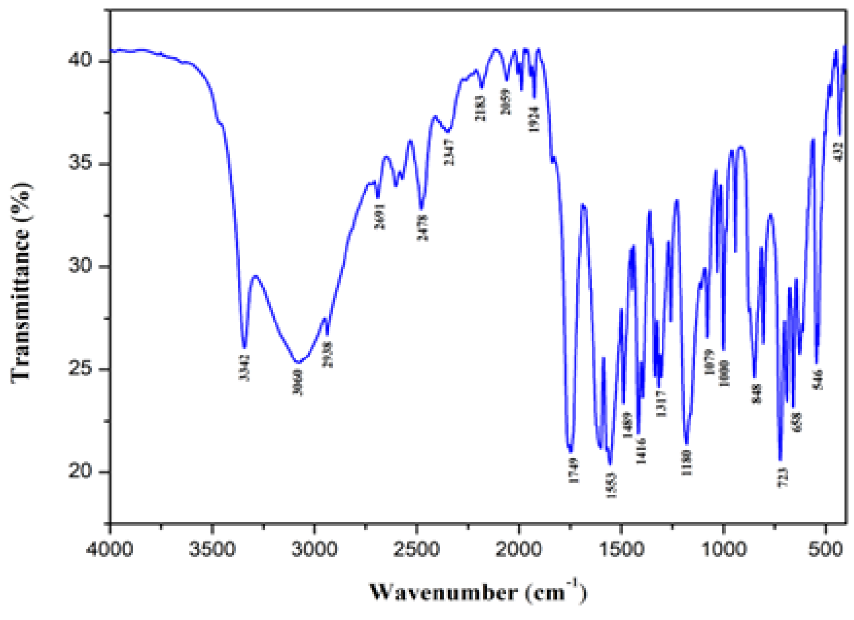

Fig. 3: FT-IR spectral pattern of LOMHA

Table 2: FT-IR analysis

Wavelength region(cm^{-1})	**Functional Group**
3342	N-H Stretching
3060	C-N Stretching
2691	CH_2 Stretching
2478	CH_2 Stretching
2347	Hydrogen bonding interaction of COOH in crystal lattice
1749	C=O Stretching
1553	N-C-N Stretching
1489-1416	C=S Asymmetric Stretching
1180	CH_2 Stretching
1079-1000	C-N Stretching of aliphatic amines present in hippuric acid
848	C-H Stretching
723	C=S Symmetric Stretching
658	N-C-S Symmetric Bending

3.4 UV Visible spectral analysis

One important NLO crystal parameter is optical transmittance. UV-Vis spectral analysis, sometimes referred to as UV-Vis or UV/Vis spectrophotometry, is a workhorse technique in analytical chemistry. Since the promotion of electrons in the s and π orbitals from the ground state to higher energy states occurs during the absorption of UV and visible light, the optical properties of the materials are significant because they reveal information about the electronic band structure, localized state, and type of optical transitions.

Grown crystals of 0.5 cm thickness were taken for the analysis. Using a Jasco V-570 UV-VIS-NIR spectrophotometer, the transmission and absorption spectra in the 200–800 nm wavelength range were captured [11].

$$A = 2 - \log T$$

Where, A is Absorbance and T is Transmittance

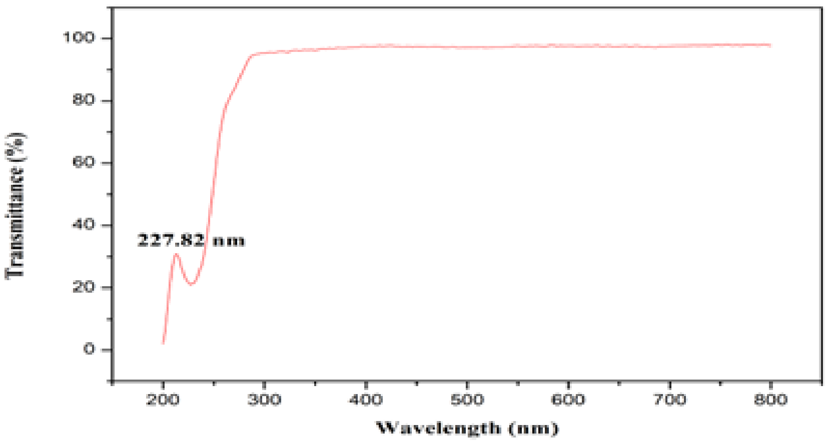

Fig. 4: UV Transmittance of LOMHA

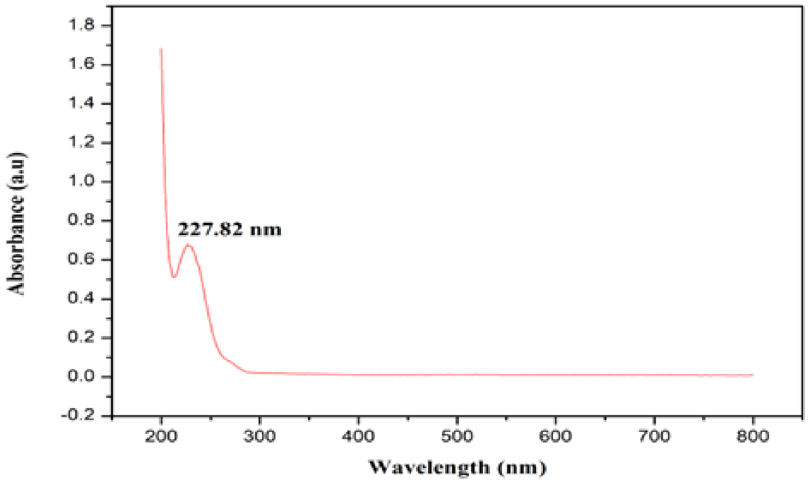

Fig. 5: UV Absorbance of LOMHA

The UV transmittance is used to found the cut off range of LMHA. The cut off range is 227.82 nm shown in Fig. 4. And the UV absorbance is used to found the cut off range of LMHA. The cut off range is 227.82 nm shown in Fig. 5.

3.5. Dielectric studies

In order to determine details of the electric field distribution, the dielectric response to frequency of the grown LOMHA crystal was examined. Fig.6. shows the measured dielectric constant change curves with applied frequency. The following relation can be used to determine the dielectric constant (ε) based on the measurement [12].

$$\varepsilon = Cd/\varepsilon_0 A$$

Here, ε is related to the capacitance of chosen crystal (C) with a thickness of ‘d’ and area of the chosen crystal ‘A’. In LOMHA crystal, it is seen from the curves that the dielectric constant increases at lower frequency region which lowers at elevated frequencies. Such elevated dielectric constant can be associated with the polarization of electronic, ionic as well as dipolar and space charge in the LOMHA crystal. The Fig. 6. shows that the Log f dependent of Dielectric constant.

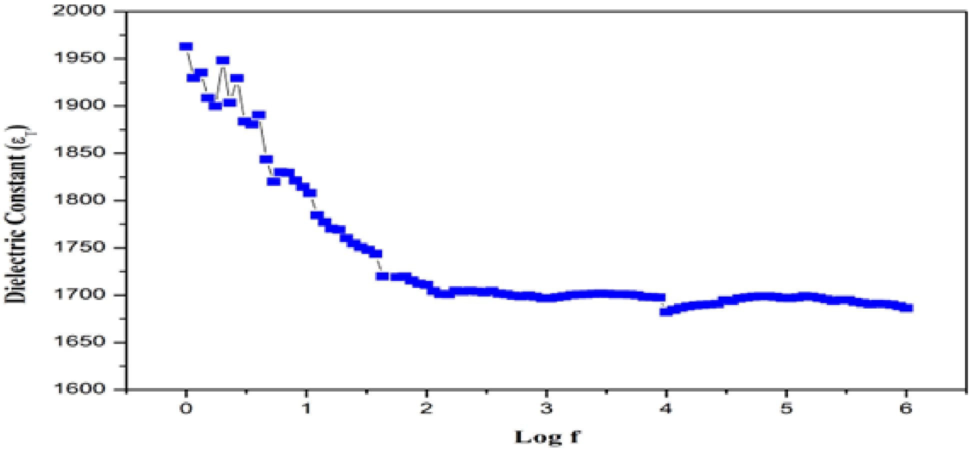

Fig. 6: Log f dependent of Dielectric Constant of LOMHA

At room temperature, dielectric loss with varying frequency was also measured which illustrated in Fig.7. The results demonstrate that the dielectric loss observed for the present crystal is lower at higher frequencies. The dielectric loss and dielectric constant suggest that the LOMHA crystal is suitable for NLO applications. Fig.7. shows that log f dependent of Dielectric Loss for LOMHA crystal.

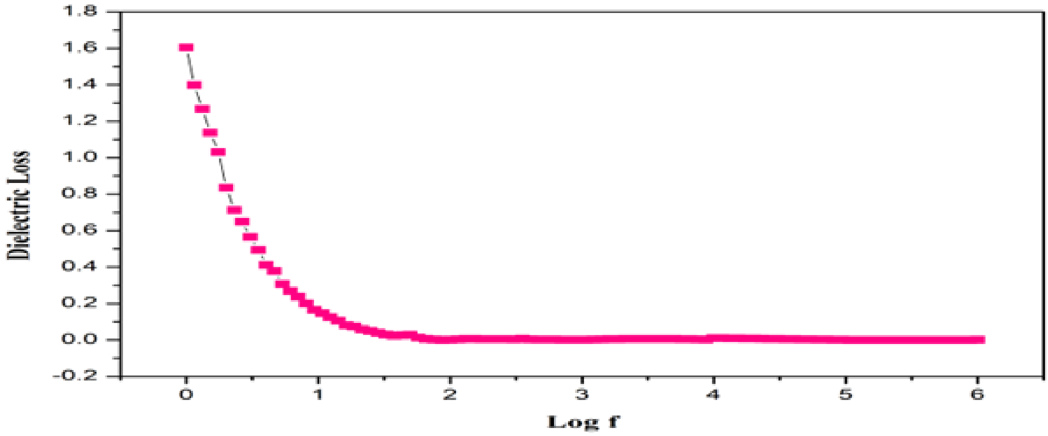

Fig. 7: Log f dependent of Dielectric loss of LOMHA

3.6. Thermo Gravimetric and Differential thermal Analysis

The phase transition, different stages of the decay of the crystal system and the water of crystallization of the crystal are given by the Differential thermo gram analysis (DTA) and Thermo gravimetric analysis (TGA) [13]. Thermal studies of LMHA crystal were analysed by Thermo gravimetric Analysis (TGA) and Differential Thermal Analysis (DTA) between the room temperature and 700 °C in the PerkinElmer instrument at a rate of heating 25° C/min. The thermal image is shown in the Fig.(8). The material is found to be stable up to 250.64°C above the endothermic peak in DTA, which was identified at 250.64°C from the DTA curve [14].

After reaching an endothermic transition, the materials start to break down. The melting point in TG at which weight loss has been seen is determined to be the endothermic peak.

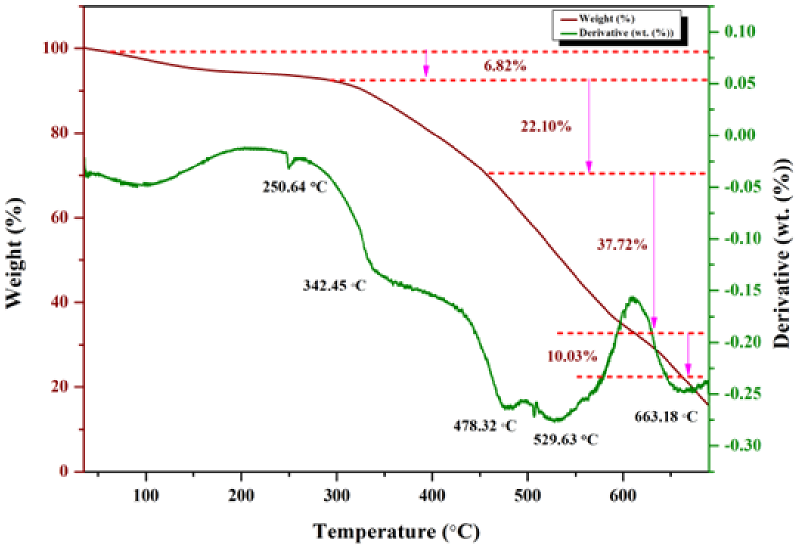

Fig. 8: TG-DTA curve of LOMHA crystal

3.7. Second harmonic generation efficiency

The NLO efficiency of LOMHA crystal was tested using Kurtz and Perry method. The sample was illuminated using Q-switched Nd: YAG laser with the first harmonic output of 1064 nm with a pulse width of 8 ns. The SHG was confirmed by the emission of green light (λ=532 nm). Thus the SHG efficiency of LOMHA is 1.2 times of KDP. Emission of green radiation from the sample confirms the presence of NLO property.

Conclusion:

L-Ornithine Monohydrochloride doped Hippuric Acid Crystal is the new combination of Non-linear of optical organic crystal and it grown by the slow evaporation method. The powder XRD pattern of LOMHA crystal is plotted and its hkl values are matched. The FT-IR analysis the Hippuric acid doped L-Ornithine monohydrochloride crystal and found functional group and molecular structure. The UV-Visible analysis of absorbance and transmittance of the Hippuric acid doped L-Ornithine monohydrochloride crystal were analysed. The UV transmittance is used to found the cut-off range of LOMHA. The cut off range is 227.82 nm for both transmission and absorbance. The thermal characteristics of the crystal are investigated using the thermal gravimetric analysis. The material is found to be stable up to 250.64°C above the endothermic peak in DTA, which was identified at 250.64°C from the DTA curve. The dielectric constant and dielectric loss both were shows that the curves are increases at lower frequency region and indicates the LOMHA crystal is appropriate for NLO applications. LOMHA crystals have SHG efficiency 1.2 times greater than that of KDP.

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MEDICINAL ASPECTS OF SOME COMMON WILD PLANTS OF RANIKHET

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Abstract:

Ranikhet, is situated in the Uttrakhand, India, boasts a diverse array of wild plants with significant therapeutic attributes. While allelopathic medicines show quick effects but may pose potential side effects also. Ayurvedic medicines are often considered safer because it have fewer adverse reactions, as they primarily utilize natural ingredients. This study investigates the important phytochemicals and medicinal value of some wild plants of the Ranikhet.

This review aims to bridge the gap between natural sciences and chemistry, enhancing our understanding of the region's natural resources and their potential to benefit human health. It is an effort that not only enhances our understanding of the intricate web of life in this unique ecosystem but also promises to unlock nature's pharmacy for the benefit of humanity.

Keywords: Allelopathic, Phytochemicals, Resources, Intricate web, Ecosystem.

Introduction:

Ranikhet, a region has a beautiful and diverse landscape of Himalayan mountains is situated approximately 1,869 meters above sea level. It is the home of a diverse array of wild plants. These plants have long been an important part of the ecosystem and the local culture of the Ranikhet [Kumari *et al.*, 2012].

The Ranikhet's unique geography, spanning from high-altitude temperate forests, including a wide variety of herbs, shrubs and trees. These plants have adapted to thrive in the region's challenging conditions, and many have been traditionally used by local communities for different purpose. This indicates a deep-rooted connection between the people of the Ranikhet and their surrounding. The traditional knowledge of the medicinal properties of these wild plants has been passed down through oral tradition. These plants contribute to the well-being of the local inhabitants, offering natural remedies for various diseases and enhancing the overall quality of life of this area [Jain *et al.*, 2020; Kaul, 2020]. While allelopathic medicines show rapid initial efficacy, they subsequently tend to induce more or less adverse effects on the body [Blum, 2018]. However, there are only a small percentage of those plants that have been subjected to pharmacological or biological screening [Mahesh & satish 2008]. The Ranikhet's wild flora encompasses a spectrum of botanical wonders. This study of medicinal wild plants in Ranikhet is a significant aspect of life sciences. It involves exploring the rich biodiversity of the region to identify bioactive compounds that could hold promise for pharmaceutical applications [Choudhary, *et al.*, 2014]. This exploration connects ecological studies, botany, pharmacology, and human well-being, making it a valuable interdisciplinary field.

Methodology

Literature on the published works of *these mentioned plants was* obtained using different search engines, such as Google Scholar, the WSU online database (PubChem), Science Direct etc. An extensive review of the literature on these plants was used to summarize their phytochemicals and medicinal potential. Different research paper relating to the areas of our focus were reviewed. The results from the search were carefully sorted, based on a general understanding of the related objectives.

Description of medicinal properties of some common wild plants of the Ranikhet

1. Botanical name- *Cannabis sativa* L.

Common name- Bhang

Family- Cannabaceae

Habit- Herb

Medicinal properties- *Cannabis sativa* L., commonly known as Marijuana or hemp, is one of the oldest plants described in ancient Vedic texts as a medicinal herb. In Uttrakhand and many other parts of the world it is also known as "Bhang". In Indian society, particularly among Hindus, it also holds a significant aesthetic and cultural status. The medicinal use of this plant primarily involves the flowers, leaves and buds of the female plants. These parts contain high amounts of Tetrahydrocannabinol (THC) and Cannabidiol (CBD), terpenes, Cannabigerol (CBG), Cannabinol (CBN), Myrcene, Linalool, Pinene which are used for various medical purposes. Another part of the plant can also be used in certain preparations. In the twentieth century, there was a strong prohibition on this plant due to its high potential for abuse [Hussain *et al.*, 2021].

It is used as an analgesic, anti-inflammatory, medical cannabis is often prescribed to cancer patients undergoing chemotherapy to reduce nausea and vomiting and reduce morning sickness [Chauhan *et al.*, 2023]. Certain strains of cannabis, particularly those high in CBD and low in Tetrahydrocannabinol (THC), are used to reduce anxiety and stress. It is use as appetite stimulator and improves digestion. In utrakhand sauce of bhang is use as a traditional dish. cannabinoids may have neuroprotective properties, making them potentially useful in the treatment of neurodegenerative diseases like Alzheimer's and Parkinson's disease. It can help individuals with insomnia or sleep disturbances by promoting relaxation and improving sleep quality. It also can reduce intraocular pressure, making it beneficial in managing glaucoma.

2. Botanical name- *Berginia ciliata* (Haw.) Sternb.

Common name- Pather phor

Family- Saxifragaceae

Habit- Herb

Medicinal properties: It is traditionally used as a diuretic (promoting increased urine production), anti-inflammatory, antioxidant and antimicrobial. It reduces the risk of chronic disease symptoms and may help soothe digestive problems. It is traditionally used to prevent kidney stone formation [Kasote *et al.,* 2017]. It may support heart health by helping to regulate cholesterol levels and reduce the risk of cardiovascular diseases [Chauhan *et al.,* 2012]. Quercetin and catechins compounds may have potential anti-ulcer properties, which could help protect the stomach [Shrivastava *et al.,* 2008]. The plant contains compounds like flavonoids, alkaloids, and tannins, arbutin, rutin, and vitamin C which may contribute to its effects. The major bioactive compounds are bergenin, (+)-catechin, gallic acid, β-sitosterol, catechin-7-*O*-*β*-D-glucoside, (+)-afzelechin, *arbutin,* 4-*O*-galloylbergenin, 11-*O*-galloylbergenin, caffeoylquinic acid, pashaanolactone, 3,11-di-*O*-galloylbergenin, bergapten, kaempferol-3-*O*-rutinoside, quercetin-3-*O*-rutinoside, (+)-catechin-3-*O*-gallate, 2-*O*-caffeoylarbutin, leucocyanidin, methyl gallate (gallicin), sitoinoside I, *β*-sitosterol-D-glucoside, avicularin, reynoutrin, procyanidin B1, afzelin, and aloe-emodin [Rafi *et al.,* 2017; Kasto *et al.,* 2017].

3. Botanical name- *Chenopodium album* L.

Common name- Bathua

Family- Amaranthaceae

Habit- Herb

Medicinal properties: This leafy green serves as an economical reservoir of vitamins, minerals, dietary fibers, and essential amino acids [Raju *et al.,* 2007]. In developing regions where dietary patterns are characterized by starchy staples, vegetables emerge as a cost-effective and readily available reservoir of these vital nutrients. Many local and wild vegetables globally remain underutilized due to insufficient scientific knowledge about their nutritional potential. Chenopodium is a prime example of such a vegetable. The plant is used in the diet not only to provide minerals, fiber, vitamins and essential fatty acids but also to enhance the functional parameters of the food. The plant has been traditionally used as a blood purifier, diuretic, sedative, hepatoprotective, antiscorbutic, laxative, anti-diabetic, antihelminthic, wound healing, diuretic, antimicrobial, anti-inflammation, antioxidant, antipruritic, antinociceptive properties. [Pal *et al.,* 2011; Singh *et al.,* 2011]

Marisiddaiah *et al.* (2007) found that *C. album* contains higher levels of both β-carotene and lutein in the range of 114.61–187.59 mg/100 g dry wt. which were higher than other green leafy vegetables. It also has many other phytochemicals like Kaempferol, kaempferol 3-*O*-βglucoside, kaempferol 3-*O*-β-diglucoside, kaempferol-3-*O*-arabinoglucoside, quercetin, quercetin 3-*O*-xylosylglucoside, and quercetin-3- *O* rhamnoglucoside were isolated from the aerial parts *of C. album* (Bylka and Kowalewski 1997). Chludil *et al.,* (2008) isolated six known flavonoid glycosides and their antioxidant activity was determined by DPPHassay1,quercetin-3-O-(2,6-di-O-R-L-rhamnopyranosyl)-beta-D- glucopyranoside;2,kaempferol-3-O-(2,6-di-O-R-L-rhamnopyranosyl)-beta-D- glucopyranoside;3, quercetin-3-O-beta-D-glucopyranosyl-(1 → 6)-beta-D-glucopyranoside; 4,rutin; 5,quercetin-3-O-beta-D-glucopyranoside; and 6,kaempferol-3-O-beta-D-glucopyranoside that have many medicinal properties [Poonia &Upadhyay 2015; Shahi etal 1977]

4. Botanical name- *Berberis aristata* DC.

Common name- Kilmora/ Daruharidra

Family- Berberidaceae

Habit- Shrub

Medicinal properties- It is one of the wild crops of Uttrakhand which play an important role in the social and ecological condition of Uttrakhand.

Berberis aristata contains alkaloids such as berberine, which exhibit potent anti-inflammatory effects. The plant is rich in antioxidants, reduce the risk of chronic diseases and supports overall health. It has Antibacterial and Antimicrobial, Antidiarrheal, antiviral, Hepatoprotective Effects, Cardioprotective, Anti-Hyperglycemic Activity. Berberine specifically has been studied for its potential to help regulate blood sugar levels. It may be beneficial for individuals with type 2 diabetes and can improve insulin sensitivity [Sharma *et al.,* 2011; Bano & Ahmed 2017]. It contains protoberberine and bis isoquinoline berbamine, Berberine, oxycanthine, epiberberine, palmatine, dehydrocaroline, jatrorhizine and columbamine, karachine, dihyrokarachine, taximaline, oxyberberine, aromoline, pakistanine, 1-Omethylpakistanine, pseudopalmatine chloride and pseudoberberine chloride, palamatine. It was found that plants growing at lower altitude have more Berberine content. Berberine content in plants is also influenced by the potassium and moisture content of the soil. [Sharma *et al.,* 2011; Saied etal. 2007; Bhakuni *et al.,* 1968; Chakarvarti *et al.*,1950]

5. Botanical name- *Ficus palmate* Forssk.

Common name- Bedu

Family- Moraceae

Habit- Tree

Medicinal properties- *Ficus palmata* Forssk. Is commonly known as Bedu in Uttrakhand. It is a traditional fruit of Uttrakhand. It is a keystone species of Uttrakhand. It contains phytochemicals like quercetin and kaempferol, which are known for their anti-inflammatory properties. The plant is rich in antioxidants, including flavonoids, tannins, and phenolic compounds. It is Anti-

Diabetic, Anti-Infective and immunomodulatory and may help soothe digestive problems, reduce high cholesterol levels, potentially improve heart health, protect against gastric ulcers, relieve muscle spasms and cramps. The presence of compounds like kaempferol, Taraxasterol, α-Amyrin, Stigmasterol, Brucine, 12-Oleanen-3-yl acetate, (3.α.), Lupeol, β-Amyrin, Octadecanoic acid, Bergapten, n-Hexadecenoic acid, 2,7-Naphthalenediol, Hydroquinone [Chauhan *et al.*, 2014, Al-Quhtani *et al.*, 2023; Sirisha *et al.*, 2010].

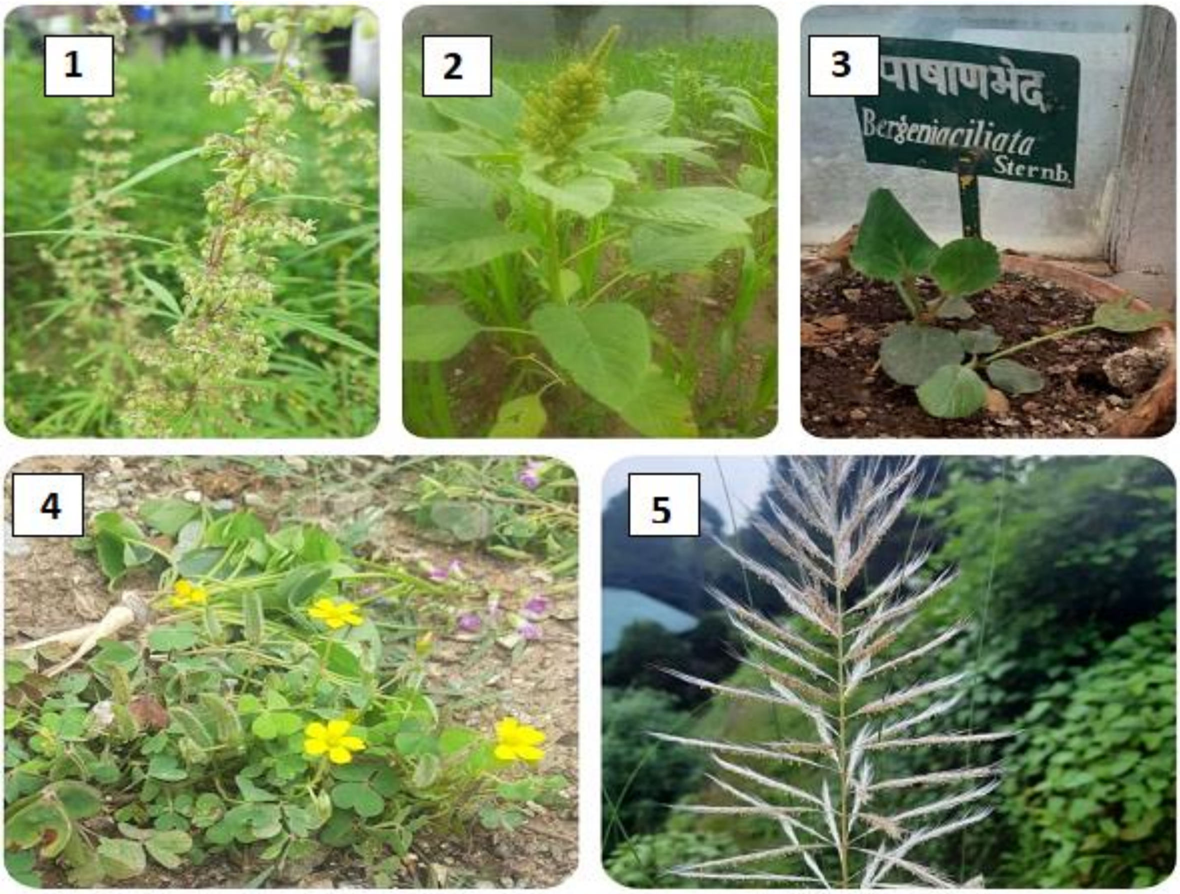

Fig. 1: 1. *Cannabis sativa L.* 2. *Chenopodium album L.* 3. *Berginia ciliata (Haw.) Sternb.* 4. *Oxalis corniculata L.* 5. *Demostachya bippinata (L.)Stapf,*

6. Botanical name- *Rubus ellipticus* Sm.

Common name- Hisalu

Family- Rosaceae

Habit- Shrub

Medicinal properties- *Rubus ellipticus* Sm., commonly known as 'Hisalu' in Uttarakhand, is a wild plant referred to as the "farmer's fruit" due to its ability to replenish water, sugar, and minerals during the summer. This plant exhibits numerous medicinal properties, largely attributed to its phytochemical constituents, including vitamin C, vitamin E, and flavonoids [Joshi, *et al.*, 2022].

These compounds help protect cells from oxidative stress. It has Anti-Inflammatory, Antimicrobial, Anti diarrheal, Antispasmodic and Wound Healing properties. It improve Gastrointestinal Health and acts as cardioprotector as well as immunomodulator. It also has anti-inflammatory, antioxidant, antimicrobial, central and peripheral analgesic and antipyretic, and anticancer activity [George *et al.,* 2013]. Common use of the plant is for the treatment of cough, fever, constipation, diarrhea, relief of stomach worms in children, and healing of bone fracture [George *et al.,* 2013]. The root paste is used for the treatment of bone fracture (as poultice), to promote wound healing, and is applied on the forehead for severe headach, against urinary tract infections, diarrhea, fever, hyperglycemia, and gastric problems, colic pain relief, used to treat warm, the inner root bark is used as a renal tonic and ant diuretic. Ripe fruits show laxative effects, young fruits paste is used for the treatment of gastritis, and cancer, diarrhea, reduce fever and for colic, sore throats and colds [Pandey & Bhatt, 2016]. The leaves exhibit anticonvulsant effects against electrically induced convulsions. It has many phytochemicals like ellagic acid, kaempferol and quercetin, saponins, tannins and glucosides. Fruit is rich in phenols, flavonoids, glycosides, vitamin C, pectin, and tannins [Muniyandi *et al.,* 2019]. The bioactive compounds in the fruits include catechin, ascorbic acid, vanillin, caffeic acid, m-coumaric acid, p-coumaric acid, and cinnamic acid. Catechin presents the highest concentration. Many scientists suggest that the use of these fruits in the nutraceutical, food, cosmetic, and medicinal industries will result in a wide range of benefits [Dhatwalia *et al.,*2022; Kewlani *et al.,* 2022].

7. Botanical name- *Pyracantha crenulata* D.Don.

Common name- Ghingharu

Family- Rosaceae

Habit- Shrub

Medicinal properties- *Pyracantha crenulata* D. Don, the wild apple, locally known as 'Ghingharu' in Uttarakhand, holds ecological significance and has numerous potential medicinal properties. The biochemical composition of berries was assessed by determining moisture percentage, flavonoids, vitamin A, vitamin B12, vitamin C, vitamin E, protein content, calcium, magnesium, potassium, and flavonoids. Notably, oligomeric proanthocyanidins are significant biologically active compounds found in these fruits [Kewlani *et al.,* 2022]. It also has phytochemical compounds such as tennin, terpenoids, saponins, glycosides and alkaloids mainly phenolic acids, such as hyperoside, isoquercitrin, quercetin and rutin, cyanidins, biphenyl glycosides. A compound, pyracrenic acid, isolated from *P. crenulata* bark revealed to be a potent anti-inflammatory agent [Otsuka *et al.,*1981]. linoleic, oleic and palmitic acids were the major fatty acids present in *P. crenulata* seed extract. Approximately 30 compounds are present in the Pyracantha's fruiting and flowering parts. Pyracanthoside and rutin, two flavonoids, appear during all stages of the plant life cycle [Quiroga *et al.,* 2003; Singh *et al.,* 2018; Bisht, 2013). It has antioxidant, anti-Inflammatory, anti-Microbial, antidiarrheal, antispasmodic, analgesic properties. The plant has traditional uses for addressing gastrointestinal issues, wound healing. It may support heart health by helping to regulate cholesterol levels and reduce the risk of cardiovascular diseases (Sharifi-Rad *et al.,* 2020; Saklani & Chandra 2014; Otsuka *et al.,* 1981).

8. Botanical name- *Urtica dioica* L.

Common name- Bichhu buti

Family- Urticaceae

Habit- Herb

Medicinal properties- *Urtica dioica* L., commonly known as 'Bichhu buti' in the Uttrakhand, is a plant with a range of potential medicinal properties. It contains compounds like quercetin, rutin, and beta-sitosterol, which exhibit anti-inflammatory properties. The plant is rich in antioxidants, including flavonoids, carotenoids, and vitamin C, which protect cells from oxidative stress. It has antihistamine, anti-inflammatory, antibacterial, antiviral. It is a natural diuretic, promoting the elimination of excess fluids from the body, potentially due to compounds like flavonoids and organic acids. It may help soothe digestive problems. It has been used to stop bleeding due to compounds like vitamin K and tannins. Extracts of stinging nettle have been used in hair and skincare products for their potential to promote healthy hair growth and alleviate skin conditions [Dorota *et al.,* 2018; Adhikari *et al.,* 2016] Certain phytochemicals in stinging nettles, such as beta-sitosterol, may have immunomodulatory properties, helping to regulate the immune system's response. It is the hub of bioactive phytochemicals namely Isorhamnetin-3-Oneohesperidoside, Kaempferol, Quercetin, sorhamnetin, Scopoletin, sorhamnetin-3-O-glucoside, Nicotiflorin, soquercitrin, Quercetin-3-glucoside, Astragalin, Rutin, Betaine, Choline, Lutein 5,6-epoxide, Serotonin, beta-Carotene, Acetylcholine, Violaxanthin, nIsolariciresinol Vanillin, Secoisolariciresinol, Vanillic acid, Homovanillyl alcohol, beta-Sitosterol, Histamine, (-)-Pinoresinol, Dehydrodiconiferyl alcohol (+)-Neoolivil, Chlorogenic acid, Ursolic acid,Erucic acid,4-Hydroxycinnamic acid [Chauhan *et al.,* 2023; Di Virgilio, 2014]

9. Botanical name- *Demostachya bippinata* (L.) Stapf

Common name- Kush

Family- Poaceae

Habit- Herb

Medicinal properties- *Demostachya bipinnata* (L.) Stapf, commonly known as Kush in the Uttrakhand and used as a holy herb in different rituals in our Vedic culture [Pangety *et al.,*1989]. It is a plant with various potential medicinal properties. Phytochemical analysis of the plant resulted in the isolation of scopoletine and umbelliferone, kaempferol, quercetin, quercetin-3-glucoside, trycin and trycin-7-glucoside 2,6-dihydroxy-7-methoxy-3H-xanthen-3- one), Stigmasterol, βsitosterol, daucosterol, stigmast-5-en-3β, 7β-diol and stigmast-5-en-3 β, 7 β –diol, camphene, isobornyl acetate, tricyclene, caryophyllene diepoxide, I²-eudesmol, eseroline and calarene. The oil also contained smaller percentages of diphenyliodinium bromide, 1- limenone, 2-cyclohexene-1-one and 8-nitro-12- tridecanolide. Linoleic acid ethyl ester, palmitic acid ethyl ester, oleic acid ethyl ester, linoleic acid, palmitic acid, oleic acid, ρ- hydroxycinnamic acid ethyl ester, 2- methoxy-4-formylphenol (vanillin) and stearic acid ethyl ester,Tetradecane, Octylcyclohexane, Octadecene, Phthalic acid, Hexadecane, Nonylhexane, Myristic acid, 6,10,14-Trimethyl-2-pentadecanone, Pentadecanoic acid, Nonadecane, hexadecanoate, Palmitoleic acid, Octadecanol, Heptadecanoic acid, Heneicosane, Linoleic acid, Oleic acid, Pentacosane, Hexatriacontane, Triacontane, Tetracosanoic acid, Tetracontane, Docosanoic acid, Triacontanediol and n-Tetratriacontane, 2- Methoxy-4-formylphenol (Vanillin), Elemicin, n-Hexadecane, Zierone, Myristic acid, Benzyl benzoate, Octadecane, ρHydroxycinnamic acid, Eicosane, Octadecanol, Heptadecanoic acid, Stearic acid, n-Pentacosane, 9- Tricosene, 1,2-Benzenedicarboxylic acid mono (2- ethylhexyl) ester, n-Hexacosane, n-Tetracosane, nPentatriacontane and Docosanoic acid [Al-snafi, 2017; Kumar etal 2010;Shakila *et al.*,2014].

It has anti-inflammatory, antioxidant, anti-diabetic, antimicrobial, anti-ulcer properties. It also has been used traditionally to improve liver health. In traditional medicine, this plant has been used for wound healing [Awaad *et al.,* 2008; Kumar *et al.,* 2010; Arya *et al.,* 2014]

10. Botanical name- *Oxalis corniculata* L.

Common name- Khatti buti

Family- Oxalidaceae

Habit- Herb

Medicinal properties- *Oxalis corniculata* L, commonly known as Chilmora in the Uttrakhand, is a small creeping type of woodsorrel. It is a green perennial herbaceous plant. It is use as a wild edible plant and as forage. The important phytocompounds like β-carotene, Vitamin C and niacin, tannins, flavonoids, polyphenols, steroids, alkaloids, volatile oil, fatty acid and glycosides. Essential fatty acids like palmitic acid, linoleic acid, linolenic acid, stearic acid and oleic acid presence were detected in this plant from earlier studies [Sisodia & Sahu 2020].

It contains various antioxidant compounds like ascorbic acid which can help combat oxidative stress and protect cells from damage caused by free radicals. Traditionally it is used for stomachache, curing the ailments of liver and digestive problem. It has been used to soothe digestive and jaundice problems. This plant is anthelmintic, antiinflammatory, antibacterial, analgesic, astringent, depurative, diuretic, emmenagogue, febrifuge, relaxant, lithontripic, stomachic and styptic. It is used in the treatment of influenza, fever, urinary tract infections, enteritis, diarrhoea, traumatic injuries, sprains and poisonous snake bites [Khare, 2007]. This plant is also used in the treatment of scurvy as it has very high content of vitamin C. The leaves are used as an antidote to poisoning by the seeds of Datura and poisoning by heavy metals like arsenic and mercury. The leaf extract is useful remedy to insect bites, burns and skin eruptions. A decoction of leaves is also used as a gargle [Sarkar *et al.*, 2020]

The plant leaves are a huge source of vitexine-2-0- beta-D-glucopyrunoside, vitexine, fiber and calcium. The stem and leaves are also source of citric and tartaric acid and the stem contains mallic acid also. It is enriched with oxalates and the leaves and stem taste acidic due to the presence of acidic phytocompounds. The plant may be used as a supplementary food source for its easy availability and low cost and it does not require special care for farming. Therefore, considering its entire potentiality it can be concluded that there is ample scope for future research on it [Saikia & Khan, 2011].

Fig. 2: 6. *Ficus palmate Forssk.* 7. *Urtica dioica L.* 8. *Berberis aristate DC* 9. *Pyracantha crenulata D. Don i Rubus ellipticus Sm.*

Result and Discussion:

Ranikhet, situated in the middle Himalayan range of the Uttrakhand, has a rich assemblage of wild plant species that have been traditionally acknowledge for their therapeutic properties. This review provides a comprehensive perspective on the biochemical and medicinal properties of 10 wild plants of the Ranikhet.

The indigenous plant life, having evolved to survive in distinct environmental conditions so they possesse specific bioactive compounds that also have medicinal significance [Kumari *et al.*, 2012]. This review serves as an effort to unveil the specific bioactive compounds present in these wild plants that not only contribute to maintaining the sustainable ecosystem of the Ranikhet but also have medicinal efficacy. In recent times, as scientific methodologies have advanced, there is a growing interest in substantiating these traditional claims with empirical evidence [Pandey *et al.*, 2013]. Understanding the pharmacological basis of the therapeutic effects attributed to these wild plants holds promise for developing novel pharmaceutical compounds and contributing to the broader field of natural products research [Samant *et al.*,1998]. The medicinal plants have not only their curative properties but also in their role in supporting biodiversity, sustainable agriculture, and traditional knowledge systems [Shakya, 2016]. By incorporating plant usage into contemporary healthcare approaches, we can explore innovative and potent treatments, simultaneously fostering environmental conservation and reviving indigenous wisdom [Sen & Chakraborty, 2015; Shrivastava, 2018].

Conclusion:

In this chapter, we have examined the medicinal properties and essential phytochemicals present in 10 common wild plants of the Ranikhet. This effort is anticipated to enrich the ongoing discourse between traditional knowledge and modern scientific methodologies, aiming to cultivate a heightened understanding and acknowledgment of the diverse natural resources present in the Ranikhet. The potential medicinal benefits that may be provided by these plants are aimed to be unveiled by combining the wisdom transmitted through oral traditions with modern scientific research. This investigation into the therapeutic properties of the wild plants within the Ranikhet seeks to illuminate on the traditional, ecological and medicinal importance of these botanical treasures this review also help to conserve that traditional knowledge which knew the importance of local flora either it is cultivated or wild.

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CHARACTERIZATION OF CdS NANOMATERIAL ITS APPLICATION

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Abstract:

The CdS nanomaterial were synthesized by simple chemical precipitation synthesis method. The absorption spectrum of the prepared nanomaterial have been recorded in the UV-Visible region at room temperature. The study their microstructure and optical characteristics utilized X- ray diffraction XRD, UV–VIS spectroscopy, and the electrical properties was also studied. The XRD pattern exhibited the Spherical phase structure of CdS nanoparticles. The useful for many commercial and potential application in photovoltaic, as hetero junction solar cells and thin film solar cells.

1. Introduction:

In recent years, specific properties due to the CdS nanomaterial have novel electronic, structural, and thermal properties which are of high scientific interests in basic and applied fields [1]. CdS nano particles are also used as pigment in paints and in engineered plastic due to their good thermal stability [2]. CdS have large band gap energy of 2.42eV at room temperature that enables its nanoparticles to be remarkable in optoelectronics, photonics, photovoltaic can be used in optoelectronics for marking photocells, light emitting diode (LED) [3], and Lasers field effect transistor [4]. In photonics, due to its photo conducting and electrical properties can be used in sensors, photo detectors, optical filters, and optical switches, its band gap appears in the visible spectrum [5,6,7]. In this work, we have synthesized and developed stable and strong CdS nanomaterials of by the simple chemical precipitation method. In present study, the spectral characterization *i.e.*, absorption.

Nanomaterial have attractive research in recent years because of their unique chemical and physical properties. Under the physical properties in low dimensional and to explore their vast potential for application in spectroscopy.In 1993 the high quality quantum dots of CdS were synthesized for the first time. They emitted different colors depending upon their size,morphology and band gap[6,8,9]

2. Synthesis of cadmium sulfide (CdS) nanomaterials

cadmium sulfide nanoparticles synthesized using a simple chemical precipitation method of cadmium nitrate and sodium sulfide and particles size protected by diethylence Glycol 50 ml 0.1M(0.325gm) cadmium nitrate tetrahydrate ($Cd(NO_3)_2.4H_2O$) was taken in Borosil Biker. Around 5 ml of Diethylene Glycol (DEG) was added to cadmium Nitrate tetrahydrate solution under constant stirring. After 30 minutes,100 ml 0.1M (0.823gm)Sodium sulphide solution under constant stirring,reaction was kept 3hrs(80^0c) at constant stirring and yellow precipitate of CdS formed,washed with ethanol and distilled water dried at room temperature[10,11].

Fig. 1: A flow chart Diagram of synthesis of CdS Nanomaterial

3. Result and Discussion

CdS nanomaterials have been characterized by SEM, XRD and Absorption.Optical properties of nanomaterial have been discuses.

3.1. Scanning Electron Microscopy (SEM)

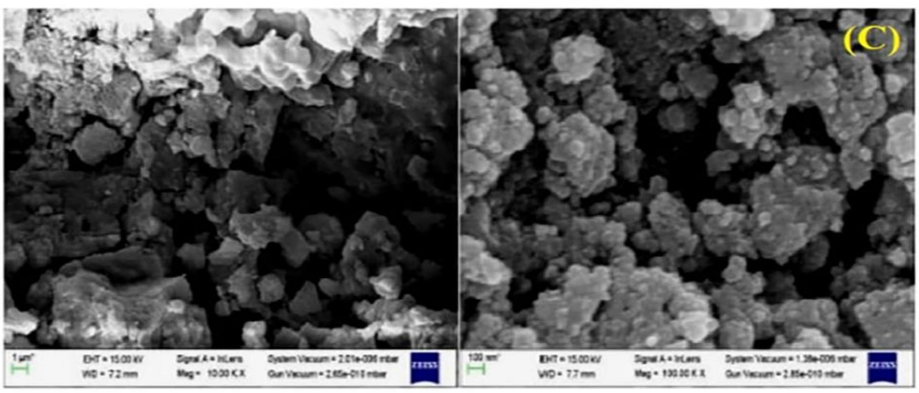

Fig. 2: SEM micrograph CdS nanomateral.

The SEM image CdS nanoparticles prepared by simple chemical pricipetation method at room temperature. The image shows that approximate spherical shape to CdS nanoparticle and size of the particles around 1μ-100nm.It demonstrates clearly the formation of spherial CdS nanoparticles,and change of morphology of the nanoparticles.

3.2. XRD (X-ray Diffraction)

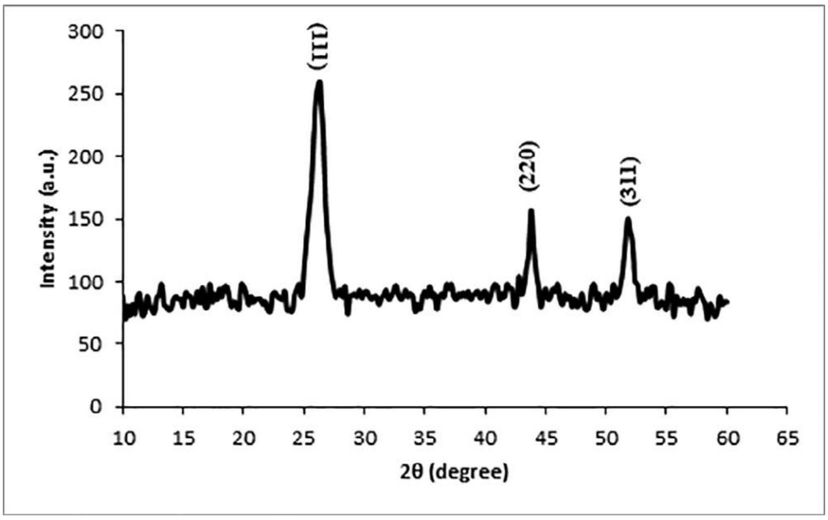

Fig. 3: XRD micrograph CdS nanomaterial

Sharp peaks in the XRD patterns indicate crystalline nature of the samples. XRD pattern of CdS nanomaterials with Nd^{3+} have been shown in Fig.3. The variations of peak position and Sharp diffraction ($2\theta^0$) have been collected XRD patterns indicated that successfully incorporated into the crystal lattice of CdS matrix. The XRD results also confirmed the proper spherical phase formation and improved crystalline. It can be seen that diffraction patterns CdS show only diffraction peaks corresponding to hexagonal wurtzite CdS Joint Committee on Powder Diffraction Standards (JCPDS card # 36-1451).

3.3. UV-visible Absorption spectra

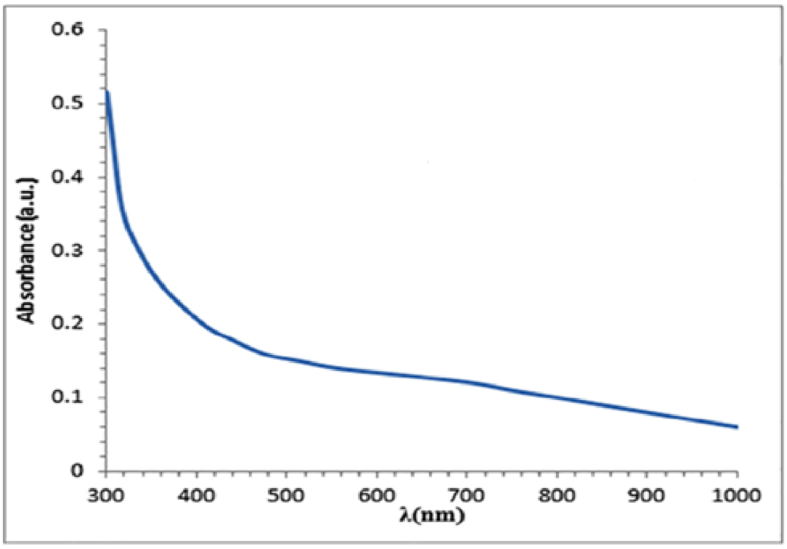

Fig. 4: Absorption spectrum of CdS nanomaterial [12].

The Uv-Visible absorption spectra CdS nanoparticles were at room temperature. The absorption spectra recorded visible region in wavelength range 300-1100 nm fig.4. and correspond to transitions from the level to excited levels. The Uv-Visible spectra region from energy transistions involve the outer orbital or valence electrons[13]. This spectra in liquid media are usually broad, relatively featureless bands a result indicated a blue shift absorption. Uv-visible spectrophotometer used for primary application in quantitative analysis and calculated different parameters[14]. The study of the energy level structure is necessary for interpretation of spectra. The absorption spectra in visible consist of narrow weak band. This chapter has been focused on the along with the interpretation of the observed optical absorption spectra of ions doped CdS nanomaterial in terms of energy state and intensity of transistions[15]

The Uv-Visible absorption spectra CdS nanoparticles were at room temperature. The absorption spectra recorded visible region in wavelength range 300-1100 nm and correspond to transitions from the level to excited levels

Conclusions:

Cadmium nanoparticles were successfully prepared simple chemical precipitation synthesis. The XRD pattern exhibit a spherical phase structure of CdS nanomaterial. Absorption spectrum has high absorption in UV wavelength region due to the quantum confinement effect. The useful hetero junction therefore based on responsivity value this technique is a simple, low-cost, and promising method to fabricate photodetectors, sensor LED etc.

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STUDY OF HYBRID SOLAR CELL AND FUTURE SCOPE: A REVIEW

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Abstract:

In present years with the rapid increase of efficiency more than 25% during the past few years, the perovskite solar cells have advanced more attention because of their high power conversion efficiency (PCE), easy fabrication process, light-weight, low-cost materials manufacturing etc. Hybrid solar cell or organic-inorganic metal halide perovskite solar cells (PSCs) have recent progressive research topic for the researchers due to their various advantages such as long carrier diffusion lengths, widely energy band gap with large absorption coefficient. Due to their low-cost fabrication techniques and high efficiency are more advanced comparable to silicon solar cells. In this review chapter focused on Perovskite materials, Properties and efficiency of perovskite solar cells.

Key words*:* Perovskite Solar Cell, Perovskite Materials, External Efficiency

Introduction:

Solar energy is the most abundant and clean form of energies offering an answer to the increasing concern of global warming and greenhouse gases by fossil fuels. PSCs represent an innovative progress in the field of renewable energy. PSCs have specific crystalline structure that shown remarkable properties for light absorption and more conversion efficiency [1-2]. PSCs have the recent progress in the advance technology in the field of green energy. PSCs manufacturing in the form of thin film and vapor deposited semiconductor based technologies, like the other solar cell like as CdTe or CIGS [3-4]. The key advantage of PSCs of perovskite materials lies as their ability to absorb more light sufficiently across a broad spectrum even when the layers are thin, and having high performance in solar energy conversion. The organic-inorganic halide perovskite solar cells (PSCs) have attracted a great deal of attention of solar cell research community due to an amazing device efficiency improvement from 3.8% to 22.1% since 2009 and 25% in the year 2021 [11-12]. The PSCs have much advantage as a possible replacement of the silicon solar cell, which is most, occupied the most governing position in the green energy market; with enhance efficiency of about 26% [13]. This hybrid solar cell efficiency attracted recent more attention distinctly from the researchers with experience in the organic solar cells because some materials can be used in both inorganic and organic solar cells. The device structure of PSCs also generate from the device structure of synthesized [14]. The perovskite materials (CH_3NH_3PbX3) have been exhibit with largely variable energy band gap from 1.5 electron volt (eV) to 2.3 (eV) [15]. The perovskite material having higher light absorption coefficient [16], which is similar to other thin film solar cell materials such as CdTe and (CZTS) [17-18]. Due to their low cost fabrication techniques its have more advantage over the silicon device. The spin coating and screen printing techniques are used to fabricate the solar cell device [19–20]. The perovskite solar cell light absorption layer has a general formula of ABX_3, where A is an organic cation, B is a metal cation and X stands for the halide anion (e.g., I_3). The first record of perovskite-based solar cell efficiency, however, was reported by Miyasaka *et al.,* [21] only less than one decade ago. They reported an efficiency of 3.8% based on a DSSC structure. Due to the application of liquid electrolyte in the hole-transporting material (HTM), the stability of solar cell was very weak and did not attract much attention. Similar trial was done by Park *et al.,* [22] with the increased efficiency of 6.5% but stability was still the main problem because of the instability of HTM layer due to the liquid medium. The fast growth of the efficiency of PSCs makes PSCs being prospected to be compared with the best performance of crystalline silicon solar cells. Whereas all other kinds of photovoltaic devices mourned great barriers in other improvements. According to the theoretical calculation based on the well-known Shockley-Queisser limit, the PSCs have achieved the power conversion efficiency around 25–27% based on perovskite materials ($CH_3NH_3PbI_3$) [23]. This result indicates that there is further need to improve the efficiency of PSCs.

Perovskite materials:

Perovskite materials have become one of the most promising classes of materials for next-generation solar cells due to their exceptional optoelectronic properties and ease of fabrication. These materials are named after the mineral perovskite, which has a specific crystal structure (ABX_3), where "A" and "B" are cations and "X" is an anion, typically halides such as iodine, bromine, or chlorine. The most commonly used perovskite in solar cells is a hybrid organic-inorganic lead halide (e.g., methylammonium lead iodide, $CH_3NH_3PbI_3$), though alternative materials like tin-based perovskites are being explored to reduce toxicity concerns.

Perovskite materials have a become one of the most promising classes of materials for next generation solar cell due to their important properties of fabrication. The name Perovskie comes from nickname for their specific crystal structure (ABX_3), where A and B are two positively charged ions (cations) and X is a negatively larger than the 'B' atoms. The real cubic structure has the B cations in 6- fold coordination and the A cation in 12-fold cuboctahedral coordination. Perovskite structures are taken by many oxides that have the chemical formula ABO_3. The idealized shape is cubic structure which is rarely confronted. The orthorhombic and tetragonal phases are the most common non-cubic variants. Although the perovskite structure is named after $CaTiO_3$, this forms a non-idealized form. $SrTiO_3$ and $CaRbF_3$ are examples of cubic perovskites. Barium titanate is an example of a perovskite which can take on rhobohedral, orthorhombic tetragonal and forms depending on temperature. The structure of solar cell materials is shown in figure 1a, 1b and 1c.

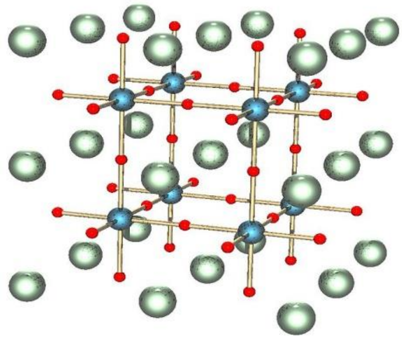

Fig. 1a

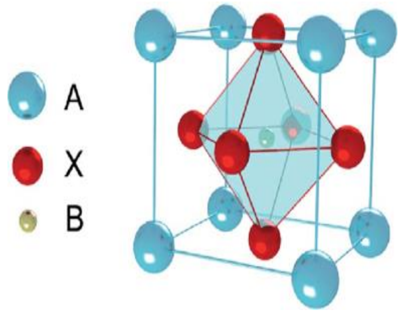

Fig. 1b

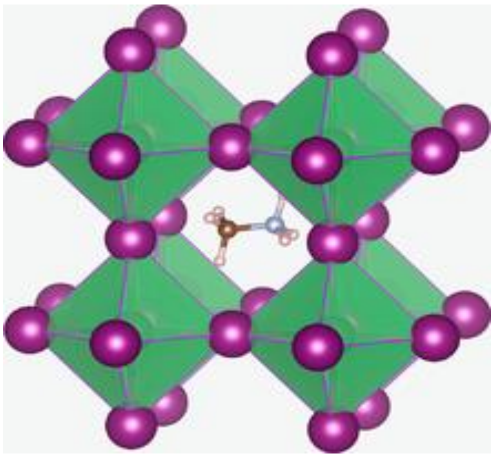

Fig. 1 c

Structure of perovskite solar cell:

Perovskite solar cells (PSCs) are made of perovskite materials, which are hybrid organic-inorganic compounds with structural formula ABX_3, where X is a halide (I, Br, Cl) [24]. A is monovalent cation (Methylammonium, Formaidinium or Cesium), B is a divalent metal (Lead or Tin). The active layer of perovskite material is deposited in between two electrodes, (TCO) transparent conductive oxide and a metal, the two charge transport layers ETK and HTL. The working principle of perovskite solar cell is similar to as organic solar cell (OSCs). In which light absorption by the perovskite active layer produces excitons (electron-hole pairs). Excitons are subsequently transported to the electrodes and separated by the electric field at the perovskite interfaces, producing an open circuit voltage (V_{oc}) and a photocurrent. PSCs have many advantages, as including a higher absorption coefficient, a longer diffusion length, a slow rate of recombination [25]. These factors increase the power conversion efficiency (PCE) because they increase both V_{oc} and short- circuit current density Jsc. The conventional PSCs device consist of five layers; conducting substrate indium tin oxide (ITO), the HTL, Perovskite active material layer, ETL and the metal electrode (as Cu, Au, or Ag). When the solar cell is illuminated, the ETL/HTL extracts photogenerated electrons / holes from the perovskite absorption layer and transports them to the cathode/ anode, as shown in figure 2.

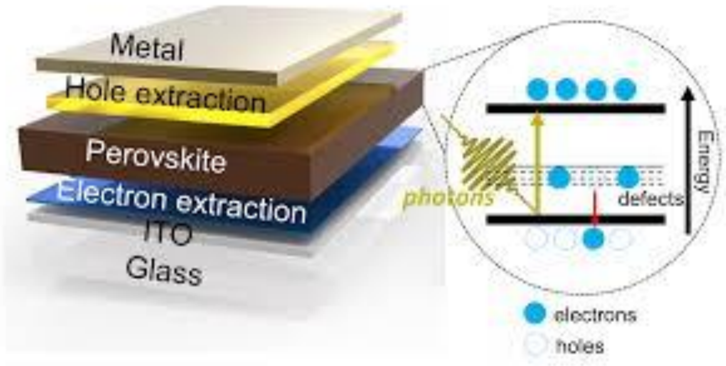

Fig. 2: Structure of perovskite solar cell

Fabrication methods:

The methodologies for producing active layer of perovskite material are Solution and vapor based techniques which absorbed the light. The vapor assisted technology providing better thin film uniformity. Solution-processed deposition is performed technique using various methods such as spin coating, slot-die coating, doctor blading, spray coating, screen printing, and inkjet printing. Vapor deposition process produces highly crystalline and uniform nanometer thick films compared to micrometer thick films using solution processed methods [26]. The impotant advantages of vapor deposition technique over solution processing methods are that multilayer films can be produced over large areas. The charge collection at interfaces can be easily tuned by using vapor deposition processes. Vapor deposition is therefore one of the optional methods for producing PSCs layers uniform thickness. The main drawback of this method is the requirement of vacuum. In this method vacuum is used to increase the mean free path of the vapors for producing highly uniform thin films of very high purity.

Spin coating method:

The spin coating process is used to fabricate inverted and regular perovskite solar cell (PSC) structure. The main advantage of this method is high efficiency. This method is not applicable to producing a uniform film on a larger scale. Due to the slow processing speed and consistent material wastage, this method is not good solution for large scale PSC production. By adjusting spin speed, acceleration and spin coating time, film thickness and quality can be optimized. Liang *et al.*, first reported the preparation of PSCs using a two step spin coating method, while the maximum efficiency obtained at large scale by this method was about 22.1%.

Doctor blading:

Doctor blading is widely used method for producing uniform thin films in various applications. This method involves the use of a doctor blade to spread a liquid solution on a substrate in a controlled manner, leaving behind a thin and even film. A liquid or dispersion is placed onto a flat substrate with the help of a doctor blade. The blade is typically made of metal, plastic or ceramic and has an adjustable gap. The doctor blade is positioned above the substrate, with the gap between the blade and the substrate set to determine the desired thickness of the thin film. The gap is adjustable based on the viscosity of the solution and the target film thickness [27]. This method consistently decreases the use of precursor solution, requiring only 10 to 20 μL for a film with an area of 2.25 cm^2, which is much smaller than the spin coating method.

Screen printing:

Screen printing is a popular and versatile method for producing thin films for the photovoltaic cell, sensors and various coating processes. It is useful for depositing material layers onto substrates and can be used to generate both conductive and insulating films. A mesh screen is coated with a photo-sensitive solution. The shape of the thin film pattern is then transferred onto the screen, to getting a photomask and UV exposure. For screen printing, the deposition area can reach several square meters, and the material utilization can be high as 100% for a continuous process. A triple mesoporous carbon based hole transport layer (HTL) free PSC stack fabricated at A4 size models was demonstrated using commercially available screen printable pastes and using only 1.6 ml of perovskite solution per model.

Slot-Die Coating:

Slot-Die coating is a highly efficient and precise method used to deposit thin, uniform films onto a substrate. It is commonly used in industries such as photovoltaics, flexible displays, and coatings. The technique is particularly useful for continuous, large-area deposition of thin films, and it offers significant advantages in terms of control over film thickness, uniformity, and stability. Slot-die coating is the one of the most promising techniques to fabricate large scale PSCs through roll-to-roll process [29]. This method works similarly to blad- coating and the main difference is that the sped is replaced with a coating head composed of two metal sheets, which feeds composer solution from the narrow gap. The use of slot-die printing in PSCs manufacturing can help preventing precursor contamination during the coating process [30]. This technology shows a high solution utilization rate and exhibits a greater tolerance towards solution viscosity, concentration and composition.

Conclusion:

In this research paper studies the structure of hybrid solar cell and solar cell materials. The many structures and functions of solar cells are examined in this chapter. A solar cell is a type of photovoltaic device that uses the photovoltaic effect to transform solar energy into electrical energy. A polymer solar cell that uses perovskite materials is called perovskite solar cell or hybrid solar cell. The hybrid materials are inexpensive to produce, have a flexible substrate, and a high absorption coefficient and high motilities. To attain the great goal concerning efficiency as well as stability just modifying the current perovskite materials or interface is not enough. The efficiency of hybrid solar cell is more than the other solar cell till now. Research is go on to improve the PCE of perovskite solar cell. In order to improve the exterior efficiency of solar cells, researchers are trying to find novel materials

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STRUCTURAL AND PHYSICAL PROPERTIES OF Pr^{3+} DOPED GLASS MATERIAL

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Abstract:

The present works gives the information about the structural and physical analysis of borosilicate glasses with praseodymium ions. Glass specimen was prepared with the chemical composition (50-x) B2O3 - (10+x) SiO2 – 10Na2O – 20PbO – 10ZnO - 1Pr6O11 (where x= 0, 5, 10, 15, 20, 25, 30, 35, 40) by standard method. The composition of the glass specimens was finalized by EDX. The presence of various stretching and bending vibrations are confirmed with the help of FTIR analysis. XRD were recorded for confirmation of the amorphous nature of the samples. The SEM image confirmed the XRD results. Various physical parameters have been calculated for knowing the structure of present glass with increasing the SiO2 concentration. Oxygen Packing Density (OPD) decreases with increase in SiO2 concentration. Decrease in the value of OPD shows that glass structure is now loosely packed.

Keywords: Physical Properties, Absorption Spectra, Urbach's Energy, Energy and Judd – Ofelt Intensity Parameters.

1. Introduction:

Praseodymium ion when added as a dopant in the glass matrix, electronic structure will be changed. This directly modifies the optical properties of dopants such as spectral substructure, spectral broadening etc. Praseodymium ion has hc (4H) structure and has unpaired electron. Pr^{3+} ion has distinct advantage when it is used as dopant atoms to modify the optical properties of a glass. Due to this Praseodymium ion doped glasses are of great interest due to their potential applications as 1.3 µm optical amplifiers [1], memory devices, solid state lasers, solid state – batteries, optical waveguides, optical telecommunication, non-linear optical materials and optical fibers [2]. In literature laser action in visible region is reported for the transition $^1D_2 \rightarrow {}^3H_4$. The laser transition $^1G_4 \rightarrow {}^3H_5$ ($\sim 1.3 \mu m$) for Pr^{3+} doped glass fibres is a very potential transition for the development of fibre amplifier for communication purpose in the telecom window [3]. Structural and physical analysis of borosilicate glasses with Pr^{3+} ions [4] and laser action in praseodymium doped borosilicate glasses in visible region [5] have been published recently by our group [4, 5].

In this chapter brief detail of preparation of Pr^{3+}doped borosilicate glasses, their characterization (XRD, SEM, EDAX, and FTIR), absorption and fluorescence results, various parameters (i.e. Judd – Ofelt, Slater-Condon, Racah, Lande' and radiative properties) and their discussion of rare earth ions i.e. have been collected.

2. Methodology:

2.1. Chemicals Used

The starting materials used are silicon dioxide (SiO_2), Borax ($Na_2B_4O_7.10H_2O$), Lead carbonate ($PbCO_3$) and Zinc carbonate $\{ZnCO_3\}_2$ $\{Zn(OH)_2\}_3$ of A. R. grade and were procured from E. Merck (India), Glaxo (India) and Aldrich (USA). All are 99.99% pure. The rare earth Pr^{3+} ($4f^2$), Nd^{3+} ($4f^3$), Sm^{3+}($4f^5$) and Er^{3+}($4f^{11}$) are 99.99% pure, were used for doping. Cerium oxide is used for lapping and polishing which is 99.10 % pure.

2.2. Melt Quenching Technique

The starting materials such as silicon dioxide, borax, lead carbonate and zinc carbonate for preparation of borosilicate glass specimens were weighed by using analytical electronic balance. Now this batch material was taken in an automatic agate pestle mortar for two hours for attaining the homogeneity of the specimens. A crucible containing $CaCl_2$ was placed in the covered chamber of the mortar to avoid absorption of the moisture by the batch material. The ground batch material was heated in platinum crucible to 250^0C in a electronic furnace. The temperature was then slowly raised to remove the moisture and evolved gases. Finally the temperature was raised to the working temperature *i.e.* 1000 ± 25^0C. This temperature was kept constant for six hours to ensure complete degassing. Homogeneity of the melt was ensured by stirring the melt with a platinum rod from time to time. After six hours the melt was quenched by pouring it into a preheated (about 300^0C) rectangular shaped brass mould placed on a brass plate. A heavy brass hammer was then immediately pressed on it. The sudden transfer and cooling of the melt in moulds is known as quenching. After 12 hours the glass specimens were taken out.

The glass specimen of the material were then removed from the mould and kept for annealing in an electric furnace at 350^0C for three hours. The annealing was done to remove stresses and strains. This further gives the thermal stability and strength to the specimens. The prepared specimens were laped with fine embery powder of grade 302 on the mechanically rotating flat. They were then polished to all the sides by mechanically driven device containing a flat covered with polishing cloth. For initial and final polishing, ZrO_2 and CeO_2 were used as polishing medium respectively. Water was used as coolant both for lapping and polishing. The polished specimens were cleaned thoroughly with acetone and were kept for drying. Again these samples were kept in the electric furnace at 300^0C for two hours to remove mechanical stresses which might have developed during lapping and polishing. The prepared amorphous materials were of good optical quality and transparent. The glass specimens had colures typical of the tri-positive rare earth ions [1].

Table 1: Compositions of various Pr^{3+} ($4f^2$) doped borosilicate glass specimens.

S. No.	Composition of Glass Specimens (wt. %)	Dopants Ions (wt. %)	Specimen code
1	50.0 B_2O_3 – 10.0SiO_2 – 10.0Na_2O - 20.0PbO –10.0 ZnO	Pr_6O_{11} (0.0)	BSGU01
2	50.0 B_2O_3 – 10.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (1.0)	BSGPR02
3	45.0 B_2O_3 – 15.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0 ZnO	Pr_6O_{11} (0.0)	BSGU03
4	45.0 B_2O_3 – 15.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (1.0)	BSGPR04
5	40.0 B_2O_3 – 20.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (0.0)	BSGU05
6	40.0 B_2O_3 – 20.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (1.0)	BSGPR06
7	35.0 B_2O_3 – 25.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (0.0)	BSGU07
8	35.0 B_2O_3 – 25.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (1.0)	BSGPR08
9	30.0 B_2O_3 – 30.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (0.0)	BSGU09
10	30.0 B_2O_3 – 30.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (1.0)	BSGPR10
11	25.0 B_2O_3 – 35.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (0.0)	BSGU11
12	25.0 B_2O_3 – 35.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (1.0)	BSGPR12
13	20.0 B_2O_3 – 40.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (0.0)	BSGU13
14	20.0 B_2O_3 – 40.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (1.0)	BSGPR14
15	15.0 B_2O_3 – 45.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (0.0)	BSGU15
16	15.0 B_2O_3 – 45.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (1.0)	BSGPR16
17	10.0 B_2O_3 – 50.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (0.0)	BSGU17
18	10.0 B_2O_3 – 50.0SiO_2 – 10.0Na_2O - 20.0PbO – 10.0ZnO	Pr_6O_{11} (1.0)	BSGPR18

3. Characterization of glass specimens

The borosilicate glass samples doped with Pr^{3+} were characterized by XRD, EDAX, SEM and FTIR.

3.1. XRD of Pr^{3+} doped borosilicate glass specimens

XRD of Pr^{3+} doped borosilicate glass specimens have been recorded for knowing the amorphous nature of the glass samples. The XRD of BSGPR16 glass samples are shown in Fig.1.

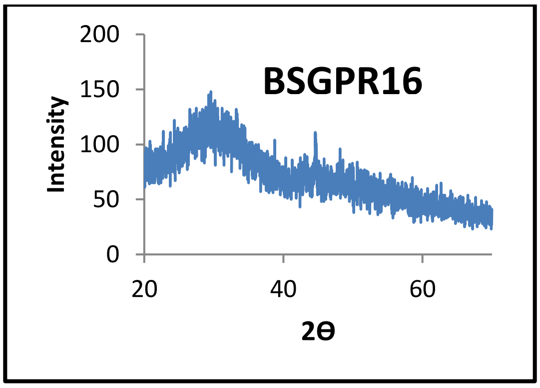

Fig. 1: XRD of BSGPR16 glass samples

3.2.1. SEM of Pr^{3+} doped borosilicate glass specimens

Representative SEM image of BSGU01 and BSGPR10 glass specimens have been shown in Fig. 2.

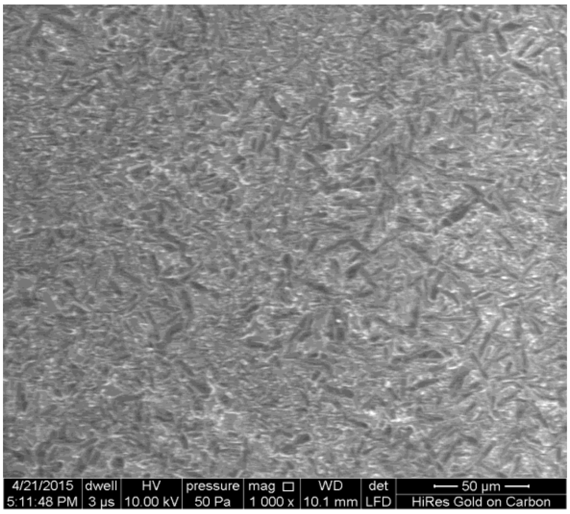

Fig. 2: SEM image of BSGU01 glass specimen at pressure 50 Pa with magnification 1000 x.

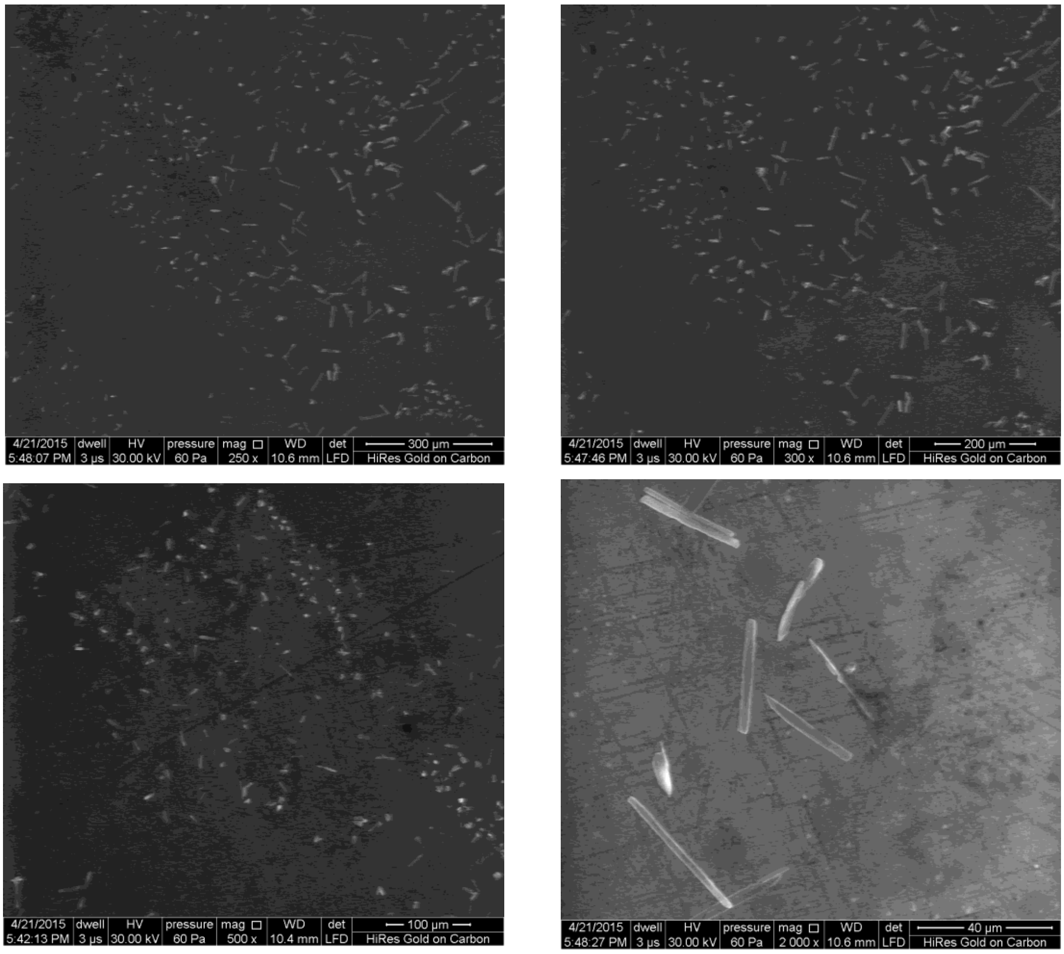

Fig. 2.1: SEM image of BSGPR10 borosilicate glass specimen at pressure 60 Pa with different magnifications

SEM image verifies the amorphous nature of the glass samples. SEM image of BSGU01 and BSGPR10 glass specimen have been shown in Figs. 2. Fig.2.1 is for undoped glass specimen is taken at pressure 50 Pa with magnification 1000 x. Fig. 2.1 for BSGPR10 glass specimen are at pressure 60 Pa with magnifications 250 x, 300 x, 500 x and 2000 x respectively. From these figures it is observed that that there are no grains on these images, which reveals the amorphous nature of the present glass specimens and shows that there is change in structure at same pressure with different magnifications. SEM image verifies the results of XRD according to which the prepared glass samples are amorphous in nature.

3.2.2. EDAX of Pr^{3+} doped borosilicate glass specimens

Representative EDAX spectrum of BSGU01 and BSGPR10 glass specimen has been shown in Fig. 2.2 and 2.3 respectively.

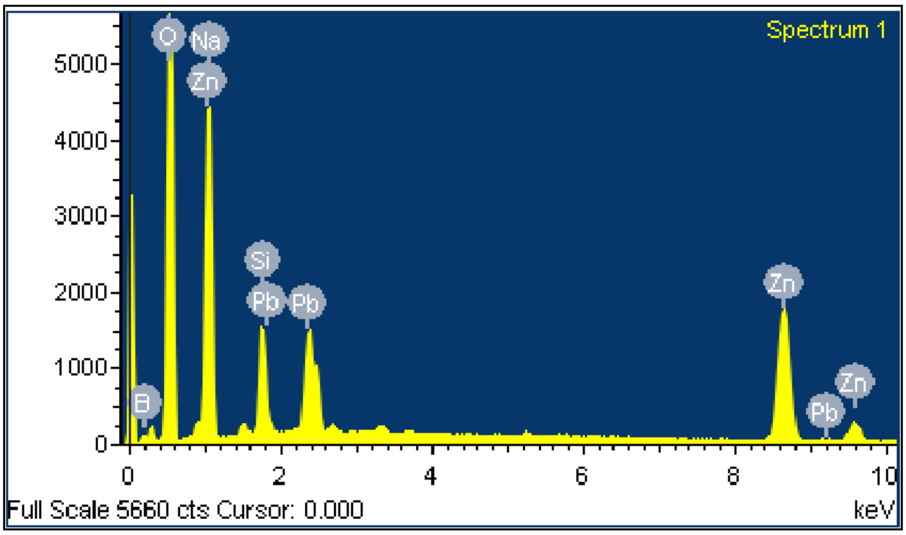

Fig. 2.2: EDAX spectrum of BSGU01 glass specimen.

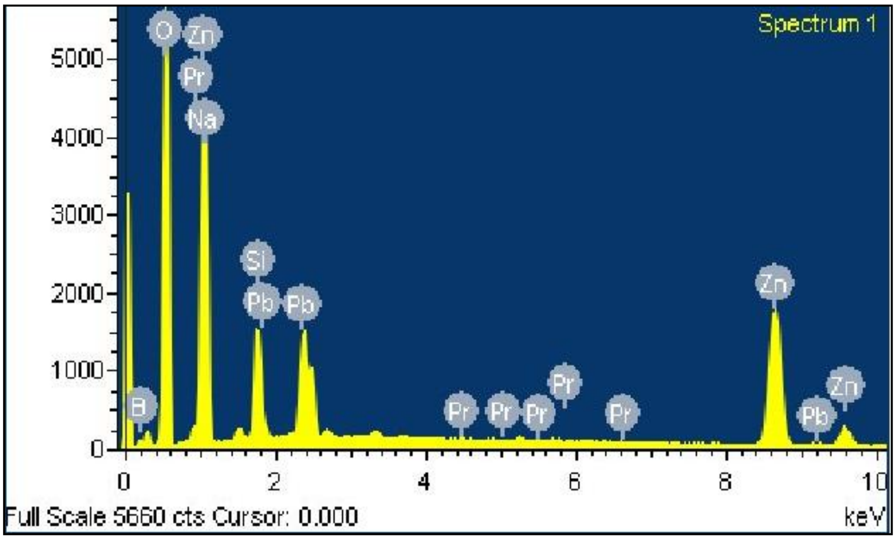

Fig. 2.3: EDAX spectrum of BSGPR10 glass specimen.

The EDAX spectrum of BSGU01 and BSGPR10 glass specimens were shown in Fig. 2.1 and 2.2 respectively. These spectra reveal that all the elements are present in the final composition which is taken initially. It is observed that there are no rare earth elements in the spectrum of BSGU01 glass specimen (Fig. 2.1), verifying that this is the figure of undoped glass specimen. Fig.2.2 shows that this figure is for Pr^{3+} doped borosilicate glass specimens.

3.2.3. FTIR of Pr^{3+} doped borosilicate glass specimens

As infrared spectroscopy is the powerful tool for exploring the presence of the functional groups in the prepared glass samples. FTIR spectra of BSGU01, BSGPR02, BSGPR06 and BSGPR12 glass specimens were recorded in the wavelength region 400-4000 $cm^{-1}$and given from Figs. 3.9-3.12.

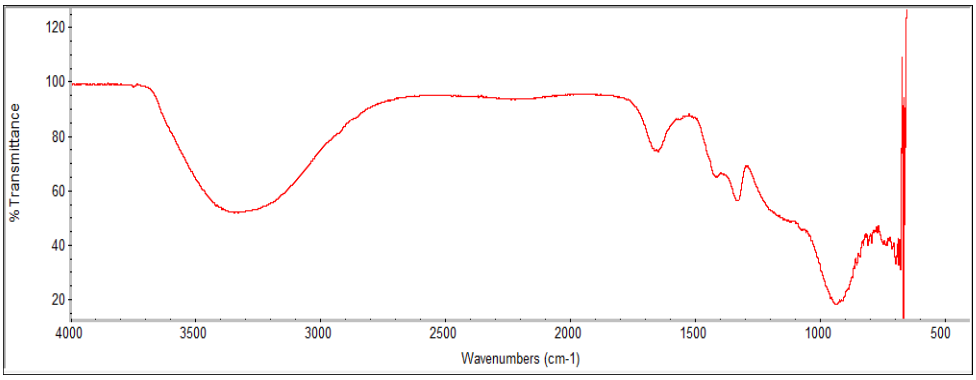

Fig. 2.3: FTIR spectrum of BSGU01 glass specimen

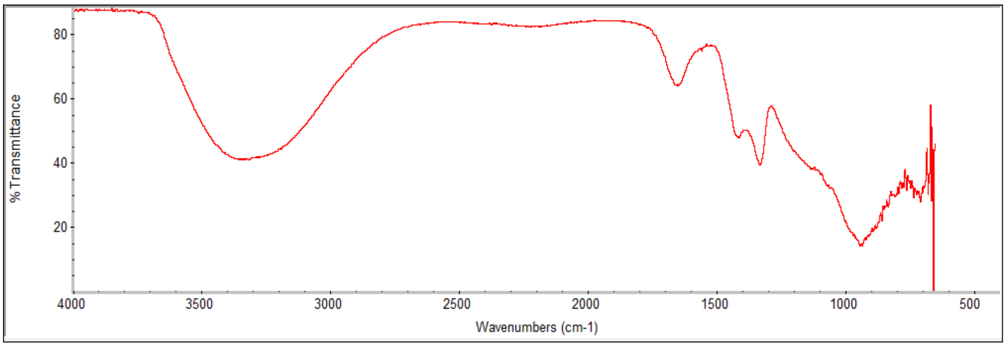

Fig. 2.4: FTIR spectrum of BSGPR02 glass specimen.

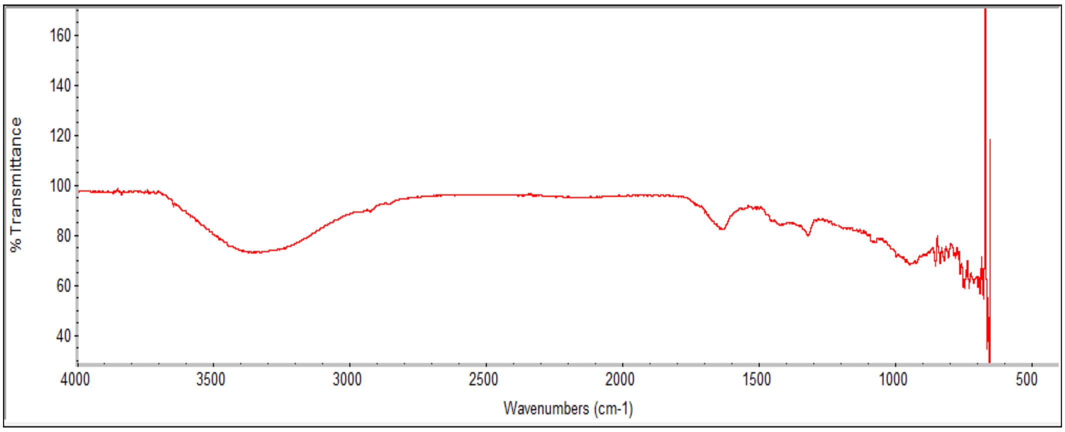

Fig. 2.5: FTIR spectrum of BSGPR06 glass specimen.

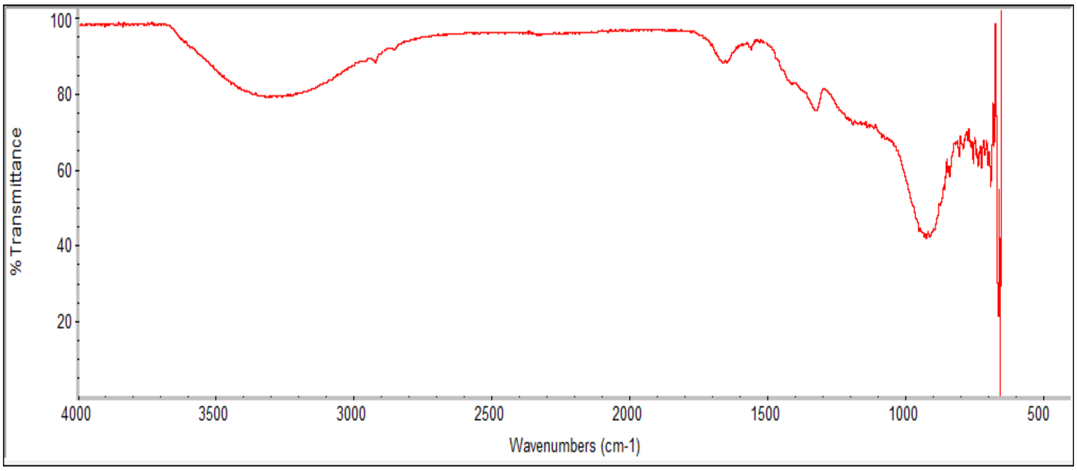

Fig. 2.6: FTIR spectrum of BSGPR12 glass specimen.

The FTIR spectra of BSGU01, BSGPR02, BSGPR06 and BSGPR12 glass specimens have been shown in Figs. 2.3-2.6 respectively and recorded in the wavelength region 400-4000 cm^{-1}. The corresponding transmission band positions along with their assignments for Pr^{3+} doped borosilicate glass specimens were collected in Table 1. The FTIR spectra is very much useful for analyzing the borate network and for all the prepared glass samples, it is present in the wave number region 650-1700 cm^{-1}. The presence of the hydroxyl group is the most dominant characteristic in all the infrared groups.

Conclusion:

The Pr^{3+} doped borosilicate glass specimens have been prepared by conventional melt quenching technique with varying concentration of host matrix and keeping the dopant concentration constant. The prepared glass specimens were cut and polished for optical measurements. The glass specimens were characterized by XRD, SEM, EDAX, and FTIR optical properties of the Pr^{3+} doped borosilicate glass specimen have been calculated.

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MICRO/NANOTECHNOLOGY: TRENDS AND GROWTH IN REMEDY

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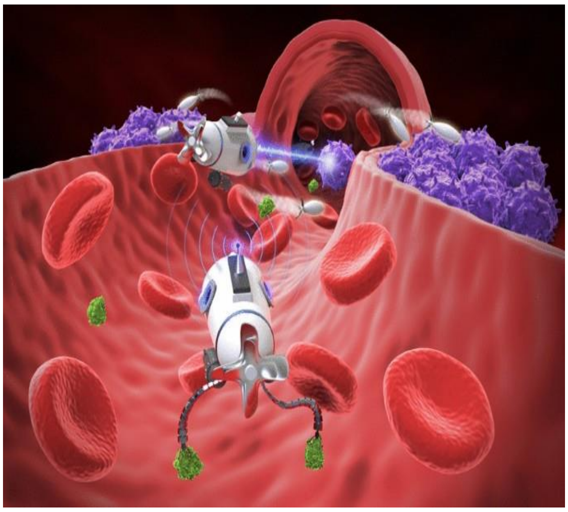
Abstract:

Numerous dimensions are used in surrounding. all of that one measurement are used with material on tiny scale is nanometer. The nanometer (nm) is one-millionth of a millimeter means 10^{-9}m. The study of micro/nanotechnoly and its uses in our environment holds the undertake revolutioning. It is great mile stone in virus analysis and handling. due to their small size and ability its can be used in various field. its play very important role in medical science. in contrast to predictable analytic as well as behavior method, micro/nanorobots display vast latent owing toward their tiny dimension with skill near break in profound tissue.

Keywords: Nanometers, Nanotechnology, Revolution, Nanorobots, micro

Introduction:



Micro/nanotechnology, create at the molecular phase, is a multidisciplinary correct field undergoing likely to blow up growth. The genesis of micro/nanotechnology can be traced to the guarantee of innovative advances across remedy [1, 2], communications, genomics and robotics. this branch the treatment of area at the small and molecular size to construct equipment with really different and new material goods, is a fast-expanding area of study with enormous possible in many sectors, ranging from healthcare to construction and electronics. Nanotechnology can be defined by the ability to generate, control, and operate substance with nanometer-scale size. since a equipment scope appreciably force its uniqueness at the nanoscale, particle size is key in nanotechnology [3, 4].

Trends and growth in medicine

The applications of micro science and micro/nanotechnology have evolved rapidly over the previous hardly any decades and continue to have great possible to give considerable payback to civilization. Breakthroughs in energy cells, vaccines, battery, and structure tools, are all made possible through the successful finishing of micro/micro/micro/nanotechnology. In remedy, it promises to develop drug delivery, gene therapy, diagnostics, and a lot of areas of study, growth and trial use. Micro /nanotechnology may also be very essential in the hard work to contest environmental refuse. However, engineered micro/nanomaterial with totally novel individuality also has the potential to generate adverse environmental and health risks. The emerging range of nonomaterial and their unstable nature mean such risks are still life form unspoken.

The word 'Micro/nano'comes from Greek word dwarf. Micro/nano refers to one billionth (10^{-9}) of something like micro/nanometer (nm). A micro/nanometer is about 2-5 atoms wide or 45,000 times smaller than the width of human hair.

Micro/nano materials or Micro/nanoparticles are of great methodical interest as they are a successful bridge between bulk materials & tiny or pixel structures. The inspiring properties of fabric are mainly due to large outside area, which dominates the gift made by the Micro/nano-particle usually forms the inner part of micro/nano-biomaterial. They may be used as a means float up for molecular get-together, it may be collected of inorganic or polymeric supplies. It can also be in the shape of micro/nano-vesicle surrounded by a membrane or a coat. The shape is more often round but sphrical, cylindrical, plate-like and clusters other shapes are promising. Nanomedicine, also known as nanobiomedicine, uses micro/nanotechnology in drug. It influences biological arrangement board and conception, poor health finding, monitoring, and cure. The use of nanotechnology here operation has huge assure [5, 6,7,8].

The core particle is often protected by several monolayers of inert material, for pattern silica. The same layer might act as a biocompatible fabric. However, more often an additional layer of linker tiny particles is required to proceed with further functionalisation. This linear linker molecule has reactive groups at both split ends. One cluster is aimed at attaching the linker to the materials surface and the other is used to bind various moieties like biocompatibles (dextran), antibodies, fluorophores etc., depending on the function required by the use. They can be implanted inside body. The field of microbiology has been successfully used as a springboard for the initial development of robotic functions in nanobiotechnology. Although microrobots and nanorobots can be constructed and have function [9], Biochemical effect time is much shorter. Devices are quicker & more susceptible than characteristic lesser strategy are less insidious. remedy detoxification is also another application for micro/nanoremedy which has shown promising results in rats. The whole system leads to a special function related to treating, preventing & diagnosing diseases, sometimes called smart drugs or the agnosticsMany forms of micro/nanoremedy that have already been tested in rats and are pending human trials are using gold micro/nanoshells to help identify and treat cancer, and using liposomes as vaccine adjuvant and as vehicles for drug bring.,. The goal of this system. More specific drug targeting & delivery.

decrease in toxicity as maintaining beneficial result. Greater safety & biocompatibility. Faster development of new & safe samples.

It may be achieved by molecular target by micro/nano technical devices. They are targeting the molecules and delivering remedy with unit care. The force of drug delivery systems is their skill to modify the pharmacokinetics. Drug freedom systems, lipid- or polymer-based micro/nanomaterial can be designed to improve the pharmacy and remedial properties of drugs. To use drug delivery is based upon details. Successful release of that drug there. Efficient encapsulation of the drugs, Successful delivery of said drugs to the targeted region of the body.

Micro carriers are predominantly localized on the epithelial lining. without the problems of particle aggregation or blockage of fine blood capillaries. built on extensive experience in pharmaco- chemistry, pharmacology, toxicology, and nowadays is being pursued as a multi-and interdisciplinary effort in novel biopharmaceutics delivery systems for the treatment of diabetes, cancer, AIDS, Alzheimer’s disease, and other neurodegenerative diseases. B. Protein Detection. Proteins are the important part of the cell's language, machinery and structure, and understanding their functionalities is extremely important for further progress in human well being. Gold micro/nanoparticles are widely used in immune his to chemistry to make out protein-prot. With increasing interest in the future of dental applications in nanotechnology has given birth to nanodentistry involving maintenance of oral health by using nanomaterials, biotechnology and nano-robotics.[10]

Minerals, Proteins are the important part of the cell's verbal communication, equipment and arrangement or constitution, and understanding their use is extremely important for further growth in human well life form. Gold micro/nanoparticles are broadly used in immunohisto chemistry to spot protein-protein interaction. The small size of micro/nanoparticles can be very useful in oncology, particularly in imaging. Quantum dots when used in conjunction with magnetic resonance imaging, can produce exceptional images of tumor sites. These micro/nanoparticles are much brighter than organic dyes and only need one light source for excitation which shows that the use of fluorescent quantum dots could produce a higher contrast image and at a lower cost than today's organic dyes used as contrast media.

They are extra superior to traditional organic dyes. Quantum dots are 25 times brighter & 99.9 times more stable than traditional dyes. A differnt micro/nanoproperty, high surface area to sum ratio, allows plentiful useful groups to be fond of to a micro/nanoparticle, which can search for out and join to positive tumor cells. Additionally, the tiny size of micro/nanoparticles allows them to preferentially accumulate at tumor sites Sensor test chips containing thousands of micro/nanowires, able to detect proteins and other biomarkers left behind by cancer cells, could enable the finding and diagnosis of cancer in the early stages from a few drops of a patient's blood The micro/nanoshells can be under fire to connection to cancerous cells by conjugating antibodies or peptides to the micro/nanoshell plane.

It is difficult to path a small group of cells during the remains, so scientists used to color the cells. The way out of this difficulty is use of quantum pixles, they are micro/nanoparticles of semiconductor supplies of metals in dimension.

Supplementary than 92% of the human prepare cells beginning deferral adhered to the micro/nanostructured metal surface, but only 60% in the manage taster. It was shown that using a biomimetic move toward. a slow growth of micro/nanostructured apatite pictures from the replicated body solution – resulted in the formation of a powerfully believer, standardized micro/nanoporous coat.

Micro/micro/nanotechnology involve the identification of accurate targets related to exact medical setting as well as option of the fitting micro/nano carrier to get the necessary responses even as minimize the side things. Mononuclear phagocytes, dendritic cell, endothelial cell, and cancers are means aim. now, micro/micro/nanotechnology and micro/nanoscience approaches to subdivision aim and formulation are start to enlarge the market for a lot of remedy and are form the root for a very gainful within the industry, but some predicted benefits are puffed up.

The latest developments in micro/nanotechnology are micro/nanorods. Nanobiotechnology gives one more aspect in robotics nanorobotsis also known as ‘nanobots’. as a substitute of the stage actions from exterior the stiff. nanobots resolve be miniaturized used for opening addicted to the remains from side to side the vascular structure or next to the finish of catheters into a range of vessel as well as supplementary cavity within the person [11]. These tiny, micro/nano-sized robots are currently troublesome the ground of remedy or bioremedy, with exacting advancements going on in applications for example cancer identification and remedy relief. Nanorobots are so minute that they will easily traverse the physical human body. Nanorobotics is that technology which creates robotic or machines on the brink of microscopic scale of nanometers. [12, 13]. Nanorobots will be aimed to be contructed in such a way that they will take care of the method which initiates from diagnosing the condition, treating it, and further preventing the disease, thus intercepting diseases and improvising human health by the use of molecular tools and knowledge of molecular nature of human body.

Conclusion:

Microscopic or nanoscopic robots be an expansion of obtainable ingestible plans with the purpose of gradually shift during the gastrointestinal area with get together in order. negligible capability necessary of potential strategy be: element sense; contact means getting in order as of, with transmit in a row to, exterior the organization, plus message by additional nanobots medical events execute in the company of top correctness by means of Nanorobots and precision than humans. This could result in more effective patient treatment with fewer side effects and shorter recovery time. Physician functioning on that remedy of chemotherapy would propose the tolerant a shot of a extraordinary kind of micro/nanorobot so as to would look for out cancer cell and wipe out them, dispelling the sickness at the basis, departure strong cells unhurt different the usual treatment of rays to kill not just cancer tissues except as well in good physical shape creature being cells.

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METAMATERIAL AND NANOMATERIAL: A REVIEW

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Abstract:

A family of engineered materials known as metamaterials is created to have unusual and exotic qualities not found in natural materials. They are made up of structures that have been created artificially and are capable of extraordinary manipulations of mechanical, acoustic, and electromagnetic waves. Numerous industries, including optics, communications, energy harvesting, sensing, and cloaking, have found use for metamaterials. After metamaterial discussed nanomaterial, nanoparticles (NPs) are the unique tiny materials which exist on a nanometer scale ranging from 1 to 100 nm. These NPs exist in variety of forms. They can be categorized into different groups such as Organic, Inorganic and Carbon-based NPs on the basis of their origin, properties, shape and size. The NPs exhibit enhanced physical and chemical properties such as high surface area, reactivity, stability, sensitivity etc. due to their small size. These NPs can be synthesized by various methods. In recent years, there has been an extensive employment of NPs in a number of industrial & environmental areas of application which is considered to be of prime importance. This review article highlights the types, advantages, similarities of metamaterial and nonmaterial.

Keywords: Metamaterial, Nanomaterial, Carbon based NPs, Inorganic NPs, Nanoparticle.

Introduction:

Metamaterials are artificial materials engineered to provide properties which “may not be readily available in nature”. These materials usually gain their properties from structure rather than composition, using the inclusion of small inhomogeneities to enact effective macroscopic behavior. The metamaterials have entered into the main stream of electromagnetics. The word ‘’Meta’’ is taken from Greek whose meaning is “beyond”. “Metamaterials” has the exotic properties beyond the natural occurring materials. These are the materials that extract their properties from their structure rather than the material of which they are composed of. The first and one of the most important contributions to this topic was made in 1968 by V. G. Veselago who said that materials with both negative permittivity and negative permeability are theoretically possible. In 1999, John Pendry identified a practical way to make left-handed metamaterials (LHM) which did not follow the conventional right-hand rule. He proposed his design of periodically arranged Thin-Wire (TW) structure that depicts the negative value of effective permittivity. It was shown that the structure is having a low plasma frequency than the wave in the microwave regime. Because of its low plasma frequency, this structure can produce an effective negative permittivity at microwave frequencies [3] [14]. It was also demonstrated that negative magnetic permeability could be achieved using an array of split-ring resonators.

Advantages of Metameterials

Metamaterials have peculiar electromagnetic properties that make it possible for them to bend, reflect, or transmit electromagnetic waves in ways that are not conceivable for natural materials. They can be used for a variety of purposes because of this, including cloaking devices, super lenses, and antennas.

Improved acoustics: Metamaterials' ability to modify sound waves makes them beneficial for noise reduction, soundproofing, and acoustic imaging. Many metamaterials are robust and lightweight, which makes them helpful in aerospace and defence applications including the development of improved composites for aeroplanes and spacecraft. Metamaterials can be created with tunable properties, which means that they can vary their behaviour in response to outside factors like temperature, light, or magnetic fields. They can be used as sensors and actuators as a result [4].

Energy harvesting: Metamaterials can be made to collect energy from a range of sources, including radio waves, sound waves, and sunlight. They can be used in energy-harvesting devices as a result.

A. Directivity Enhancement Metamaterials has inherent property that controls the direction of electromagnetic radiation in order to collect the originating energy in a small angular domain around the normal to the surface. A DNG material enhances the directive properties of an antenna.

B. Bandwidth Enhancement Metamaterials antenna increase achieved bandwidth as compared to the conventional patch antenna. This is achieved by use of superstrate of metamateial over conventional antenna or by loading of LHM [12] [15].

C. Radiated Power Enhancement A small antenna can increase the radiated power through the application of DNG metamaterials. A small dipole antenna enclosed with DNG metamaterials is use to increase the radiated power much more as compared to the conventional antenna.

D. Beamwidth and side lobes the metamaterials antennas decrease the beamwidth and side lobe ratio and thus enhance the directivity and reduce the return loss of antenna [11].

Types of Metamaterials

Metamaterials are artificially engineered materials designed to exhibit unique properties that are not found in natural materials. They derive their characteristics from their structure rather than their composition. The classification of metamaterials is primarily based on their electromagnetic, acoustic, mechanical, or optical properties. Below is a theoretical overview of the types of metamaterials [13].

1. Electromagnetic Metamaterials: These metamaterials interact with electromagnetic waves in unconventional ways, altering their propagation [5] [6] [7].

- **Negative-Index Metamaterials (NIMs)**: Exhibit a negative refractive index, allowing light or electromagnetic waves to bend in the opposite direction compared to natural materials.
- **Double-Negative Metamaterials (DNGs)**: Possess both negative permittivity (ϵ\epsilonϵ) and negative permeability (μ\muμ). Known for reversing the direction of wave propagation.
- **Single-Negative Metamaterials (SNGs)**: Either permittivity (ϵ\epsilonϵ) or permeability (μ\muμ) is negative, but not both.
- **Epsilon-Negative Metamaterials (ENGs)**: Negative permittivity; examples include thin metal wires.
- **Mu-Negative Metamaterials (MNGs)**: Negative permeability; examples include split-ring resonators.
- **Chiral Metamaterials**: Lack mirror symmetry and exhibit optical activity, meaning they can rotate the polarization of light.
- **Hyperbolic Metamaterials**: Exhibit hyperbolic dispersion relations, enabling propagation of high-momentum waves.
- **Electromagnetic Bandgap (EBG) Metamaterials**: Block specific frequency ranges of electromagnetic waves.

2. Optical Metamaterials: These are specifically designed to manipulate light waves, including visible, infrared, and ultraviolet wavelengths.

- **Photonic Metamaterials**: Control light propagation using structured arrays.
- **Plasmonic Metamaterials**: Exploit surface plasmon resonances (oscillations of free electrons at metal-dielectric interfaces).
- **Transformation-Optics Metamaterials**: Control the flow of light to achieve cloaking or concentration of optical energy.

3. Acoustic Metamaterials: These materials manipulate sound waves in ways that natural materials cannot.

- **Negative Bulk Modulus Metamaterials**: Exhibit negative bulk modulus, enabling unique sound attenuation properties.
- **Negative Mass Density Metamaterials**: Have an effective negative mass density, allowing them to block specific sound frequencies.
- **Sonic Crystals**: Periodic structures that control sound waves similar to how photonic crystals control light.

4. Mechanical Metamaterials: These are designed to achieve unusual mechanical responses such as negative Poisson's ratio or negative compressibility.

- **Auxetic Metamaterials**: Exhibit a negative Poisson's ratio, meaning they expand laterally when stretched.
- **Pentamode Metamaterials**: Allow deformation in only one specific mode while being rigid in other modes.
- **Elastic Metamaterials**: Manipulate elastic wave propagation to control vibration or seismic waves.

5. Thermal Metamaterials: These manipulate heat flow and thermal conduction.

- **Thermal Cloaking Metamaterials**: Redirect heat flow around an object to create thermal invisibility.
- **Thermal Conductivity Metamaterials**: Enhance or suppress thermal conductivity in specific directions.

6. Tunable and Reconfigurable Metamaterials: These metamaterials can change their properties in response to external stimuli.

- **Electrically Tunable Metamaterials**: Properties can be controlled by applying an electric field.
- **Mechanically Reconfigurable Metamaterials**: Structures can be altered mechanically to change their properties.

7. Metamaterials for Quantum Applications: Designed to exploit quantum effects in materials. Examples include quantum metamaterials for quantum computing, communication, and sensing.

Nanomaterials:

Over the last century nanotechnology branch is flourishing to a great extent. And today many types of research are directly or indirectly related to the nanotechnology. Nanotechnology can be stated as the developing, synthesizing, characterizing and application of materials and devices by modifying their size and shape in nanoscale" In each and every stream the prefix ‘‘nano" is using as a keyword even in advertising the products also [1]. Actually, the word ‘‘nano" is derived from the Greek word nanos or Latin word nanus means which ‘‘dwarf". It is the combination of physics, chemistry, material science, solid state, and biosciences. So profound knowledge in one field will not be sufficient, the combined knowledge of physics, chemistry, material science, solid state, and biosciences is required. The applications of Nanotechnology are spreading in almost all the branches of science and technology. The difference between the nanoscience and nanotechnology is the nanoscience gives the knowledge about the arrangement of atoms and their basic properties at nanoscale whereas the nanotechnology is the technology used in governing the matter at the atomic level for the synthesis of the novel nanomaterials with different characteristics. The nanotechnology getting attention in almost all engineering branches but the common people didn't get the knowledge about its existence in daily life but its vast usage in the medicine, engineering, environment, electronics, defense, and security is still increasing. Even though so much work was done using this technology but still have space for developing the new novel nanomaterials in various fields for the progress of mankind. The basic and the key elements of nanotechnology are the ‘‘nanomaterials”. The nanomaterials are the materials with less than 100 nm size ones at least in one dimension. That means they have very less size than that of microscale. The nanomaterials are usually in size that means it is one billionth of a meter [2].

Types of nanomaterials:

Nanomaterials are classified into various types based on their size, shape, structure, and chemical composition. This classification helps in understanding their unique properties and applications. Below is a different type of nanomaterials:

1. Based on Dimensionality: Nanomaterials are categorized based on how many of their dimensions fall within the nanoscale range (1–100 nm).

- **Zero-Dimensional (0D) Nanomaterials**: These materials have all three dimensions confined at the nanoscale. Examples include nanoparticles, nanoclusters, and quantum dots. Their small size leads to quantum confinement effects, which make them useful in optical and electronic applications.
- **One-Dimensional (1D) Nanomaterials**: These materials have one dimension larger than the nanoscale, while the other two are confined. Examples include nanowires, nanorods, and nanotubes. They are highly efficient in conducting electricity and heat along their length, making them ideal for sensors and electronics.
- **Two-Dimensional (2D) Nanomaterials**: These materials are confined in thickness but have extended length and width at the nanoscale. Examples include graphene, nanosheets, and transition metal dichalcogenides. Their large surface area and exceptional mechanical properties make them suitable for energy storage and flexible electronics.
- **Three-Dimensional (3D) Nanomaterials**: These materials consist of nanostructures interconnected in three dimensions. Examples include nanostructured foams, aerogels, and porous materials. They exhibit unique structural and functional properties, useful in catalysis and lightweight materials.

2. Based on Composition: Nanomaterials are also classified by the type of material they are composed of.

- **Carbon-Based Nanomaterials**: Composed entirely of carbon, arranged in various nanostructures such as spheres, tubes, or sheets. Examples include fullerenes, carbon nanotubes, and graphene. They are known for their exceptional strength, conductivity, and thermal properties.
- **Metal-Based Nanomaterials**: Made of metals or their alloys at the nanoscale. Examples include gold nanoparticles, silver nanoparticles, and metal nanowires. These materials are widely used for their optical, electrical, and catalytic properties.

- **Metal Oxide Nanomaterials**: Consist of metal oxides like titanium dioxide (TiO_2) and zinc oxide (ZnO). They are highly functional in applications such as photocatalysis, UV shielding, and sensors.
- **Polymeric Nanomaterials**: Made of nanoscale polymer chains. Examples include polymer nanoparticles and nanogels. They are biocompatible and commonly used in drug delivery systems and tissue engineering.
- **Ceramic Nanomaterials**: Composed of inorganic, non-metallic materials like silica or alumina. They are known for their hardness, thermal stability, and chemical resistance, making them useful in high-temperature applications.
- **Composite Nanomaterials**: A combination of two or more types of nanomaterials to enhance functionality. Examples include polymer-carbon nanotube composites and metal-oxide hybrids. These materials are designed for specific applications such as improved strength, conductivity, or reactivity.

3. Based on Structure: Nanomaterials can also be categorized by their structural arrangement at the nanoscale.

- **Nanoparticles**: Solid particles with dimensions in the nanoscale range. They can be spherical, cubic, or irregular in shape.
- **Nanotubes**: Cylindrical structures with hollow interiors. Carbon nanotubes are a prominent example, known for their exceptional mechanical and electrical properties.
- **Nanowires**: Wire-like structures with diameters at the nanoscale and lengths extending into the microscale. These are highly conductive and useful in electronic applications.
- **Nanoclusters**: Aggregates of a small number of atoms or molecules. They exhibit unique optical and catalytic properties due to their small size.
- **Nanosheets**: Thin, flat structures with only one dimension in the nanoscale. Examples include graphene and molybdenum disulfide sheets, which are highly conductive and flexible.

4. Based on Functional Properties: Nanomaterials are classified based on the specific properties they exhibit, which make them suitable for specialized applications.

- **Optical Nanomaterials**: Designed for manipulating light at the nanoscale. Examples include quantum dots and plasmonic nanoparticles.
- **Magnetic Nanomaterials**: Exhibit unique magnetic behavior, such as superparamagnetism. These materials are used in data storage and biomedical imaging [9].
- **Catalytic Nanomaterials**: Enhance the efficiency of chemical reactions due to their high surface area. Widely used in industrial catalysis and environmental remediation.

- **Biological Nanomaterials**: Engineered for compatibility with biological systems. Examples include liposomes and biodegradable nanoparticles for drug delivery.

Advantages of Nanomaterials:

- **Chemical functions**: Nanomaterials can be tailored to perform specific chemical functions.
- **Drug delivery**: Three-dimensional dendrimers can be used to deliver drugs.
- **Food packaging**: Nanomaterials can be used to improve food packaging and safety.
- **Skin protection**: Metal oxide nanoparticles can be used to protect skin from UV rays.

Some similarities and differences between metamaterials and nanomaterials:

1. **Properties**: Metamaterials are artificial materials with properties not found in nature, while nanomaterials have properties that differ from bulk materials.
2. **Structure**: Metamaterials are designed with multilevel-ordered microarchitectures, while nanomaterials have at least one dimension in the nanometer range.
3. **Surface area**: Nanomaterials have a large surface area-to-volume ratio, which makes them highly reactive.
4. **Applications**: Metamaterials are used in various research fields, and nano-metamaterials are a promising candidate for diagnostic and therapeutic agents.
5. **Electromagnetic waves**: Metamaterials can manipulate electromagnetic waves in ways not possible with conventional materials, such as achieving a negative index of refraction [10].
6. **Classification**: Metamaterials are classified based on permittivity and permeability, such as mu-negative fabric, epsilon-negative material, double-positive material, and double-negative material [11].

Conclusion:

A family of synthetic materials known as metamaterials has special electromagnetic and acoustic characteristics that are not present in natural materials. They are created by designing their structure at the subwavelength scale, enabling the development of materials with peculiar features. Telecommunications, energy, and the medical industry are just a few of the industries that metamaterials have the potential to revolutionise. They have been utilised to make high-performance antennas, cloaking devices, and ultra-thin lenses. Furthermore, there is still a great deal to learn about how these materials interact with the environment and how to incorporate them into real-world uses. About nanomaterial, day to day the synthesis of novel nanomaterials are increasing. The nanomaterials with mixed compositions are also synthesizing to apply in different fields. The facile synthesis methods will produce the nanoparticles of desired size, shape and property one which can withstand the external conditions but still, they need some improvement. Now days wide research in going into the fields of biomedicine, electronic storage devices, and sensors but still there is a scope for the development of research in these areas.

Therefore, the present review article will provide an opportunity to make a general information about the nanoparticles. In this review article we have given a brief overview of metamaterials and nanoparticles, their types, advantages in various fields. Owing to tunable physicochemical as well as biological properties, nanoparticles have gained prominence in medicine, environmental remediation, energy harvesting and many other areas.

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MECHANICAL PROPERTIES OF POLYMER COMPOSITION ON EFFECT OF FIBER

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Abstract:

This work the physical characterization and mechanical behaviors of the hybrid polymer composites were investigate and focus on effect of the fiber content. In this study, the basalt fiber and marble dust have been used as filler material and epoxy resin LY566 as a matrix material. Based on the availability, different fibercontent has taken and fabrication have been with conventional hand-lay-up technique, keeping the mould closing as constant and increasing the content of fiber in the composites. A variety of mechanical checks have achieved on the resultant composites which as suitable compositions. Tensile, flexural, density and hardness tests have been carried out and, the connection between the basalt content and homes had been examined. The resulting materials show enhanced Mechanical behavior.

Keyword: Polymer, Composites, Characterization, Fiber, Material.

Introduction:

Composites are materials along with two or extra chemically awesome components, ona macro-scale, having a distinct interface isolating them. [12] One or more discontinuousphases are, therefore, embedded in a non-stop phase to shape a composite. [7] Thediscontinuous phase is generally more difficult and stronger than the non-stop segment and isreferred to as the reinforcement, while, the continuous phase is named as the matrix. The matrix material can be metallic, polymeric or can even be ceramic [1,2]. When the matrix is a polymer, the composite is called polymer matrixcomposite (PMC). The reinforcing phase can either be fibrous or non-fibrous (particulates) in nature. The fiber reinforced polymers (FRP) consist of fibers of high strength and modulus embedded in or bonded to a matrix with distinct interface between them. In this form, both fibers and matrix retain their physical and chemical identities.6 In general, fibers are the principal load carrying members while the matrix keeps them at the desired location and orientation, acts as a load transfer medium between them, and protects them from environmental damages [3].

Fiber reinforced polymer (FRP) composites have emerged from being exotic materials used only in niche applications following the Second World War to common engineering materials used in a diverse range of applications. Composites are now used in aircraft, helicopters, space-craft, satellites, ships, submarines, automobiles, chemical processing equipment, sporting goods and civil infrastructure, and there is the potential for common use in medical prosthesis and microelectronic devices [4]. Composites have emerged as important materials because of their light-weight, high specific strength and stiffness, excellent fatigue resistance and outstanding corrosion resistance compared to most common metallic alloys such as steel and aluminum [5,6].

Other advantages of composites include the ability to fabricate, directional mechanical properties, low thermal expansion coefficients and high dimensional stability. it's far the aggregate of exceptional bodily, thermal and mechanical residences that makescomposites appealing to use in region of metals in many applications, especially wheneight-saving is vital. As already mentioned, FRP composites are simply multi-constituent substances that include reinforcing fibers embedded in an inflexible polymer matrix [7]. The fibers used in FRP materials may be in the shape of small particles, whiskersor non-stop filaments. maximum composites used in engineering applications contain fibersmade from glass, carbon or aramid. In nearly all engineering packages requiring highstiffness, power and fatigue resistance, composites are bolstered with non-stop fibersas opposed to small particles or whiskers [8].

The physical characteristic can further be changed via adding a stable filler segment to thematrix body at some point of the composite instruction. The advanced overall performance of polymersand their composites in business and structural applications with the aid of the addition of particulatefiller materials has shown a top notch promise and so has currently been subject of considerable interest. Specific fillers (additives) are added to enhance and modify the quality of composites. The fillers play a major role in determining the properties and behaviour of particulate reinforced composite materials.

Material and Methods:

The experimental investigation suggests that successful fabrication of polymer composites with reinforcement of basalt fiber and marble dust filler is possible. Incorporation of fillers modifies the hardnessof the basalt fiber composites. The unfilled basalt fiber and marble dust composite has a strength of 50.53 MPa in tension and that this value drops to 44.97 MPa and increase 52.16MPa to 59.25 MPa with addition of 8 wt% and 16 wt% of basalt fiber respectively [9].

The fabrications of composite slab are carried out by conventional hand layup technique. The basalt fiber and marble dust powder were used as reinforcement and epoxy is taken as matrix material. The composite slabs are made by conventional hand-lay-up technique followed by light compression moulding technique. A woodmould having dimensions of 200 × 180 × 5 mm^3 is used. A releasing agent (transparent sheet) is used to facilitate easy removal of the composite from the mould after curing. The curing of the polymer resin was done by incorporation of 2% methyl-ethyl-ketone-peroxide (MEKP) as hardener prior to reinforcement [10].

Characterization

The characterization of the composites reveals that the fiber content is having a significant effect on the mechanical properties of composites. The optimum lengths of the fibre of 12 mm were investigated. The tensile strength of the Basalt fibre composites revealed at 12 mm length of fibre exhibits better properties than other lengths of fibre. Flexural strength of composites also shows better properties at 12 mm length of fibre. The length of reinforced basalt fibre plays a significant impact on some mechanical properties, Impact strength of basalt fibre reinforced composite of 12 mm length shows the maximum impact energy absorption in all the percentage of fibre.

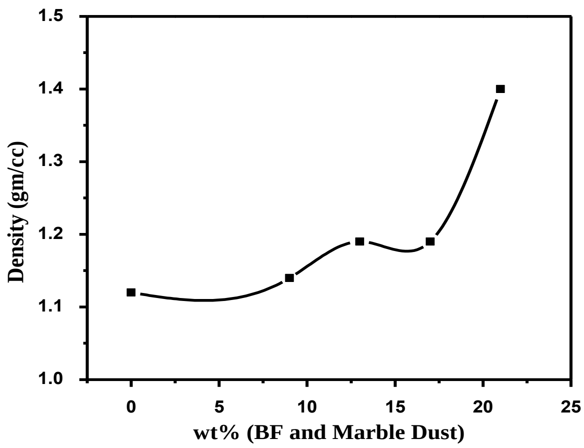

Figure 4.1.a. Reinforcement vs. Density of hybrid polymer composites

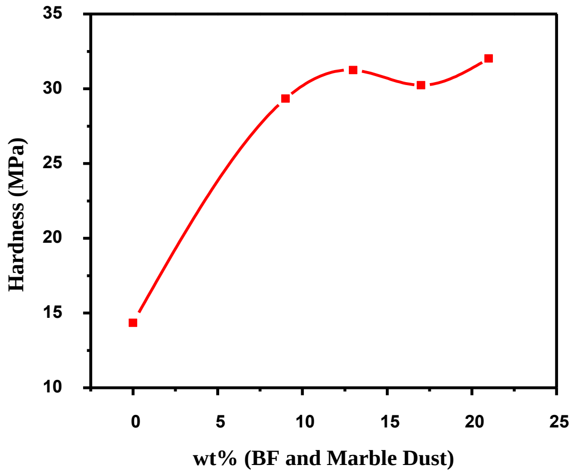

Figure 4.1.b. Reinforcementvs. Hardness of hybrid polymer composites

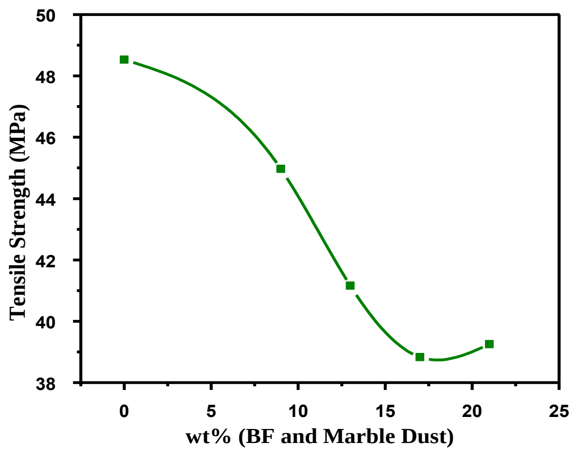

Figure 4.1.c. Reinforcementvs. Tensile strength of hybrid polymer composites

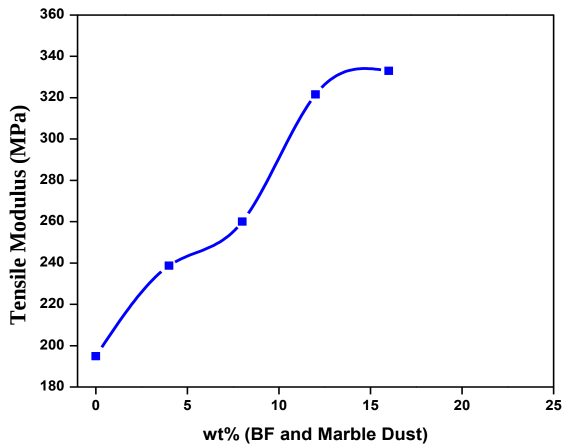

Figure 4.1.d. Reinforcement vs. Impact energy of hybrid polymer composites

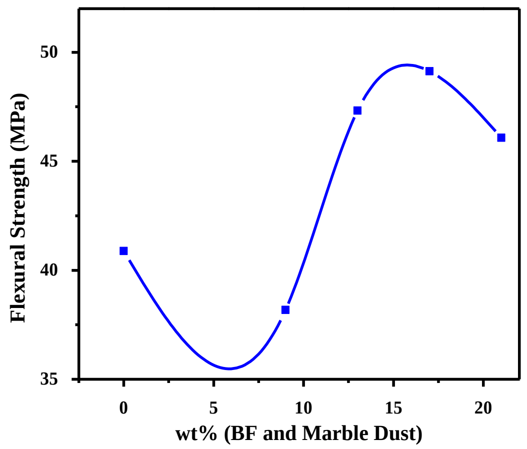

Figure 4.1.e. Reinforcement vs. Flexural Strength of hybrid polymer composites

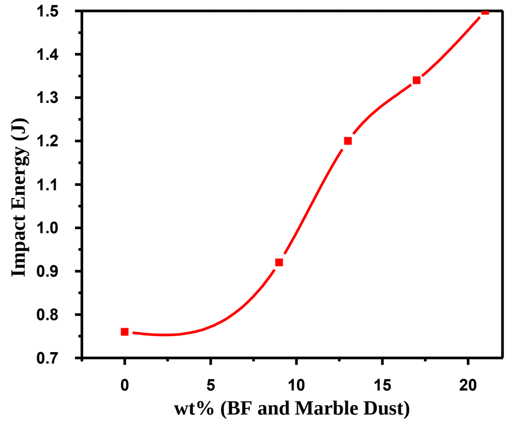

Figure 4.1.f. Reinforcementvs. Impact Energy of hybrid polymer composites

Results:

4.1 Effect of fiber loading on physical and mechanical properties

4.1.1. Density:

The measured densities along with the corresponding weight percentage are presented in figure 4.1.a. It is clearly seen that with the increase in fiber content from 4wt% to 16 wt% and 5wt% marble dust powder, there is a decrease in the density and after 4% drastically change in the density.

4.1.2. Hardness:

The variation of composite brinellhardness with the weight fraction of basalt fiber is shown in Figure 4.1b. For the composite (4wt% and 16 wt% of BF and 5wt% marble dust powder), the hardness value is recorded as 29.9 while for (8wt% and 12 wt of BF and 5wt% marble dust powder) this value is measured to be 29.8. It is thus seen that with the increase in fiber content in the composite, the hardness improves although the increment is marginal [11].

4.1.3. Tensile and Flexural strength

It is well known that the strength properties of composites are mainly determined by the fiber content and the fiber strength. So the variation in composite strength with different fiber loading is obvious. These variations in tensile, flexural strengths and tensile modulus of the composites are shown in Figure 4.2.c, 4.1.d, 4.1e. A gradual decrease in both tensile strength as well as flexural strength with the fiber 4% weight percentage is noticed. The addition of basalt fiber and 5wt% marble dust powder the tensile strength and flexural strength while the lower first and then increase. It clearly indicates that inclusion of basalt fiber improves the load bearing capacity and the ability to withstand bending of the composites. The polymer chains have enough time and amorphous regions with applied load. As per the overall observation in the flexural strength of the composite, incorporation of fibre content in the polymer composite influences the properties of the composites [12]. Increasing of fibre content in the composite increased the strength of the composites.

Conclusion:

In present study, it was found that, the content of basalt filler affected structural integrity and mechanical properties of composites. Basalt can be added to the polymers up to 4-12 wt. % and 5wt% of marble dust powder to affect the mechanical properties tensile strength, hardness, flexural strength, tensile modulus and density.

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USE OF FATTY ACID METHYL ESTER IN LUBBRICANT AS AN ADDITIVE

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Abstract:

In the small industries in developing countries often rely on waste engine oil for machinery lubrication, posing environmental and health risks. Contaminated engine oils can compromise machinery integrity by introducing abrasive particles that exacerbate wear and tear. This can lead to a range of problems, including mechanical vibrations, component misalignment, and premature failure. To ensure optimal machinery performance, particularly in demanding environments, it is essential to explore alternative lubrication solution to the use of waste engine oil is the incorporation of Fatty Acid Methyl Ester (FAME), a substance already employed as a load-carrying additive in engine lubricants. The Tribology of FAME offers potential advantages in improving lubrication quality and minimizing environmental impacts. So, instead of using waste engine oils for the purpose of lubrication as base oil additives with fatty acid methyl ester could be used to serve the purpose of lubrication. And the investigates the effects of FAME on fuel performance, compatibility, and stability, as well as its interactions with common fuel additives. The findings provide valuable insights into the benefits and challenges of integrating FAME into conventional fuel systems.

Keywords: FAME, Additive, Lubricant, Tribology

1. Introduction:

Absolutely, the push for economic and technological advancement has led many countries to introduce changes aimed at enhancing production efficiency and management practices, with a focus on ecological considerations within legislation. The increasing demand for fuel and the depletion of traditional resources have driven the adoption of renewable energy sources for producing transport fuel, especially for combustion engines.

The adaptable nature of combustion engines allows for modernization, making plant-based fuels a feasible concept. Given the depletion of petroleum resources, plant oils have emerged as a promising alternative due to their suitability for this purpose. [1].

1.2 Background:

Indeed, several studies have highlighted the effectiveness of using fatty acid methyl ester (FAME) derived from vegetable oils to improve the lubricity of diesel fuels, which directly impacts the performance of fuel pumps and injection equipment in diesel engines.

Given the significance of lubricity in engine operation, investigating the tribological performance of FAME from vegetable oils is a valuable pursuit.

Using FAME, this is already being utilized as a load-carrying additive within engine lubrication, as an additive for lubrication of external meshing machine components appears to be a viable approach. This could potentially enhance the performance and longevity of such components while also contributing to sustainable practices by repurposing FAME in a different application. [2].

2. Tribology

2.1 History of Tribology:

It encompasses the study of friction, lubrication, and wear. Tribology focuses on the engineering and science of contacting surfaces in relative motion. The term "Tribology" was coined by Jost in 2006, originating from the Greek word "tribos,". The industrial growth during that era drove significant advancements in tribology knowledge due to the growing demand for understanding friction, lubrication, and wear across various applications.[3].

2.2 Friction:

It's the force that opposes the motion of surfaces sliding against each other. Friction acts in the opposite direction to the initial force that sets the surfaces in motion. Surfaces have coefficients of friction (μ) that range from 0 to 1.

2.3 Wear:

Wear refers to the material degradation occurs when components interact and slide against each other, resulting in loss of material. Two primary mechanisms drive this degradation: surface abrasion and interfacial adhesion. Surface abrasion occurs when a harder material erodes a softer one, while interfacial adhesion leads to material loss due to surface bonding during sliding. Furthermore, repetitive loading cycles can initiate a third failure mode, even under relatively low-stress conditions. Microscopic flaws within components can nucleate tiny cracks, which, although initially benign, can propagate and grow with repeated loading, ultimately culminating in catastrophic failure [4].

2.4 Lubrication:

Lubrication involves using a lubricant to reduce wear between surfaces that are in close proximity and moving relative to each other. The lubricant is interposed between the surfaces to help carry the load or pressure generated between them. The lubricant can take various forms, including solid substances like graphite or MoS_2, solid/liquid dispersions, liquids, liquid-liquid dispersions, and even gases in exceptional cases. The primary goal of lubrication is to create a protective layer that minimizes friction and wear, enhancing the longevity and efficiency of the interacting components. [5].

It involves a lubrication film with the thinnest possible thickness, resulting in minimal separation between sliding components. In boundary lubrication, additives such as extreme pressure (EP) or anti-wear (AW) agents are used to prevent friction and wear, as there isn't a significant physical separation between the surfaces. This form of lubrication relies on the additives to form a protective layer that minimizes direct contact between the surfaces, thus reducing wear and enhancing the lubrication process. [6].

2.5 Materials used in Tribology:

Lubricating materials can exist as gases, liquids, solids, or even hybrid states. The Main role is to manage wear and friction, but they also contribute to controlling temperature, preventing corrosion, transmitting power, cleaning out debris, absorbing shocks, and more. Liquid lubricants, typically made from various sources such as petroleum, plants, animals, and synthetics, are well-known and widely used. Additionally, semi-liquid or plastic lubricants like grease are commonly employed. Solid lubricants, though less common, are highly valuable in specialized and demanding applications where their unique properties prove advantageous. [7]. Solid lubricant is often added to other lubricants to enhance their properties. They contribute specialized advantages to the lubricant mixture. Examples of solid lubricants include graphite, mica, and lead carbonate. Various metal sulfides are also employed as solid lubricants, such as bismuth sulfide, tungsten sulfide, copper sulfide, tin sulfide, zinc sulfide, and iron sulfide. These solid lubricants offer specific benefits in certain applications, helping to reduce friction, wear, and enhance the overall performance of lubricants.

2.6 Challenging of Tribology:

One of the major difficulties is the low visibility of tribology, mainly because it's a multidisciplinary domain that requires expertise from various fields to gain a comprehensive understanding. This complexity also makes it challenging to create accurate predictive models for simulating tribological processes. Another hurdle is the intricate nature of tribology itself. Much progress has come from empirical methods involving trial and error, as well as iterative experimentation, rather than a complete understanding of the underlying mechanisms. The multifaceted nature and reliance on practical experience make tribology a fascinating yet intricate field to navigate. [8]. Absolutely, advancing in the field of tribology will indeed require increased research efforts and the integration of various component fields into a unified discipline. By bringing together expertise from multiple domains and encouraging interdisciplinary collaboration, tribology can emerge as a distinct and self-standing field. This approach will enable a more comprehensive understanding of tribological phenomena and facilitate the development of effective solutions to the challenges it presents.

2.7 Lubricant:

Lubricants play a vital role in facilitating smooth interactions between moving surfaces by minimizing friction, optimizing efficiency, and reducing wear. These substances, typically liquids, also help to remove or transport contaminants and regulate temperature. The composition of lubricants generally comprises a base oil, which can be derived from petroleum, vegetable oils, or synthetic sources, supplemented with a smaller proportion of performance-enhancing additives. These additives significantly contribute to the lubricant's overall effectiveness by mitigating friction and wear, adjusting viscosity, and providing protection against corrosion, degradation, and contamination.

Beyond industrial applications, lubricants find use in various other contexts. These include biomedical applications such as lubricating artificial joints. Lubricants play a vital role in ensuring smooth operation and extending the life of mechanical components across a wide range of fields. [9].

Lubricants serve a range of crucial purposes, including:

Lubricants serve various purposes beyond the conventional functions:

- Assisting proper movement of parts, such as locks and switches, to ensure they function as intended.
- Providing water resistance to surfaces, helping to repel water and prevent damage. Preventing wear and tear from impacting surfaces, extending their lifespan.
- Facilitating the transfer of power, particularly in hydrostatic systems, where lubricants aid in power transmission.
- Transferring heat from one surface to another, helping to manage temperature and prevent overheating.
- These diverse uses of lubricants showcase their versatility in meeting specific needs across a wide range of applications and industries.

2.8 Base Oil

A clear distinction between refined and synthetic oils and explained the concepts of base oil and additives in lubrication. Refined oils, such as Paraffinic and naphthenic oils, are obtained through the refining of crude oil.

On the other hand, synthetic oils are manufactured rather than being derived from crude oil. These synthetic oils offer specific characteristics tailored to particular applications.

In all lubricants, the base oil is a fundamental component, forming the foundation before blending with additives or thickeners in the case of grease. This mixture of base oil and additives enhances the lubricant's performance and effectiveness in various applications.[10]. Selecting the appropriate base oil for a given application can indeed be a complex decision. Factors such as performance requirements, operating conditions, and budget constraints play a role in this choice. Understanding the differences between mineral oils and synthetic oils can help you make an informed decision.

Mineral oils are derived from crude oil through refining processes. They offer good general lubrication properties and are cost-effective, suitable for many applications. Synthetic oils, on the other hand, are manufactured to precise specifications, offering tailored properties like higher viscosity index, better stability at extreme temperatures, and improved resistance to oxidation. While synthetics can provide enhanced performance, they are typically more expensive.

To make the right choice, assess your application's demands. If you need improved performance under extreme conditions or specific requirements, synthetic oils might be preferable. However, for standard applications, mineral oils can be a practical and economical option. Consider consulting with lubrication experts or referring to industry guidelines to ensure you make the most suitable base oil selection for your needs.

2.9 Base Oil Categories:

This Classification helps in Understanding the Different Types of Lubricants Available:

Mineral Oil:

Derived from crude oil, mineral oils vary in quality based on the refining process. They are versatile and cover a wide range of applications.2. Synthetic Oil: Synthetics are artificially created through a synthesis process. They come in various formulations tailored for specific purposes, offering distinct properties like high temperature stability or better performance in extreme conditions.

Vegetable Base Oil:

Derived from plant oils, these represent a small fraction of lubricants. They are primarily used for environmentally-friendly and renewable reasons.

Understanding these distinctions helps in selecting the most suitable lubricant for a given application based on its performance requirements, environmental considerations, and other specific needs. [11].

3. Fatty Acid Methyl Ester

FAME, derived from various vegetable oils and fats, shares physical properties with conventional diesel fuel, its adaptability enables it to function as a blending agent in conventional diesel or as a standalone fuel, often referred to as B100. FAME's non-toxic and biodegradable nature has contributed to its adoption as a renewable alternative fuel, and it's interesting to note that FAME, along with Bioethanol, ranks as one of the leading renewable liquid fuels globally. FAME ranks as the second most prominent renewable liquid fuel in

Sweden's market. [12]. the exclusive use of rapeseed methyl ester (RME) for FAME in the Swedish market reflects a commitment to meeting climate-related regulations. Rapeseed-based FAME aligns with the sustainability goals and requirements, showcasing how specific feedstocks are chosen to support environmental objectives in different regions.

3.1 Primary Area of Use:

Fatty Acid Methyl Ester (FAME) is a biofuel commonly utilized in diesel engines, often blended with conventional diesel to boost the renewable energy component. European standards permit up to 7% FAME in diesel without requiring modifications to vehicles or distribution systems. FAME enhances lubrication properties and seamlessly integrates with fossil diesel. Although it is biodegradable and non-toxic, its susceptibility to degradation necessitates timely consumption. Moreover, using pure FAME requires manufacturer approval, and its cold-weather sensitivity must be considered. [13]. It's great to hear that rising number of vehicles approved for 100% FAME usage marks a significant milestone. Sweden's thriving B100 market and its rapid growth indicate a promising shift towards sustainable energy solutions. gained approval for using pure FAME (B100). However, you're right that there might still be a need to spread knowledge about this fuel to the rest of Europe. Raising awareness about the benefits, considerations, and approvals required for using pure FAME could contribute to its broader acceptance across the continent.

Properties:

It's evident that the production and sustainability aspects of biodiesel (FAME) has been a subject of comprehensive study within various IEA-AMF tasks, including Task 45, Task 37, Task 34-1, and Task 30. The global trend towards using biodiesel as a substitute for diesel fuel is on the rise, with volumes of production and consumption growing significantly. This transition, from minimal usage in the mid-1990s to over 10 M-toe in 2009, is indicative of the increasing interest and adoption of biodiesel as an alternative and sustainable fuel source. [14].By 2015, global biodiesel production had reached a substantial level of 23.5 M-toe, making up 21% of the total Production. However, along with this promising growth, certain technical challenges need to be addressed.

To maximize the impact of bio-derived fuels, it's important to adopt a diversified approach that utilizes various biomass feedstock and produces a wider range of fuel options. This would allow for a more comprehensive array of fuel choices, covering both gasoline and diesel replacements, while addressing the technical barriers associated with specific feedstock and climates.[15]. Absolutely, the concept of a flexible bio refinery is gaining importance as the world looks to diversify manufacturing processes. Paraffinic fuel options like HVO (Hydrogenated Vegetable Oil) are also emerging in this context.

FAME biodiesel has acceptable ignition properties, often boasting a cetane number over 50. Its advantages include low sulfur and aromatic content, as well as good lubricity. However, there are drawbacks to consider, such as its high viscosity, poor performance in cold conditions, elevated boiling point, and the presence of impurities like triglycerides, glycerol, alcohols, sodium, potassium, and phosphorus.

These factors underscore the need for continued research and development to enhance the overall performance of biodiesel fuels.

Chemical Structure:

Indeed, the process of transforming various raw materials like vegetable oils, animal fats, and recycled cooking greases into biodiesel involves a chemical reaction known as transesterification. Currently, methanol is the predominant alcohol used in biodiesel plants. The processes and catalysts employed are optimized for methanol. While higher alcohols have the potential to be used, their yields tend to be lower compared to methanol. Interestingly, using higher alcohols may lead to an increase in cetane number (ignition quality) but could also raise viscosity. It's important to note that this discussion specifically focuses on fatty acid methyl esters (FAME), one of the key types of biodiesel [16].

3.3 Limitation and concerns associated with FAME Utilization:

Chemical Structure and Constituents differences between fatty acid methyl ester (FAME) and hydrocarbon-only fuels can indeed lead to challenges when blending FAME into diesel fuels. These challenges encompass various stages of the fuel production, blending, distribution, and supply processes. It's important to ensure that these challenges are effectively managed to maintain fuel quality, engine performance, and compliance with regulations. [17].

Key considerations include the impact of FAME, both as a standalone product and as a diesel fuel additive, on various factors:

Oxidation Stability: Ensuring stable fuel quality over time and preventing oxidation-related issues, especially in terms of both longer storage and thermal

Cold Flow Properties and Filterability: Addressing potential challenges related to cold including pour point, weather performance, cloud point and the potential impact on filterability.

Microbiological Growth: Managing the potential for microbial contamination and growth within the fuel, which can lead to fuel degradation and clogged filters.

Water Content: Understanding how FAME might affect water content in diesel fuel, potentially leading to issues like degraded water shedding ability and increased dissolved water content.

Material Compatibility: Ensuring that FAME-blended fuels are compatible with the materials used in refineries, distribution systems, and fuel supply chains.

Additive Performance and Compatibility: Evaluating the efficacy and compatibility of typical distillate fuel additives when combined with FAME.

These challenges underscore the intricate nature of blending FAME with hydrocarbon fuels and the importance of addressing these considerations to ensure the quality, performance, and safety of the final blended fuels. [18].

4. Fuel Additive Performance:

It's crucial to ensure that the FAME used for blending doesn't contain additives beyond oxidation-stability improving additives to prevent compatibility issues with diesel fuel additives. Adding performance additive packages during or after blending can help optimize the fuel's properties.

Moreover, it's good to know that FAME is generally considered safe to use. However, caution should still be exercised to prevent rapid oxidation when exposed to air, especially for FAME with high iodine values. Proper handling and disposal of materials used with neat FAME are important to avoid potential hazards like spontaneous combustion. [19].

These additives are crucial for enhancing the performance, efficiency, and safety of various fuel types, whether they're used for transportation or electricity generation.

They are designed to address operational challenges and improve specific performance features, and they can be used at different stages, from refining to distribution and end use Additives can be applied individually to address specific issues, or they can be combined to create multi-functional packages that cater to the needs of the automotive industry, for example. The treat levels of these additives are generally low, with varying dosages depending on the desired benefits. It's interesting to note that additive treat levels are considerably lower than the amounts of fuel blending components like ethanol or fatty acid methyl esters (FAME), which are typically added at levels of 3-20% of the hydrocarbon base fuel volume.

5. Development of New Additives:

Absolutely, innovation is a constant requirement in the fuel additives industry, often driven by changing regulations and the need for higher quality fuels. Legislation altering fuel specifications, not just for automotive fuels, often triggers the development of new additives. For instance, the reduction of sulfur content in middle distillate fuels has necessitated the creation of lubricity additives to safeguard diesel injector pumps.

In other cases, there might be a demand for advanced multi-functional additive packages, which could involve novel additive components. These packages can contribute to improving vehicle fuel efficiency while minimizing the emission of regulated exhaust pollutants. The increasing use of diesel exhaust particulate filters has also driven the creation of fuel borne catalyst additives to aid in the cleaning or regeneration of these filters onboard vehicles. All these examples showcase the industry's need for ongoing innovation to meet evolving requirements and challenges. [20].

Conclusion:

Using waste engine oil for lubrication in small-scale industries, while common due to cost constraints, poses serious risks to both the machinery and the environment. It is important to explore alternatives like Fatty Acid Methyl Ester (FAME), which offers better tribological performance, environmental benefits, and cost-effectiveness. Implementing such alternatives can not only improve the longevity and efficiency of machinery but also contribute to sustainability in developing countries, creating a safer environment for workers and local communities.

However, challenges such as oxidation stability, cold flow properties, and material compatibility must be addressed. The development of new additives and innovative solutions is crucial to overcoming these challenges. The fuel additives industry must continue to evolve in response to changing regulations and the need for higher quality fuels.

In conclusion, FAME has the potential to play a significant role in the transition to sustainable energy solutions. Ongoing research and development are necessary to fully harness its benefits and address the associated challenges.

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STUDY ON COMPLEX NUMBER AND ITS APPLICATION

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Abstract:

This Chapter a new technique to complex numbers application have been discussed by applying the concepts of ordering real on the imaginary number. Complex numbers have applications in many scientific research, signal processing, electromagnetism, fluid dynamics, quantum mechanics, and vibration analysis. The complex number have been understanding the definition, terminology, visualization, properties, and operations of complex numbers.

Keyword: Complex Number, Properties, Definition, Operation, Application

Introduction:

Complex numbers are helpful in finding the square root of negative numbers. The concept of complex numbers was first referred to in the 1st century by a greek mathematician, Hero of Alexandria when he tried to find the square root of a negative number. But he merely changed the negative into positive and simply took the numeric root value. Further, the real identity of a complex number was defined in the 16th century by Italian mathematician Gerolamo Cardano, in the process of finding the negative roots of cubic and quadratic polynomial expressions.

In the real number system, there is no solution to the equation

$$x^2 = -1$$

The new number system is the number i.

$$i = \sqrt{-1}$$

Geometrically, complex numbers extend the concept of the one-dimensional number line to the two-dimensional complex plane by using the horizontal axis for the real part and the vertical axis for the imaginary part. The complex number $a + bi$ can be identified with the point (a, b) in the complex plane. A complex number whose real part is zero is said to be purely imaginary; the points for these numbers lie on the vertical axis of the complex plane. A complex number whose imaginary part is zero can be viewed as a real number; its point lies on the horizontal axis of the complex plane. Complex numbers can also be represented in polar form, which associates each complex number with its distance from the origin (its magnitude) and with a particular angle known as the argument of this complex number.

1. Representation of a complex number

Rectangular Form $z = a + ib$

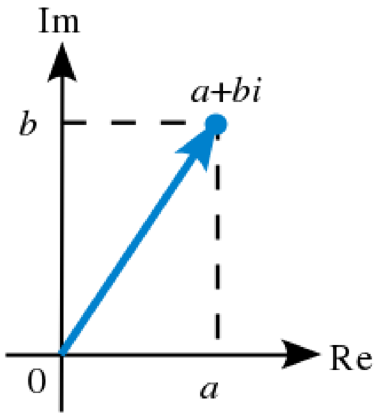

Fig. 1: Argand Diagram

A complex number is of the form a + ib and is usually represented by z. Here both a and b are real numbers. The value 'a' is called the real part which is denoted by Re(z), and 'b' is called the imaginary part Im(z). Also, ib is called an imaginary number[1].

axis, and i satisfies $i^2 = -1$.

The real part is denoted by Re (z) = a

The imaginary part is denoted by Im (z) =b

If a=0, $a + i\,b = ib$, which is purely imaginary.

If b=0, $a + i\,b = a$ which is purely real.

1.1 Polar Form $z = r(\cos\theta + i\sin\theta)$

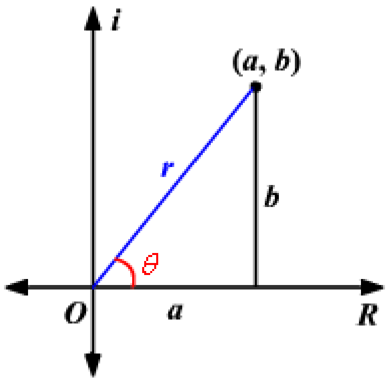

Fig. 2: Polar Form

$z = a + ib = r(\cos\theta + i\sin\theta)$

$a = r\cos\theta \;\&\; b = r\sin\theta \Rightarrow \cos\theta = \frac{a}{r} \;\&\; \sin\theta = \frac{b}{r}$

Squaring and adding we get $r = \sqrt{a^2 + b^2}$

The notation 'r' is called the modulus of a complex number.

$\tan\theta = \frac{\sin\theta}{\cos\theta} = \frac{b}{a}$

$\theta = \tan^{-1}\frac{b}{a} = \tan^{-1}\frac{Im\ (z)}{Re\ (z)}$

The number θ is called amplitude or argument and written as

$$\theta = amp\ (z) = \arg z$$

Exponential Form $z = re^{i\theta}(\theta\ is\ in\ radian)$ (Euler's Theorem).

2. Conjugate complex numbers

Definition: Two complex numbers that differ only in the sign of the imaginary part are called conjugate complex numbers.

e. g. $a + i\ b$ and $a - i\ b$ are two conjugate complex numbers.

If we denote the complex number $a + i\ b$ by 'z,' then its conjugate $a - i\ b$ is denoted by '$\bar{z}$'.

i. e. $\overline{a + ib} = a - ib = \bar{z}$

2.1. Properties of complex numbers:

1) If $a + i\ b = 0\ then\ a = 0\ and\ b = 0\ (zero\ Property)$
2) $a + ib = c + id, then\ a = c\ and\ b = d\ (equal\ Property)$

2.3. Fundamental Operations of Complex Numbers:

Addition of two complex numbers: First, collect the real parts and imaginary parts separately, then add the real and imaginary parts separately.

The sum of two complex numbers $z_1 = a + i\ b, z_2 = c + i\ d$ is obtained below

$$z_1 + z_2 = (a + i\ b) + (c + id)$$
$$= a + c + ib + id$$
$$= (a + c) + i(b + d)$$

Subtraction of two complex numbers: First, collect the real parts and imaginary parts separately, and then perform the subtraction process.

The subtraction of two complex numbers $z_1 = a + i\ b, z_2 = c + i\ d$ is obtained below

$$z_1 + z_2 = (a + i\ b) - (c + id)$$
$$= a - c + ib - id$$
$$= (a - c) + i(b - d)$$

Multiplication of two complex numbers: If $z_1 = a + i\ b$, and $z_2 = c + i\ d$ are complex numbers

$$z_1.z_2 = (a + i\ b).(c + id)$$
$$= ac + iad + ibc + i^2bd$$
$$= (ac - bd) + i(bc + ad)$$

Division of two complex numbers: If $z_1 = a + i\ b$, and $z_2 = c + i\ d$ are complex numbers

$$\frac{z_1}{z_2} = \frac{a + ib}{c + id} = \frac{a + ib}{c + id} \times \frac{c - id}{c - id}$$

(Multiplying the numerator and denominator by the conjugate of the denominator)[2,1]

$$= \frac{ac - iad + ibc - i^2bd}{c^2 - i^2d^2} = \frac{ac + bd + i(bc - ad)}{c^2 + d^2}$$

$$= \frac{ac + bd}{c^2 + d^2} + i\frac{bc - ad}{c^2 + d^2} = A + iB$$

Modulus of a Complex Numbers: The modulus of complex number $z = a + i\,b$, is written as $|z|$ or mod z

$$|z| = \sqrt{a^2 + b^2}$$

Which is always be a positive number.

Applications of Complex Numbers related to Physics

A common visualization of complex numbers is the use of Argand Diagrams. To construct this, picture a Cartesian grid with the x-axis being real numbers and the y-axis being imaginary numbers. An important property of complex numbers is the Euler's formula: it states that every complex number, can be rewritten in the form of re =r (cos + i sin), where e=2.71828. . is the Euler's constant, r is the 'distance' of the complex number from the origin and is the angle of the complex number from the positive real axis (anticlockwise, in radians). On the left is an illustration of this [3]. Euler's formula is described to be the most beautiful mathematical result in history by many mathematicians. Its aesthetic beauty lies in the fact that it implies a magical relationship between real numbers and imaginary numbers. Although I would like to demonstrate the elegant proof for this formula, it is unfortunately outside the scope of this article [4].

[1] Signal Processing

Suppose a pianist is recording in a track studio. He invites you to play a game: guess what musical notes he performs without looking at the piano. As someone who doesn't have perfect pitch (the ability to identify a musical note just by hearing it), how could you win this game?

It turns out, there is a way to deduce the notes he is playing without cheating. First, record his playing using audio-editing software. The software will save the recording in the form of a waveform. You can then apply a Fourier transform to the waveform to identify the frequencies most prominent in the recording.

This is done by detecting the 'peaks' in the resulting frequency distribution after the Fourier transform has been applied. For instance, if there are clear peaks at 256 Hz and 391 Hz (which correspond to the notes C4 and G4, respectively), you can deduce that the pianist must have played C and G on the piano.

Understanding the location of frequency peaks is essential for audio editors and music producers. They can not only identify the source of background noise but also use its frequency as a reference to eliminate it through the process of Equalization (EQ).

The idea behind the Fourier transform is rather ingenious. It proposes that any complex wave can be decomposed into multiple sinusoidal waves with varying frequencies. The Fourier transform predicts which frequencies are most likely to correspond to one of these sinusoidal waves. It does this by 'wrapping' the wave around the origin in the complex plane and computing the sum of complex coordinates for all possible points on the wrapped wave.

[2] AC Circuit Analysis

In alternating modern circuits (AC stands for alternating modern, an electric powered present day that modifications in value and direction over the years), inverse numbers are used to calculate present day, voltage, or resistance. A not unusual use of numbers (specifically Euler's formula) is to calculate the difference among two AC factors with admire to time. An example of the sort of calculation is proven to the right. However, we can constitute the two voltages as integer values of complex numbers (the x-coordinates of the Argand diagram) [5].

Complex numbers are also used to express the magnitude and phase of impedance in an AC circuit. Impedance is very similar to resistance - it slows down the electrons in the circuit. The distinction is that impedance causes a phase shift on the electrical current, while resistance does not. Impedance takes place in common electrical components such as inductors and capacitors, and so having a complex number representation is crucial. In general, complex numbers serve as a representation of phase, which is essential to analysing AC circuits [6,7].

[3] Quantum Mechanics

Quantum mechanics is a field of physics that studies the motion and interactions of subatomic particles, primarily bosons (such as photons) and fermions (such as neutrons). It provides a mathematical description of their behavior in terms of probability. In fact, complex numbers form the basis of quantum mechanics. The Schrödinger equation is as important to quantum mechanics as Newton's second law is to classical physics. Both provide reasonable mathematical predictions of particle location and energy. The complex number system is very important to the field because it provides a simple language for expressing wave charge without violating the laws [8,9]. Complex numbers are relevant in the formulation of quantum mechanics, where complex Hilbert spaces provide the space for such formulations that are convenient and perhaps standard. The foundational formulas of quantum mechanics – Schrödinger’s equation and Heisenberg’s matrix mechanics – use complex numbers [10].

[4] Electromagnetism

Instead of taking the magnetic and electrical parts as two different real numbers, we can represent it as a complex number.

[5] Relativity

In general, and special relativity, some formulas for measuring space-time become simpler if we take the time variable as imaginary. Although this is no longer standard in classical relativity, it is used in an essential way in quantum field theory [11].

Fluid mechanics

Complex numbers are used to describe potential flow in two dimensions. This can be used to calculate forces and moments of inertia in an airplane, the mass flow of oil through pipelines, and predictions of weather patterns. Complex numbers are used in fluid dynamics, particularly for studying potential flows. The complex potential function is used to investigate fluid flow around objects, assisting engineers and physicists in their understanding of aerodynamics and hydrodynamics [12].

Conclusions:

The defined for the complex numbers gives the possibility of ordering the complexnumbers and adds many properties related to the ordering of complex numbers, that have been defined for a long time. This new concept will be very useful for real life application of research as well new scientific idea**.**

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INTRODUCTION TO OPTICS AND SPECTROSCOPY AND ITS USE IN MEDICINE

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Abstract:

Optic spectrometer is the study of light-matter interactions with the goal of better understanding material properties and optical behaviour. Typically, at incident low light intensities, materials' optical characteristics are independent of light intensity. However, at high light intensities, the optical properties become intensity-dependent, and Nonlinear Optics enters the picture, complete with its own phenomena, selection rules, and criteria, so establishing a new and intriguing research subject. Then, based on the use of nonlinear (NL) optical phenomena, numerous spectroscopic techniques were created to gain a comprehensive understanding of materials. In this chapter, we will focus on the nonlinear optical spectroscopy of metal nanoparticles (MNPs) and metal nanoclusters (MNCs) contained in liquids, as well as some of their applications. The study of how matter absorbs and emits light and other radiation is known as spectroscopy. Similar to how a prism divides light into a rainbow of colours, it entails separating light into its individual wavelengths, or spectrum. Actually, a prism and photographic plates were used to do old-fashioned spectroscopy.

Keywords: Spectroscopy, Molecular Spectra, Electronic Band Spectra, Intensity and Radiation

1. Introduction:

1.1 History of Optical spectroscopy:

In optical spectral analysis, a single electron absorbs energy to reach the higher energy level or the higher orbital. Furthermore, electrons release energy as they return to a lower energy level or orbital. As a result, electrons either absorb or expel energy in the form of photons. Because each element has a unique amount of electrons, an atom absorbs/releases energy according to a pattern specific to its elemental identity, such as Ca or Na. As a result, photon absorption and emission follow distinct patterns [1]. The kind of atoms in a sample or the number of atoms in a sample can be determined by detecting variations in light wavelengths and intensity. Another significant aspect of optical spectroscopy is time resolved observations. Optical spectroscopy is one of the most versatile modern research tools, allowing for investigations spanning from steady state to femtoseconds. Time resolved optical spectroscopy can be used to investigate a wide range of reactions in physics, chemistry, and biology. To address this variety, five time units are commonly used:

- Milliseconds: 1 ms = 10^{-3} s, e. G. In biological reactions such as ion transport;
- microseconds: 1 μs = 10^{-6} s, e. G. In diffusion controlled chemical reactions in liquid phase, triplet state reactions;
- nanoseconds: 1 ns = 10^{-9} s, e. G. In photochemical reaction, singlet state reactions;
- picoseconds: 1 ps = 10^{-12} s, e. G. In intra- and short distance intermolecular electrontransfer, energy transfer, primary reactions in natural photosynthesis;
- Femtoseconds: 1 fs = 10^{-15} s, e. G. In molecular vibrational motion, “hot” carriers dynamics, optical (electronic) vibrations.

1.2 Types of Optical Spectroscopy:

Optical spectroscopy further divides itself into the two following parts:

- Atomic absorption spectroscopy
- Atomic emission spectroscopy

2. Molecular Spectroscopy:

According to the language above, molecules, like atoms, fluctuate between lower and higher energy levels, and vice versa. We are aware that the electromagnetic spectrum is a collection of wavelengths that are produced when a substance is exposed to electromagnetic radiation. Certain wavelengths that have higher electronic, vibrational, and rotational energy levels are absorbed by molecules. Thus, a molecule's absorption of a range of wavelengths results in a unique molecular spectrum. The particular area of the electromagnetic spectrum contains a unique chemical spectrum [2].

2.1 Types of Molecular Spectra:

The three types of molecular spectra are:

1. Pure rotational spectra
2. Vibrational rotational spectra
3. Electronic band spectra

2.1.1 Pure Rotational Spectra:

Within the same vibrational level, a molecule changes from one rotational level to another as it receives less energy. In the far-infrared and microwave spectral regions, rotational spectra can be seen. Furthermore, these spectral areas have incredibly low energies. Rotational spectra are therefore referred to as microwave spectra.

2.1.2 Vibrational Rotational Spectra:

When enough energy is absorbed by a molecule, it moves from one vibratory level to another inside the same electronic level. Consequently, both a rotational and a vibrational transition occur in this instance. Vibrational rotational spectra are obtained in this manner.

The near-infrared spectrum is where the vibrational spectra can be seen. The vibrational rotational spectra are referred to as infrared spectra [3,4].

2.1.3 Electronic Band Spectra:

When a molecule moves from one electronic state to another due to the radiation's exciting energy being sufficiently high. Both rotational and vibrational level changes occur during this transition. Additionally, a series of closely spaced lines emerge for every vibrational shift.

These closely spaced lines are called bands because of the associated changes in rotational level. We refer to it as the electronic band spectrum as a result.

2.1.4 Molecular Spectroscopy Stages:

The availability of nuclear degrees of freedom in the target, which will be activated by the projectile and take part in the decay process, is what gives the molecular spectra their certainty. When a molecule (M) and a photon collide, the ultimate outcomes could be:

$M + \hbar\omega$

$\rightarrow M^{n} + ne^{-}$ (Ionization)

$\rightarrow M^{*} + \hbar\omega'$ (resonance fluorescence)

$\rightarrow A^{+} + B$ (neutral dissociation)

$\rightarrow A^{+} + B^{-}$ (ion-pair formation)

3. Introduction:

3.1 History of Spectroscopy:

In order to learn more about the composition and characteristics of matter, spectroscopy is a scientific field that studies the spectra of electromagnetic radiation as a function of its wavelength or frequency as determined using spectrographic equipment and other methods. In astronomy, chemistry, materials science, and physics, spectroscopy—mainly in the electromagnetic spectrum—is an essential exploratory tool that enables the investigation of matter's composition, physical structure, and electronic structure at the atomic, molecular, and macro scales as well as over astronomical distances [5].

In contemporary spectroscopy, light is dispersed using a diffraction grating and then projected onto charge-coupled devices, or CCDs, which resemble digital cameras. Errors in scientific comprehension might result from the frequent interchangeability of scientific phrases and the ongoing revision and reinterpretation of descriptions that are considered scientifically acceptable. Although such mistakes cannot be totally avoided, they can be minimised by increasing our awareness of them, improving our knowledge of the jargon, and applying methodical and meticulous scientific techniques.

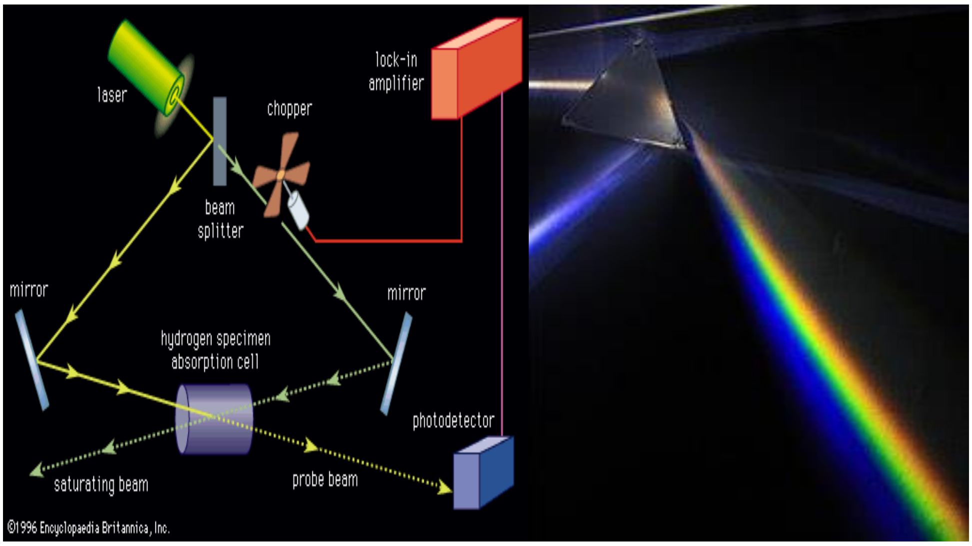

Fig. 1: Spectroscopy

Spectroscopy began with Isaac Newton splitting light with a prism; a crucial moment in the development of ultramodern optics. Accordingly, under James Clerk Maxwell's exploration, the study of visible light — what we call color — wasoriginally expanded to encompass the full electromagnetic diapason. While colour plays a part in spectroscopy, it is n't the same as the colour of substances or objects, [6] which are determined by the immersion and reflection of specific electromagnetic swells.

4. Principle of spectroscopy:

The primary purpose of spectroscopy is to determine and clarify the factors and rudiments of tittles and motes. They're quantified by looking at the radiant energy that the sample or point emits or absorbs. Then, the sample is exposed to an electromagnetic radiation ray, similar as UV or infrared shafts, and the wavelength of the electromagnetic diapason delivered from the external energy source is used to measure the sample's response.

4.1 **What's Spectrometer?**

A spectrometer is a scientific device that's primarily used to measure and separate the spectral factors of electromagnetic radiations according to their physical marvels in order to assay their wavelength. For molecular spectroscopy, the spectrometer is constantly utilised. The radiation source and discovery and analysis outfit make up the maturity of the spectrometer [7].

4.2 What's Spectroscope?

A spectroscope is a device that measures the characteristics of light in a particular region of the electromagnetic diapason. Spectroscope is also known as optic spectroscope, spectrophotometer or spectrograph. In order to measure light wavelengths and intensities, the spectrometer in the spectroscope frequently generates spectral lines.

5. Types of Spectroscopy:

Then, a many important types of spectroscopy with their parcels and operations are explained below.

5.1 IR Spectroscopy:

The electromagnetic diapason that falls inside the infrared region will be the primary focus of infrared spectroscopy. Their primary area of moxie is immersion spectroscopy. The primary purpose of infrared spectroscopy is to determine a material's chemical makeup. IR spectroscopy styles are the primary system used by Fourier transfigure infrared (FTIR) spectrometers. Near-, far-, andmid-infrared are the three primary orders into which the infrared electromagnetic diapason is divided. The 14000 – 4000 cm- 1 near- infrared diapason will be useful for probing undertone or harmonious climate [8]. The 4000- 400 cm- 1mid-infrared diapason will be useful for studying the introductory climate and related rotational- vibrational structure. The 400 – 10 cm- 1mid-infrared diapason will be useful for studying low- energy microwave oven areas that could be employed in rotational spectroscopy.

5.2 Spectroscopy in the UV:

Immersion spectroscopy and reflectance spectroscopy are other names for ultraviolet spectroscopy. conterminous to the infrared region is the ultraviolet region's electromagnetic diapason. The primary operations of UV spectroscopy are medicine identification, bacterial culture, and nucleic acid chastity testing. The gamuts of all independently multiple ionisedrudiments fall below 200 nm in the ultraviolet range. In the region, numerous organic chemicals of metabolic significance have both emigration and immersion gamuts, and all motes produced immersion gamuts.

5.3 Mass Spectroscopy:

The primary use of mass spectroscopy is the disquisition of protein- protein relations. thus, biomolecules or proteins set up in natural samples can be linked by mass spectroscopy. The mass- to- charge rate will be used by the mass spectroscopy sensor to examine the material. Then, mass, haste, and charge are the primary determinants of ion deviation.

5.4 Raman Spectroscopy:

Raman spectroscopy frequently relies on photon immersion. The material will be examined using Raman spectroscopy grounded on how photons scatter at different frequentness. Depending on the oscillation or gyration of the motes, photons may gain or lose energy when they strike tittles or notes. Rayleigh scattering is the medium by which the maturity of incidentphotons are dispersed by the sample without causing any changes in frequence. The monochromic visible ray is generally the source of the Raman gamuts. The radiation is analysed using a phototube- equipped scanning optic monochromic as a sensor [9].

5.5 luminescence Spectroscopy:

One of the most significant forms of electromagnetic spectroscopy is luminescence spectroscopy. They're substantially employed for a sample's luminescence. Luminescence spectroscopy is frequently performed under UV light. The primary use of luminescence spectroscopy is the analysis of organic factors in the disciplines of chemical, natural, and medical exploration. luminescence spectroscopy can be applied at the bitsy position through the use of microfluorimetry. We can identify the element in air, water, or other fluids by employing infinitesimal luminescence Spectroscopy (AFS) ways.

5.6 FTIR Spectroscopy:

Fourier- transfigure infrared spectroscopy is another name for FTIR spectroscopy. An infrared diapason of a solid, liquid, or gas's immersion or emigration is used to gain this fashion. The analysis of natural and nanomaterial's, the dimension of water content in plastics and compositions, chromatography sensors, etc., all make expansive use of FTIR spectroscopy.

5.7 Biomedical spectroscopy:

Medical spectroscopy is a different study content involving spectroscopic technologies for operations in the realm of biomedical wisdom. By detecting the vibrational modes of the constituent motes, vibrational spectroscopy, similar as Raman or infrared spectroscopy, can be used to ascertain a material's chemical composition. glamorous resonance imaging (MRI) is one spectroscopic fashion that's constantly utilised in clinical settings for illness opinion. Chemical imaging using Fourier transfigure infrared (FTIR) spectroscopy relies on the material's composition to give discrepancy [10].

NOCISCAN: The first, substantiation- supported, Saabs platform to influence MR Spectroscopy to noninvasively help croakersdistinguish between painful and no painful discs in the chine.

i. Spectroscopy is generally utilised for assaying the structure of motes and tittles. Spectroscopy will examine the structure and electron configurations of tittles and motes using a broad wavelength.
ii. Spectroscopy can also be used to determine a material's unknown chemical composition. fastening on a many corridor per million of a trace element in a material is made easier by the emigration diapason of spectroscopy.
iii. Astronomers will be suitable to probe distant worlds with the aid of the spectral emigration lines. This will grease a comprehensive analysis of the macrocosm. The Doppler shift of spectral lines will also be used by astronomers to make compliances. A Doppler shift frequently happens when the radiation source, similar as a star or nebula, shifts in relation to the bystander.

6. Examples of Spectroscopy Applications:

- Monitoring diffused oxygen content in freshwater and aquatic ecosystems.
- Determining the atomic structure of a sample.
- Characterization of proteins
- Respiratory gas analysis in hospitals
- Cure monitoring of composites using optical fibers.
- Estimating weathered wood exposure times using near infrared spectroscopy.

- Measurement of different compounds in food samples by absorption spectroscopy both in visible and infrared spectrum.
- Measurement of toxic compounds in blood samples
- Non-destructive elemental analysis by X-ray fluorescence.
- Electronic structure research with various spectroscopes.
- Determining the metabolic structure of a muscle
- Monitoring dissolved oxygen content in freshwater and marine ecosystems
- Altering the structure of drugs to improve effectiveness
- Respiratory gas analysis in hospitals
- Process monitoring in Industrial process control [10,11]

7. Classification of Spectroscopy:

Spectroscopy is such a large field that many sub-disciplines exist, each with multiple applications of distinct spectroscopic techniques. The various implementations and methodologies can be categorized in several ways

8. Type of radioactive energy:

The type of radiative energy used in the interaction distinguishes the various types of spectroscopies. In many applications, the spectrum is calculated by detecting variations in the intensity or frequency of this energy. The types of radiative energy investigated include:

- The first source of energy for spectroscopy was electromagnetic radiation. Techniques that use electromagnetic radiation are often classed by wavelength region of the spectrum and include microwave, terahertz, infrared, near-infrared, ultraviolet-visible, x-ray, and gamma spectroscopy.
- Due to their de Broglie waves, particles can emit radiation. Both electron and neutron spectroscopy are widely employed. A particle's kinetic energy determines its wavelength.
- Acoustic spectroscopy uses radiated pressure waves.
- Dynamic mechanical analysis can add energy to solid materials, analogous to acoustic waves.

8.1 Nature of the interaction:

The types of spectroscopy also can be distinguished by the nature of the interaction between the energy and the material. These interactions include:

- In absorption spectroscopy, energy from a radiative source is absorbed by a substance. Absorption is frequently determined by measuring the fraction of energy transmitted through the substance; absorption reduces the transmitted component.
- Emission spectroscopy detects the discharge of radiative energy from a substance. A material's blackbody spectrum is a spontaneous emission spectrum that is temperature dependent.

- Elastic scattering and reflection spectroscopy measure a material's ability to reflect or scatter incident radiation. Crystallography examines the arrangement of atoms in proteins and solid crystals by scattering high-energy radiation such as x-rays and electrons [12].

8.2 Molecules:

The combining of atoms into molecules creates unique sorts of energy states and, as a result, unique transition spectra. Molecular spectra can be obtained as a result of electron spin and electronic states. Rotations are collective motions of atomic nuclei that often produce spectra in the microwave and millimetre wave spectrum ranges. The terms rotational spectroscopy and microwave spectroscopy are synonymous. Vibrations are the relative motions of atomic nuclei that are examined using infrared and Raman spectroscopy.

8.3 Crystals and extended materials:

The combining of atoms or molecules into crystals or other extended forms results in the formation of new energy states. These states are numerous, resulting in a high density of states. This high density frequently renders the spectra weaker and less distinct, i.e. broader. For example, blackbody radiation results from the thermal movements of atoms and molecules within a substance [13]. The regular lattice structure of crystals scatters x-rays, electrons, and neutrons, allowing for crystallographic investigations.

8.4 Other types:

Other types of spectroscopy are distinguished by specific applications or implementations:

- Raman spectroscopy
- Saturated spectroscopy
- Scanning tunneling spectroscopy
- Spectrophotometry
- Spin noise spectroscopy traces spontaneous fluctuations of electronic and nuclear spins.[28]
- Time-resolved spectroscopy measures the decay rates of excited states using various spectroscopic methods.
- Time-stretch spectroscopy [14,15]
- Transient grating spectroscopy measures quasiparticle propagation. It can track changes in metallic materials as they are irradiated.
- Ultraviolet photoelectron spectroscopy
- Ultraviolet–visible spectroscopy
- Video spectroscopy
- X-ray photoelectron spectroscopy etc,.

Conclusion:

Spectroscopy is a flexible analytical technique that can be applied to investigate the temperature, radial velocity, and composition of different sources. Compounds across a range of disciplines, including as chemistry, biology, medicine, agriculture, engineering, and, physics can also be analyzed with it.

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APPLICATION OF RARE EARTH IONS DOPED NANOMATERIAL

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Abstract:

This study present rare-earth doping can alter the crystallographic phase, morphology, and size, leading to tunable optical responses of doped nanomaterials. Moreover, rare-earth doping can control the ultimate optoelectronic, sensor, medical and catalytic performance of doped nanomaterials in a tunable and scalable manner, enabling significant improvements in energy harvesting and conversion. In this review, we highlight recent advances in rare-earth doping in inorganic nanomaterials and the associated applications in many fields. It highlights the techniques used for the characterization of NPs and discusses their physical and chemical properties. Due to their unique properties, NMs have several applications and have become part of different field.

1. Introduction:

Nanoparticles have attracted great interest in recent years because of theirunique chemical, physical, optical, electrical and transport properties whichare different from those of either the bulk materials or single atoms. Due tothe vast surface area, all nanostructured materials posses a huge surface energy and thus, are thermodynamically unstable or metastable. One of the great challenges in fabrication and processing of nanomaterials is to overcome the surface energy and to prevent the nanomaterials from growth in size driven by the reduction of overall surface energy. Due to high surface energy of the nanoparticles, they are extremely reactive and most systems without protection or passivation of their surfaces undergo aggregation. Organic stabilizers are usually used to prevent nanoparticles from aggregation by capping their surfaces [1]. The potential applications of semiconductors in optical switching, single charge memories, single electron transistors, etc are most investigated.

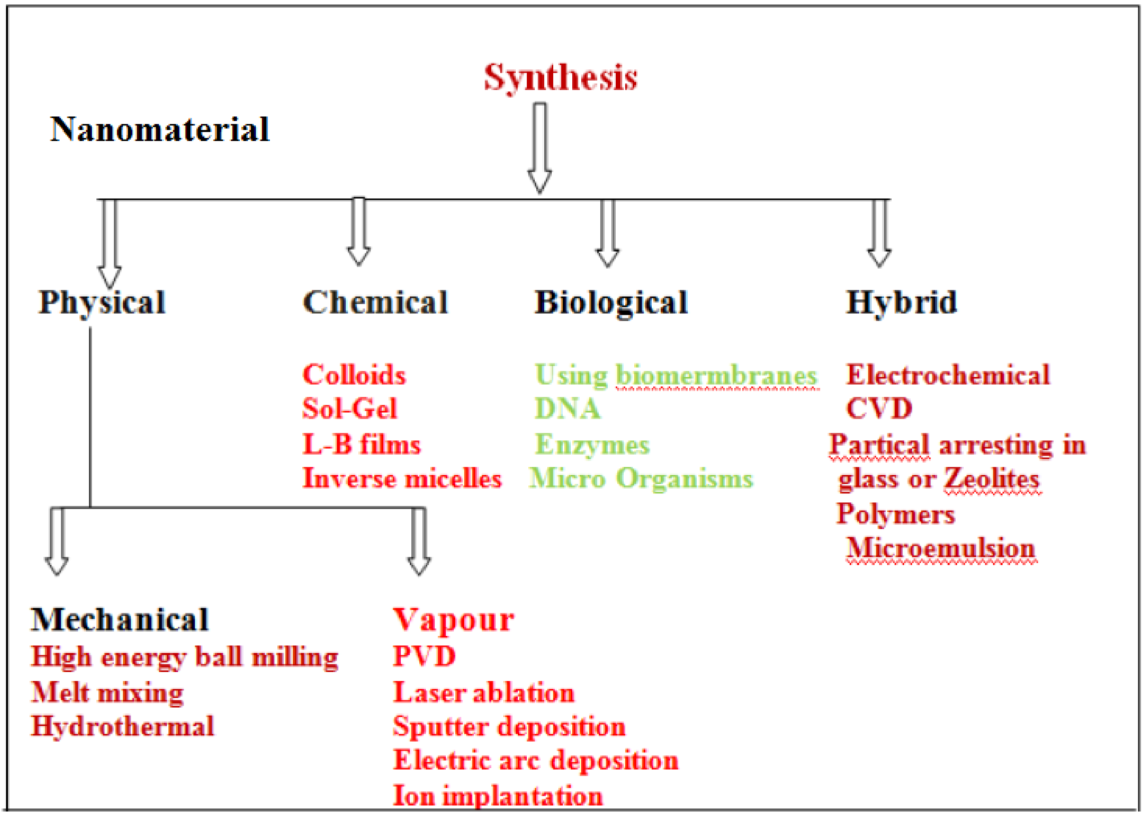

Fig. 1: Different Type of Synthesis

Recent technological developments in Nanoscience lead to the synthesis of nanostructured materials with various structures and morphologies have received much attention due to their novel applications. Most of the researchers focused on the synthesis of low dimensional nanomaterials for the functional nano devices including electrically driven transistors, lasers, light emitting diodes [2,3]

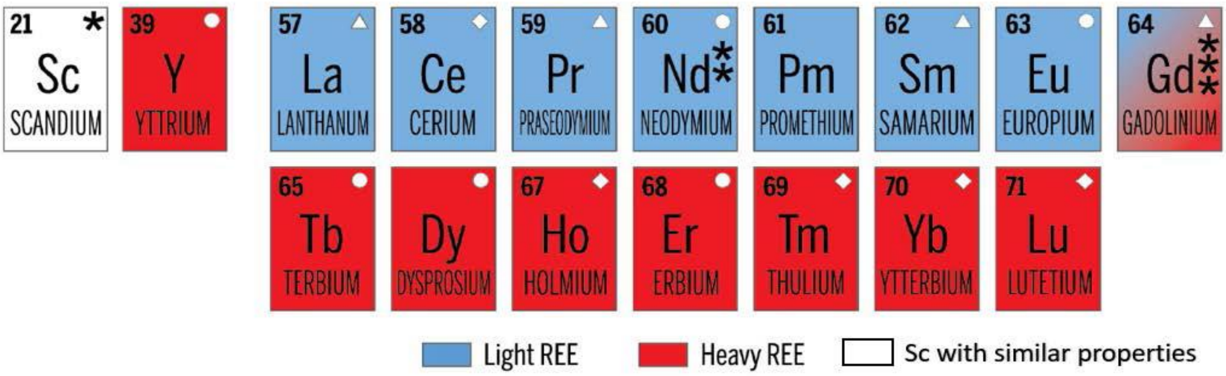

Fig. 2: List of 17 and classification of REE, modified after [4]

REE group of elements consists of the 15 lanthanide elements (La to Lu) plus Y and Sc. Based on atomic numbers, they are divided into two groups. The lower atomic weight elements from La to Sm, the most abundant ones, with atomic numbers 57-62 are referred to as light REE (LREE); while Eu to Lu, and the least common and the most valuable with atomic numbers 63-71, are known as heavy REE (HREE). Despite their low atomic weights, Y and Sc are included in the HREE subgroup because of their co-occurrence, similar ionic radii, and closer behavioural properties to HREE than LREE (Fig. 1). Because of their unique physical, chemical, electronic, optical, mechanical, catalytic, and magnetic properties, they are being extensively used to make different high-technology devices such as computers, televisions smart phones, catalysts for fuel cells, light emitting diodes, hard drives for computers, corrosion inhibitors, and magnets for wind turbines, and other power generating systems. Table 1 presents REE concentrations in different earth materials

Energy Level

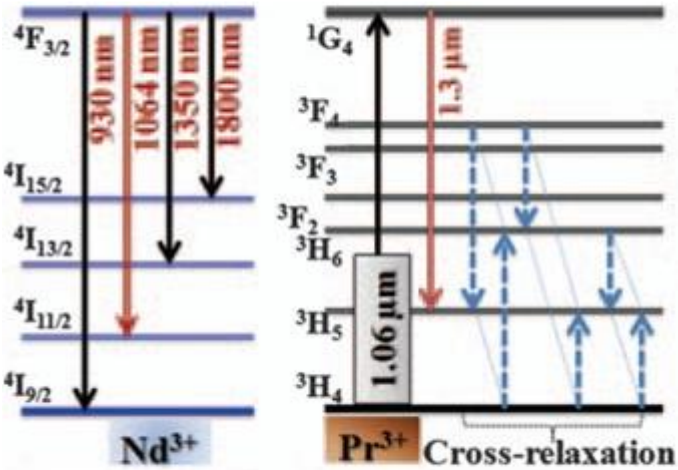

Fig. 3: Energy levels some of the transitions in Nd^{3+} Pr^{3+}[4]

Pr^{3+} has the ground state $^3H_4$ and the main excited states $^3P_0$, $^1D_2$, and $^1G_4$. Pr^{3+} typically shows blue emission at ∼483 nm ($^3P_0 \rightarrow$ $^3H_4$ transition) orangeemission at ∼610 nm (P0 → 3H6 and $^1D_2$ → $^3H_4$ transitions) and red emission at ∼643 nm ($^3P_0 \rightarrow$ $^3H_4$ transition). Although the $^3P_0 \rightarrow$ $^3H_5$ transition and $^3P_0$ → $^3F_3$,4transitions can also be detected with emission at ∼540 and∼725 nm, respectively, their emission intensities are usually relatively weak.

Nd^3 Upon energy absorption, Nd^{3+} ions in the ground state ($^4I_{9/2}$) can be excited to the $^2P_{1/2}$ $^4G_{7/2}$ states. Nd^{3+} typically emits at approximately 413 nm ($^2D_{5/2}$, $^2P_{1/2}$ → $^4I_{9/2}$ transitions), 523 nm ($^4G_{7/2}$, $^2K_{13/2}$, $^4G_{9/2}$ → $^4I_{9/2}$ transitions), 588 nm ($^2G_{7/2}$, $^2G_{5/2}$, →$^4I_{9/2}$ transitions), 640 nm ($^2H_{11/2}$ →$^4I_{9/2}$ transition), 661 nm ($^4F_{9/2}$ → ^{4}I9/2 transition), 869−900 nm (4F3/2 → 4I9/2 transition), 1060 nm ($^4F_{9/2}$ → $^4I_{11/2}$ transition), and 1330 nm ($^4F_{3/2}$ → $^4I_{13/2}$ transition). Nd3+ is usually used for its efficient NIR emission at ∼1060 nm when excited at 740 or 800 nm. Since both the excitation and emission are within the optical window (700−1100 nm), Nd3+-doped nanoparticles are ideal NIR nanophosphors for biological imaging [5,3].

2.0 Area Applications

2.1.1. Electronics

Television screens, computers, cell phones, silicon chips, monitor displays, long-life rechargeable batteries, cameralenses, light emitting diodes (LEDs), compact fluorescent lamps

(CFLs), baggage scanners, marine propulsion systems[7,8].

2.1.2. Laser technology

Neodymium, samarium, dysprosium, holmium, erbium, thulium and ytterbium have applications in lasers in both commercial and military uses, optical cables, medical and dental lasers and in solid-state lasers where Nd-doped yttrium aluminium garnet (Nd:YAG) is in use laser.

2.1.3. Batteries

A major use of lanthanum is in nickel metal hydride batteries in hybrid vehicles where approximately 8–10 kg of the metal is used. While Pm has little use due to its radioactivity, it is used in nuclear batteries and has potential to be used as a power source in space vehicles and satellites.

2.1.4. Medical science

The properties of many rare earths lend themselves to a variety of medical uses. Yttrium radioisotopes have been used in the treatment of cancers such as lymphoma, leukaemia, ovarian, pancreatic and bone cancers. A radioactive isotope of Sm can be used to treat severe pain associated with bone cancers. Europium is used in screening for genetic diseases, such as Down's Syndrome. Probably most importantly, gadolinium, due to its strongly paramagnetic properties (seven unpaired electrons), is extensively used in MRI imaging. Portable X-ray machines, X-ray tubes, magnetic resonance imagery (MRI) contrast agents, nuclear medicine imaging, cancer treatment applications, and for genetic screening tests, medical and dental lasers.[9]

2.1.5. Manufacturing

High strength magnets, metal alloys, stress gauges, ceramic pigments, colorants in glassware, chemical oxidizing agent, polishing powders, plastics creation, as additives for strengthening other metals, automotive catalytic converters.[10]

2.1.6. Catalysts:

Ln^{3+} ions are strong Lewis acids and have found many applications in organic synthesis particularly where Lewis acids are used as catalysts. Neodymium (as neodymium carboxylates) has recently found application with aluminium alkyls to catalyse the synthesis of artificial rubber.47 A wide variety of compositions has been used for these pseudo-Ziegler catalyst mixtures, with other added components.[11]

2.1.7. Technology

Lasers, optical glass, fiber optics, masers, radar detection devices, nuclear fuel rods, mercury-vapor lamps, highly reflective glass, computer memory, nuclear batteries, high temperature superconductors

2.1.8. Luminescent properties

Yttrium has its primary application in TV screens where Y2O3 is combined with europium and this combination is also used in LEDs. Cerium and terbium are also used in LED television screens as phosphor components. The green terbium phosphor is used in combination with blue and red europium phosphors, creating the technology used in trichromatic lighting. Erbium is also combined with europium isotopes to provide specific fluorescent properties. Neodymium also has application in fluorescent technology.[12]

2.1.9. Renewable Energy

Hybrid automobiles, wind turbines, next generation rechargeable batteries, biofuel catalysts.

2.2.1. Alloys

As for scandium (aforementioned), rare earths have found application in alloying with other metals, where small amounts add strength to many metals. Thus, Y is used in Al and Mg alloys, Ce in aluminium and Fe alloys, and La and Yb in steel alloys. Pr is used as an alloying agent for metals in aircraft engines, Gd is present in metal alloys to resist high temperature and Tb in several alloys, such as the magnetostrictive alloy Terfenol-d ($Tb_xDy_{1-x}Fe_2$, x ∼0.3).
such as transition metal salts. While lutetium is very expensive and therefore has few commercial uses, it has found application in petroleum cracking [13,14].

2.2.2. Ceramics

A very large amount of cerium is used as a ceramic component in the catalytic converter of automobiles, and is the largest use of rare earths in the US. Yttria-stabilised zirconia is a thermally stable refractory, a solid electrolyte in fuel cells and is used for oxygen sensing. The introduction of yttria stabilises the high temperature cubic form of zirconia.

Conclusion:

Rare earth-doped inorganic nanomaterials has grown faster than ever. These newly developed nanomaterials have created a toolbox that can be used to realize multidisciplinary applications, including bio imaging, therapy, drug delivery, neuroscience, sensing and detection, catalysis, light emission, information storage and encryption, nanolasing, and optical communication. In this chapter, we have summarized recent advances in rare-earth-doped inorganic nanomaterials in the context of material designs and new applications. Another trend for future investigations is to open up new areas for rare-earth-doped nanomaterials.

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ON SOME GLOBAL TREND OF ATMOSPHERIC POLLUTANTS AND THEIR FUTURE CONSEQUENCES

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Abstract:

Climate extremities are very impactful to the civilization. In recent days, across the world, atmospheric pollution and climate change have been a topic of significant concern. Air pollution causes almost 75% of the disease burden from the total of all pollution. PM2.5 is considered to be the most consistent predictor of health effects from studies of long-term exposure to air pollution. Air quality is generally measured by PM2.5 available in the atmosphere. Causing an estimated 11% deaths worldwide, air pollution is the greatest environmental threat to human civilization. World-wide study of population weighted average PM2.5 concentration reveals that central and south Asia is the mostly affected region for the last five years (2019-2023).

Introduction:

In the last few decades, across the world, atmospheric pollution and climate change have been a topic of significant concern. Climate plays a considerable role in spatio-temporal distribution of air pollutants. Atmospheric warming and ozone depletion in stratosphere are vital factors of climate change. Climate extremities like droughts, floods caused by heavy rainfall, extreme temperature are very impactful to the civilization. The intensified heat waves caused due to climate change have elevated the temperature levels causing thermal discomfort and several health hazards to urban residents [1]. Air pollution causes almost 3 quarter of the disease burden from the total of all pollution. Air quality is generally measured by a small subset of particulate matters (PMs) available in the atmosphere. Some of these aerodynamic particles are having diameters less than or equal to 2.5 micrometres (PM2.5) [2]. As per Health Effects Institute reports (2018) PM2.5 and tropospheric ozone (O_3) are two important air quality indicators. The dispersal of these air pollutants may cause respiratory disorders such as emphysema, asthma, allergy problems and chronic bronchitis [3]. PM2.5 is considered to be the most consistent and robust predictor of health effects from studies of long-term exposure to air pollution. Exposure to atmospheric pollutants causing tremendous health hazards is the biggest threat to civilization [4, 5]. Long-term PM2.5 exposure is a cause of all-cause mortality, cardiovascular mortality, and cardiovascular morbidity, a likely cause of respiratory effects, and a suggestive cause of reproductive and developmental outcomes. Short-term PM2.5 exposure is a cause of mortality and cardiovascular effects, and a likely cause of respiratory effects [7, 8]. Air pollutant emissions are predicted to grow extensively over the coming years. Key sources contributing to the present-day disease burden from ambient PM2.5 and O_3 exposure are the emissions from the residential combustion of solid fuels, land transport, and coal combustion in power plants. The objective of this chapter is to quantify the contribution of different emission sources to ambient PM2.5 concentrations and the related health hazards across the world.

Air pollutant is a complex mixture of many particles and gases. Air quality is measured by small subset of these particles and gases. Air pollution and climate change are major threats to rapidly growing cities in present times. The developing nations like India, which are switching from predominantly rural country to increasingly urban, have to face critical challenges in terms of climate action and sustainable development [9, 10]. Air pollution has emerged as one of India's serious environmental problems in recent years. In many locations, concentrations of particulate matter considerably exceed recommended national and international standards resulting in severe implications for population health. In 2019 alone India experienced an estimated 1.2 million air pollution related premature deaths. O_3 has also been reported to be associated with increased respiratory mortality. There is some evidence to indicate that high levels of vehicle emissions in cities and an urban lifestyle are correlated with the rising trend in allergic respiratory diseases [11-16].

Air pollution seems to be the biggest environmental health risk factor in the World. In India, air pollution exposure is the second leading health risk factor, contributing about 25% of the global health threat leading to the exposure of air pollution [6]. New diseases and conditions are continually being associated with exposure to air pollution. Figure 1 shows the possible size-dependent deposition of particulate matter [17].

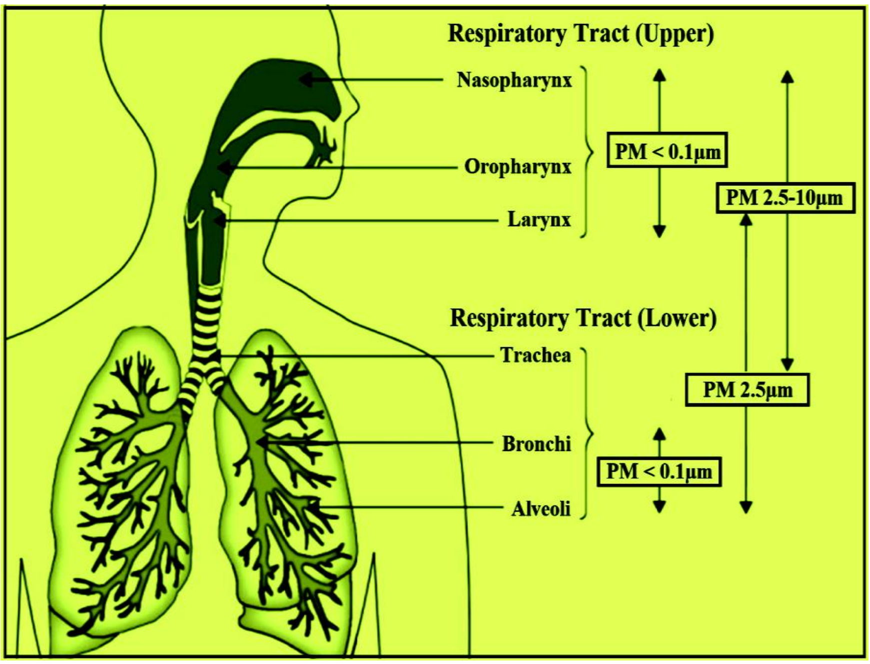

Fig. 1: Size-dependent deposition of particulate matter

Attributable disease burden is estimated to increase in the future due to population ageing and growth. India contributes approximately 25–30% of the global disease burden from air pollution. Despite this importance, research on air pollution in India is limited and little is known about the sources and processes that contribute to the countrywide air pollution. Understanding the causes and processes behind the health impacts of air pollution exposure across a range of scales is critical to reduce the substantial health hazards in India.

Air quality is generally measured by a small subset of particulate matters (PMs), some of these are having diameters $\leq$ 2.5μm (PM2.5), available in the atmosphere [18]. Causing an estimated 11% deaths worldwide, air pollution is the greatest environmental threat to human civilization. According to the World Health Organization (WHO), air pollution is responsible for an estimated 7 million premature deaths worldwide every year [19]. The world-wide study of population weighted average PM2.5 concentration reveals that central and south Asia is the mostly affected region as major cities in the countries like Bangladesh, India and Pakistan is maintaining a PM2.5 concentration of over 50 $\mu g/m^3$ *i.e.*, exceeding 10 times the target air quality level prescribed by WHO, consistently for the last five years (2019-2023).

In developing countries, the problem is more serious due to overpopulation and uncontrolled urbanization along with the development of industrialization [20]. Air pollution and climate change are closely related. Climate is the other side of the same coin that reduces the quality of our Earth [21]. Pollutants such as black carbon, methane, tropospheric ozone, and aerosols affect the amount of incoming sunlight. As a result, the temperature of the Earth is increasing, resulting in the melting of ice, icebergs, and glaciers.

Major Environmental Air Pollutants and their Health Effects

Air Pollutants have pronounced consequences on human health ranging from causing asthma, respiratory diseases, infections and risk factors for cancer. The WHO reports on 6 major air pollutants, namely particle pollution, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. Air pollution can have a disastrous effect on all components of the environment, including groundwater, soil, and air. Acid rain, global warming, the greenhouse effect, and climate changes have an important ecological impact on air pollution [22].

Carbon Monoxide (CO): When carbon monoxide (CO) is inhaled excessively, it could lead to death. This is because, CO forms strong bond irreversibly with the haemoglobin in the body which is responsible for oxygen transportation. The resulting effect is the formation of carbonxyl haemoglobin which is a stationary biochemical substance and leading to impairment in transportation of oxygen in the body and depriving vital organs of oxygen [23]. CO affects the greenhouses gases that are tightly connected to global warming and climate. This should lead to an increase in soil and water temperatures, and extreme weather conditions or storms may occur [24].

Oxides of nitrogen (NO_X): Oxides of nitrogen comprises group of gases due to different combination of nitrogen and oxygen. Two most common oxides of nitrogen of environmental importance are nitrogen dioxide (NO_2) and nitric oxide. It has been documented that nitrogen oxides are toxic to animals and human being due to its ability to form nitric acid. In the atmosphere, it is involved in acid rain formation together with other gases such as SO_2. In human, it forms nitric acid with water in lung, mucus membrane and skin. Low level exposure to NO_2can lead to increased bronchial reactivity, increase in response to allergen in asthma patients and aggravation of chronic respiratory diseases [25]. High levels of NO_2 are deleterious to crops and vegetation, as they have been observed to reduce crop yield and plant growth efficiency. Moreover, NO_2 can reduce visibility and discolor fabrics [26].

Particulate Matter (PM): Based on the size of the particles, PM can be divided majorly into coarse particles (PM 2), fine particles (PM 2.5) and ultrafine particles (PM 0.1). PM10 are aerodynamic inhalable particles between 10 μm and 2.5 μm [25]. Moreover, respiratory diseases and affection of the immune system are registered as long-term chronic effects [27]. It is worth noting that people with asthma, pneumonia, diabetes, and respiratory and cardiovascular diseases are especially susceptible and vulnerable to the effects of PM. PM2.5, followed by PM10, are strongly associated with diverse respiratory system diseases [28], as their size permits them to pierce interior spaces [29]. The particles produce toxic effects according to their chemical and physical properties. The components of PM10 and PM2.5 can be organic (polycyclic aromatic hydrocarbons, dioxins, benzene, 1-3 butadiene) or inorganic (carbon, chlorides, nitrates, sulfates, metals) in nature [30].

Volatile organic compounds: Volatile organic compounds (VOCs) are organic compounds with one or more carbon atom with very high vapour and pressure which make them readily evaporate into atmosphere at room temperature [25]. VOCs, such as toluene, benzene, ethylbenzene, and xylene, have been found to be associated with cancer in humans [31].

Ground level ozone: In the atmosphere, ozone (O_3) can be found in the stratosphere which helps in absorption of UV rays and this is termed good O_3. However, O_3 can also be found in the troposphere as a secondary pollutant due to NOx and VOCs. Tropospheric O_3 is termed bad O_3 because of its health consequence. Ground level O_3 is responsible for formation of smog which is very difficult to control and may have catastrophic environmental impact on human [29]. Halation of O_3 could lead to breathing associated problems, cough, inflammation of the respiratory airways, aggravation of lung diseases such as asthma, chronic bronchitis and progression to lung damage [25].

Table 1 describes the sources, effects and atmospheric lifetimes of different air pollutants [32].

Table 1: Air pollutants- their sources, effects and atmospheric lifetimes

Pollutant	Sources	Effects on Human Health	Atmospheric lifetime
NO_2	Combustion: transport, industry, and domestic and commercial heating	Premature mortality; ecosystems: eutrophication; climate change due to ozone formation	<1 day
NH_3	Agriculture: livestock waste and fertilised cropland	As a component of PM leading to premature mortality; ecosystems: eutrophication; climate change through PM	A few hours
VOCs	Volatile organic fuels, solvents, industrial and domestic products, and vegetation	As components of PM leading to premature mortality; photochemical production of O_3 in the atmosphere which damages human health and ecosystems, and reduces crop yields	Hours to days for non-methane organic compounds (CH_4 lifetime ~10 years)
PM	Primary PM emissions from combustion, vehicles, industry, construction. Secondary PM from atmospheric processing of primary gaseous emissions (VOCs, NH_3, NO_x, SO_2)	Premature mortality; climate: some PM cools the climate by increasing the Earth's albedo, eg sulphate, while other PM, eg black carbon, likely warms the climate	A few days
O_3	Formed by photochemical processes in the atmosphere from NO_x and VOC emissions	Premature mortality; ecosystems: reducing plant biodiversity and the productivity of crops; enhancing climate change	Several weeks in the free troposphere

Figure 2 shows the Indian burden of disease from exposure to ambient PM2.5 in 2016.

Within India in 2016, the densely populated state of Uttar Pradesh in the central IGP dominates the contribution (21%) to the national burden of disease from ambient PM2.5 exposure, ahead of West Bengal, Maharashtra, and Bihar all contributing 9% each. Regarding the mortality rate per 100,000 population, states throughout the IGP have massive burdens, especially Punjab (105), Haryana (103), Uttar Pradesh (99), and West Bengal (95). The disease burden in Delhi from exposure to ambient PM2.5 is 11,517 premature mortalities per year with a mortality rate of 57 [33].

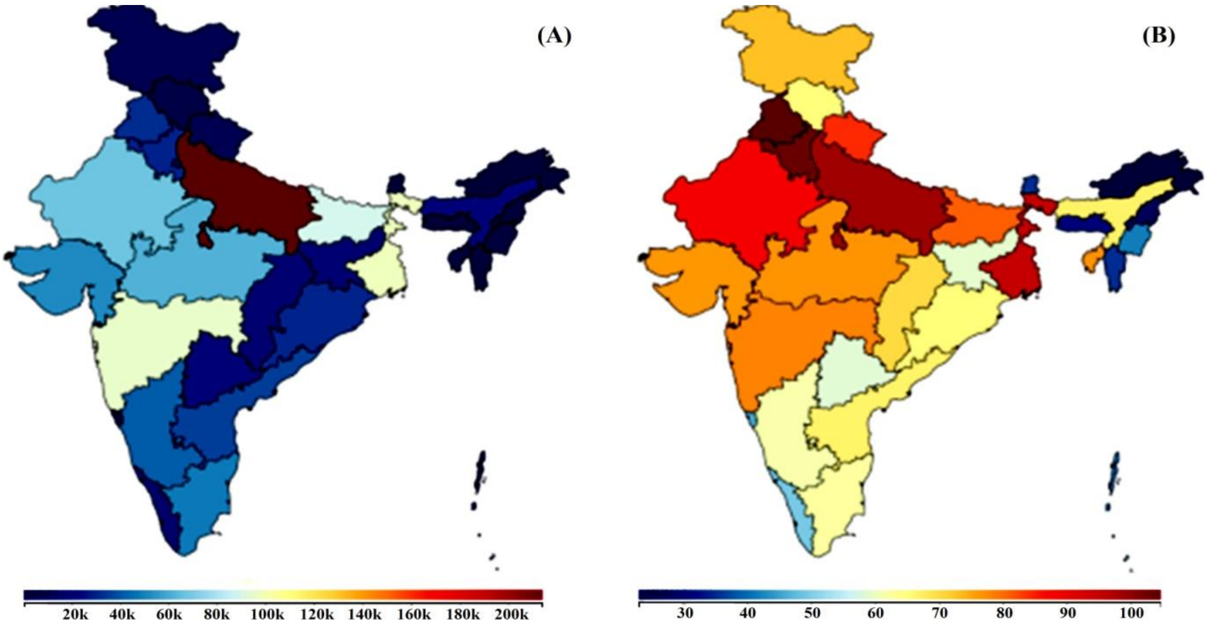

Fig. 2: The Indian burden of disease from ambient PM2.5 exposure in 2016. (a) Number of premature mortalities per state. (b) Mortality rate per 100,000 population per state [adapted from 33]

Figure 3 shows the Indian burden of disease from exposure to ambient O_3 in 2016.

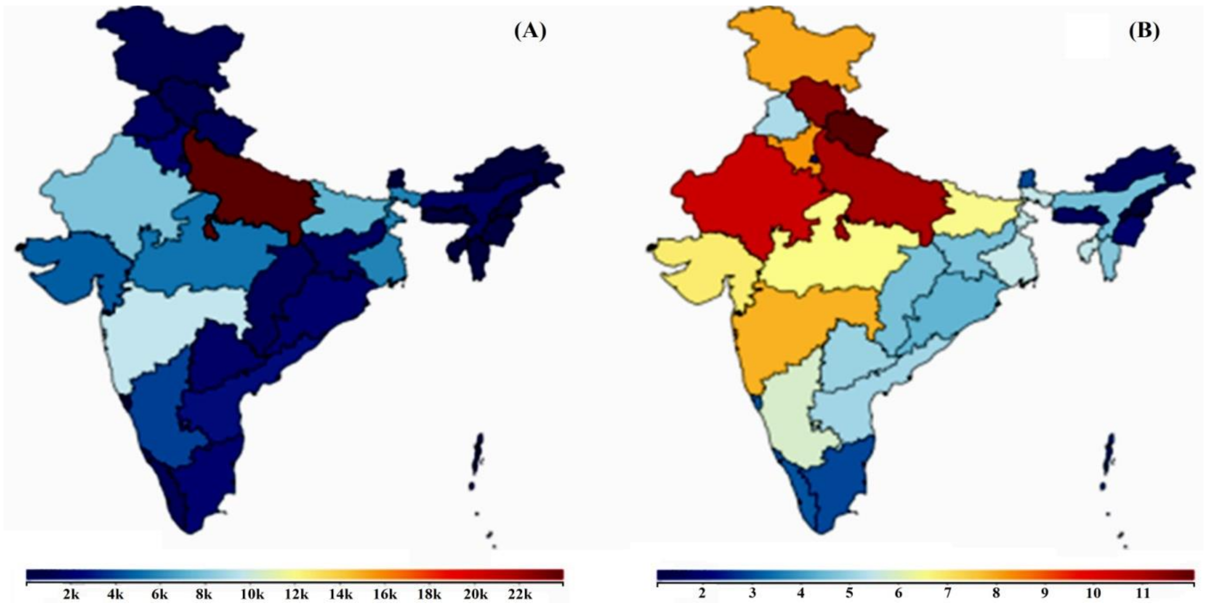

Fig. 3: The Indian burden of disease from ambient O_3 exposure in 2016. (a) Number of premature mortalities per state. (b) Mortality rate per 100,000 population per state [adapted from 33]

Uttar Pradesh dominates the contribution to ambient O_3 with 27% of the national burden. States in the western IGP have the highest mortality rate per 100,000 population with Uttarakhand (12) and Himachal Pradesh (11), followed by Uttar Pradesh (11) and Rajasthan (10). Delhi has a mortality rate of 2 per 100,000 [33].

Global Trend of PM2.5 Exposure

Worldwide PM 2.5 average data during 2018-2023 at region level is shown in Table 2.

Table 2: Worldwide PM 2.5 average data (in µg/m³) during 2019-2023 at region level

Regions	2019	2020	2021	2022	2023
Africa	23.30	20.37	27.28	32.59	24.43
East Asia	28.33	22.69	20.43	18.69	19.40
Europe	14.40	14.17	13.87	13.24	11.76
Latin America & Caribbean	14.89	12.75	11.81	10.34	11.37
Middle East	28.58	29.20	33.07	39.86	29.82
Northern America	8.35	8.45	9.40	8.15	9.70
Oceania	7.75	7.30	6.25	6.25	4.40
South Asia	45.80	39.60	44.79	38.85	41.79
South East Asia	26.81	22.59	21.69	20.20	24.44

This study for PM2.5 data relies on ground-level air quality monitoring stations, 39% of which are under government operation, while the remaining are managed by non-profit organizations/individuals employing low-cost sensors. All these data from low-cost air quality sensors gauge airborne PM2.5 levels through laser scattering technology. The global weighed average is obtained as:

$$\text{Population weighted average PM2.5 concentration} = \frac{\Sigma \text{ city mean PM2.5 } (\mu g/m^3) \times \text{ city population}}{\text{Total regional population covered by available city data}}$$

According to the 2023 world air quality report, 91% of globally reporting cities have failed to achieve the WHO annual PM2.5 guideline (Figure 4). This is a big alert for the whole human civilization.

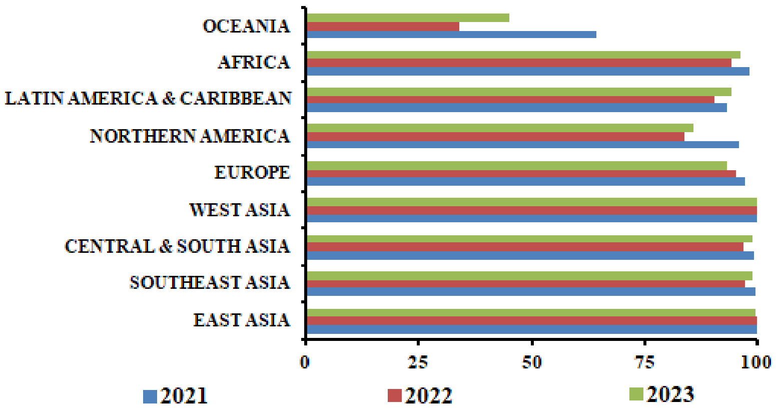

Fig. 4: Percentage of worldwide cities which have failed to achieve WHO annual PM2.5 guideline

The current study is aimed to quantify the PM2.5 exposure across different cities worldwide (Figure 5) and the suggestive measures on the effects of future air pollution control pathways.

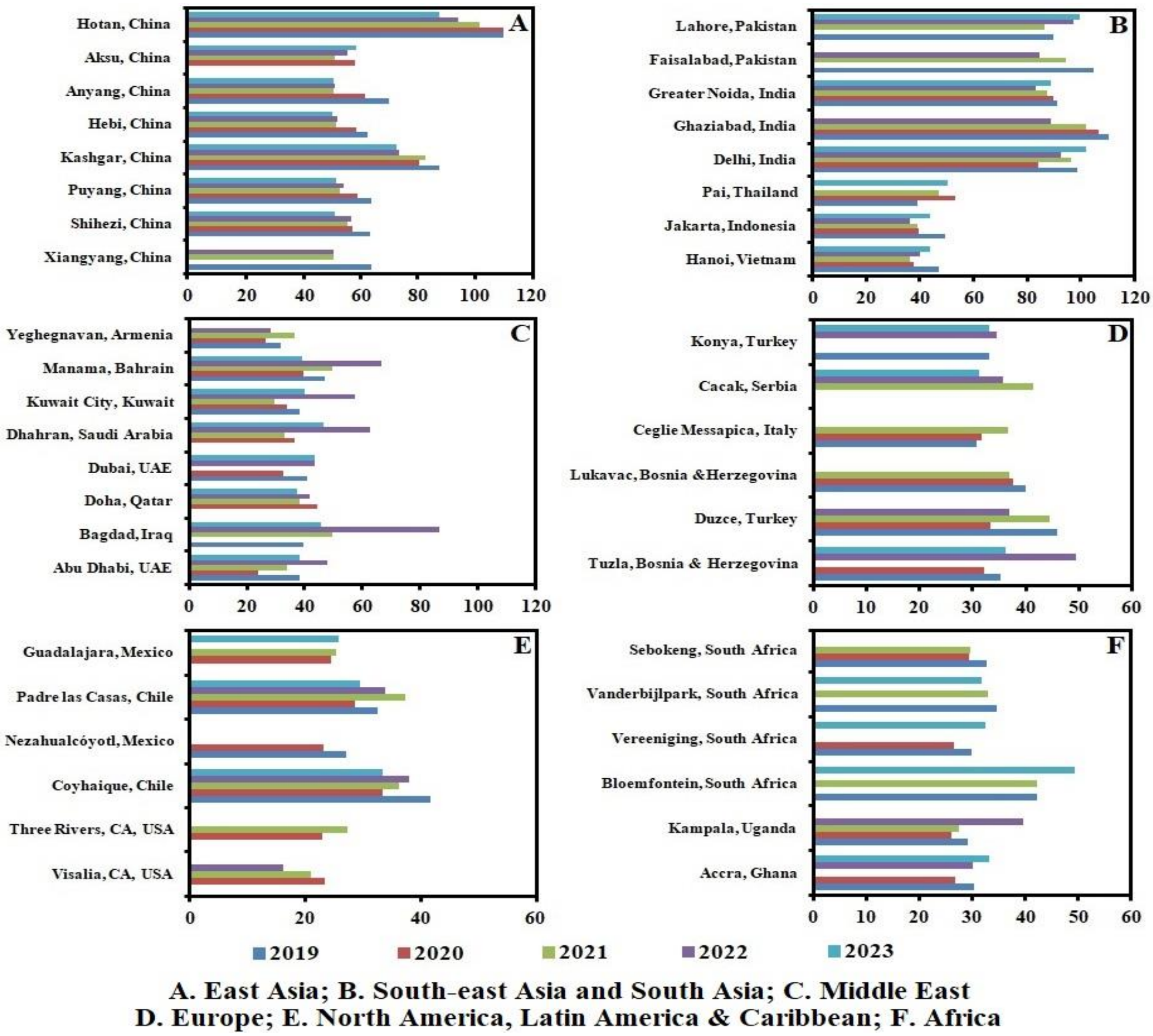

Fig. 5: PM2.5 exposure (in μg/m^3) across regional cities having potential threats worldwide

Discussions:

The future objectives would be on the investigation for the contributions of different emission sources to ambient PM 2.5 concentrations and the related disease burden across different target cities. This can be achieved by estimating the impact from different future air pollution control pathways on ambient PM 2.5 concentrations and human health; identifying critical contributing emission sources and the impacts of future policy scenarios to quantify different atmospheric pollutant induced climatic hazards. A possible air pollution and climate change mitigation pathways is given in Table 3.

Table 3: Air Pollution and Climate Change Mitigation Pathways

Sector	Power	Transport	Residential Buildings	Industry
Technology	Renewable deployment and air pollution control measures	Road transport electrification and vehicle emission standards	Enhanced use of clean fuels (LPG, PNG) for cooking	Increased energy efficiency, electricity from renewable, and air pollution control measures
Benefits	Reduced SO_2, NO_x, PM, and CO_2 emissions	Reduced NO_x, PM, and CO_2 emissions	Reduction of indoor air pollution; $PM_{2.5}$, including BC emissions	Reduced SO_2, NO_x, PM, and CO_2 emissions

Conclusions:

To achieve controlled ambient PM2.5 concentrations, the monitoring of air pollution and addressing climate change as well is very much crucial. Government schemes, like adoption of renewable, clean energy in personal and commercial transportation systems, must be undertaken worldwide for the allocation of resources to fund renewable energy initiatives. There may be initiatives such as adoption of conscientious forest management strategies to mitigate the wildfire risks; prohibition of practices for agricultural and biomass burning; promotion of eco-friendly alternatives to wood-burning ovens; control of individual waste by upcycling, recycling, and reusing existing items etc.

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SOME STUDIES ON EXTREME WEATHER EVENTS IN TWO NORTHERN INDIAN STATES HIMACHAL PRADESH AND UTTARAKHAND

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Abstract:

Investigation of extreme weather events (EWEs) is highly useful to establish their occurrence and associated climatological impacts. Various EWEs, such as prolonged heatwaves, intense floods and droughts, lightning events and strong thunders can generate damaging impacts on the social and economical lives and livelihoods of the nation. EWEs can be classified based on thresholds that either indicates the probabilities of occurrence, or the point where they can cause potential impacts. India is one of the countries that are well critically influenced from the impact of this type of climatic change, EWEs and the subsequent impacts affecting water resources, agriculture, ecosystems, economic development and health. There is no single proper attribution approach to quantify the variations in the likelihood of the EWEs. This study aims to quantify the changes in the possible risks of EWEs under different climatic conditions in one of the hotspots of EWEs in northern Indian state Himachal Pradesh. Rigorous analysis have been carried out, to study the long term trends of EWEs like rainfall, lightning, thunderstorm and the other associated hazards in 12 different districts of Himachal Pradesh, extensively. The present study will focus on the district wise occurrence statistics of the EWEs for the past three decades. Wind anomaly, velocity potential, mean sea level pressure anomaly, outgoing longwave radiation and sea surface temperature anomaly of the selected states are being considered to find the related meteorological association of the said EWEs. This will probably be helpful to find a possible statistical trend between the experienced EWEs and the associated change in the climate.

Keywords: Extreme Events, Lightning, Thunderstorm, Climatological Impact

Introduction:

Extreme weather events (EWEs) and associated climatic impact are of great apprehension for the scientists, technologists as well as the government and the policy makers; as these create direct consequences in our daily life [1]. In case of unprecedented events that cause the most severe impacts, leading to national or global concerns, both the governments and policymakers are found to be interested in search for a possible link between the experienced EWEs and the associated change in the climate [2]. By definition, EWEs are rare incidents and so observations, depending on the length of the time series and regardless of the actual reason, cannot provide an adequate sample size to detect changes in the occurrence frequency or magnitude of those events. These types of events can be considered as the “discrete episodes of extreme weather or unusual climate conditions, often associated with deleterious impacts on society or natural systems, defined using some metric to characterize either the meteorological characteristics of the event or the consequent impacts” [3]. Different types of adverse weather conditions, along with a more unfavourable atmosphere due to increased convection over warmer surfaces, are attributed to a rise in the frequency, intensity and hazards of EWEs [4-8]. Various EWEs, such as prolonged heatwaves, intense floods and droughts, and strong thunders can generate damaging impacts on the social and economical lives and livelihoods. EWEs can be classified based on ‘thresholds’ that either indicates the probabilities of occurrence, or the point where they can cause potential impacts [9]. India is one of the countries that are well critically influenced from the impact of the climatic change, EWEs and the subsequent impacts affecting water resources, agriculture, ecosystems, economic development and health [10-11]. There is no single proper attribution approach to quantify the variations in the likelihood of the EWEs. This study will aim to quantify the long-term changes in the EWEs under different climatic scenarios in a northern Indian state, Himachal Pradesh. Such events includes lightning, thunderstorm and the other associated hazards. Main focus will be given to the intensity of their impact.

Study area

The study area containing the different districts of Himachal Pradesh (HP) and Uttarakhand is shown in Fig. 1 and Fig 2 respectively.

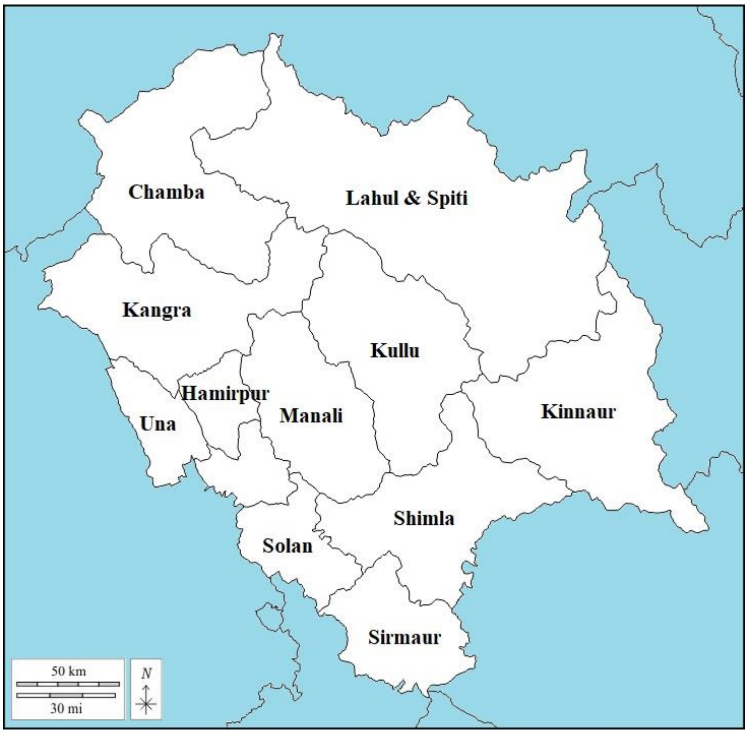

Fig. 1: Districts of Himachal Pradesh (HP)

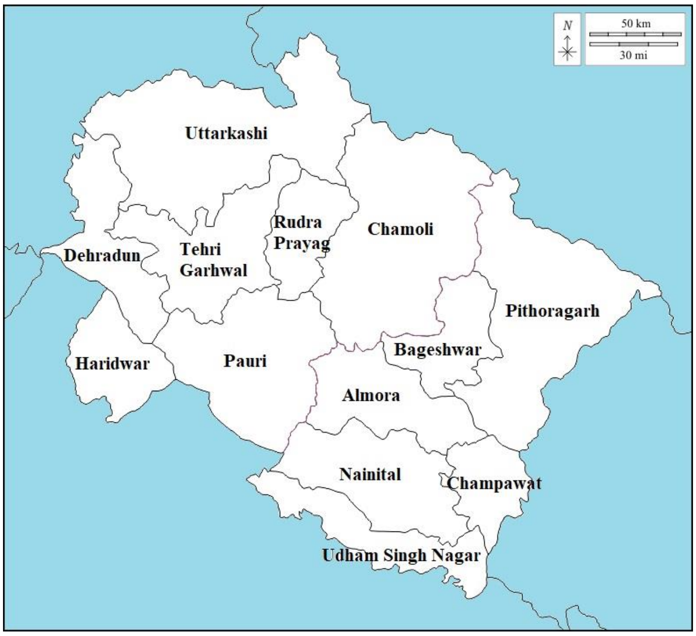

Fig. 2: Districts of Uttarakhand

In the subsequent section vulnerability of lightning flashes, extreme annual wind speed, frequency of extreme rainfall, average annual number of thunderstorm days and annual thunderstorm normalized index have been studied for all these districts of HP. This will establish their frequency of occurrence and associated climatic impacts.

Results:

Fig. 3 represents average number of lightning flashes per sq. km per day across all districts of Himachal Pradesh during 1998-2013. Fig. 4 represents average number of lightning flashes per sq. km per day across all districts of Uttarakhand during 1998-2013.

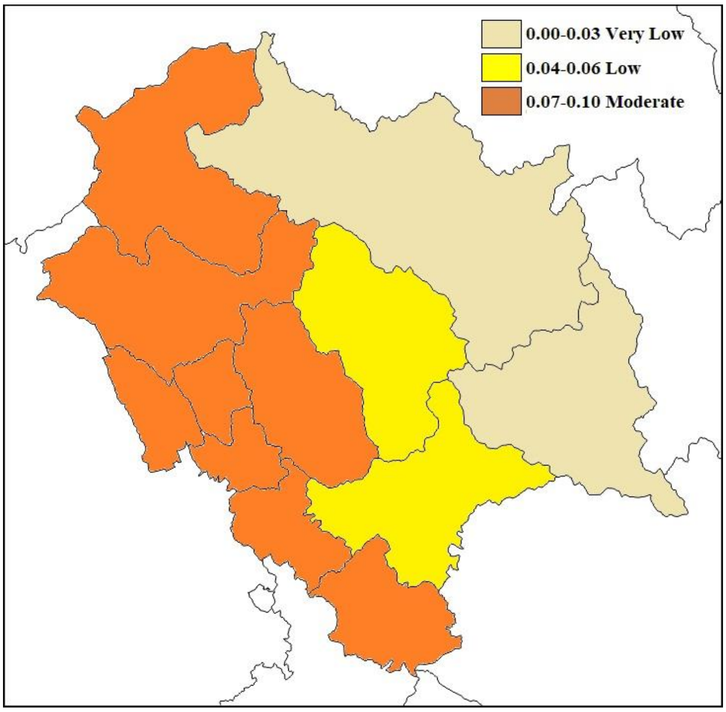

Fig. 3: Average Number of Lightning Flashes per sq.km per day (1998-2013) in HP

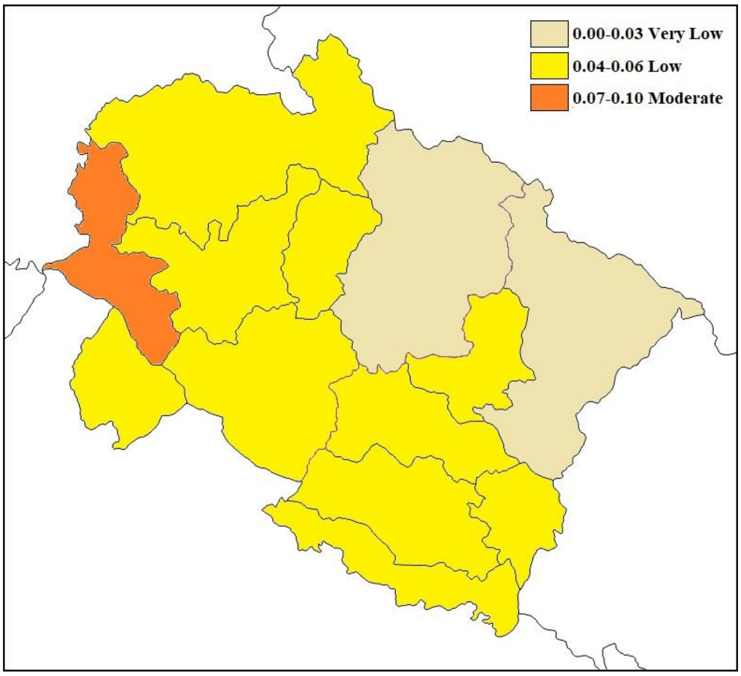

Fig. 4: Average Number of Lightning Flashes per sq.km per day (1998-2013) in Uttarakhand

Fig. 5, on the other hand represents the long term extreme annual wind speed variation across all 12 districts of HP.

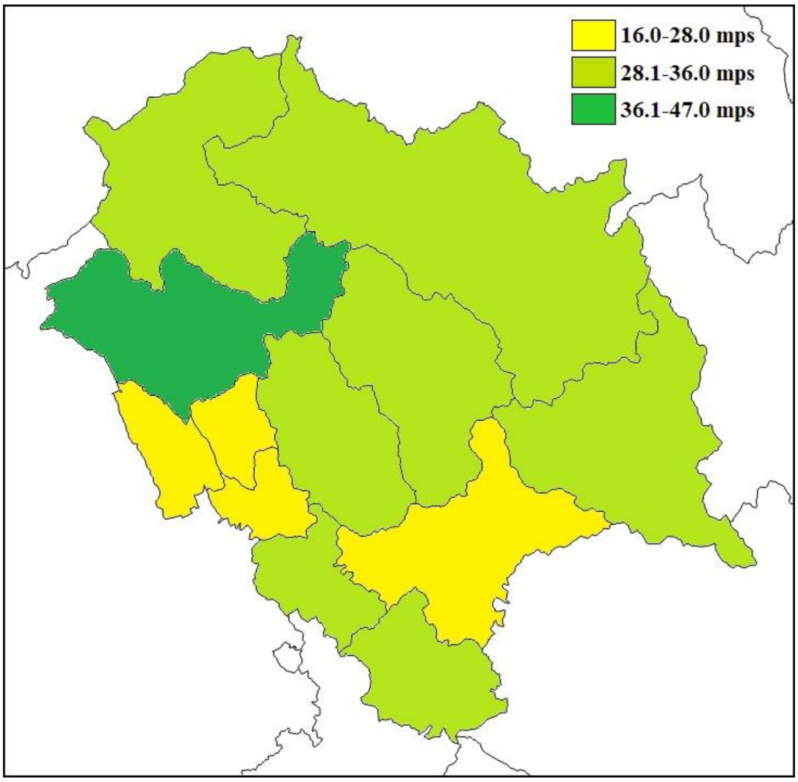

Fig. 5: Extreme annual wind speed (m/s) across all 12 districts of Himachal Pradesh (HP)

Fig. 6 represents the long term extreme annual wind speed variation across all 13 districts of Uttarakhand.

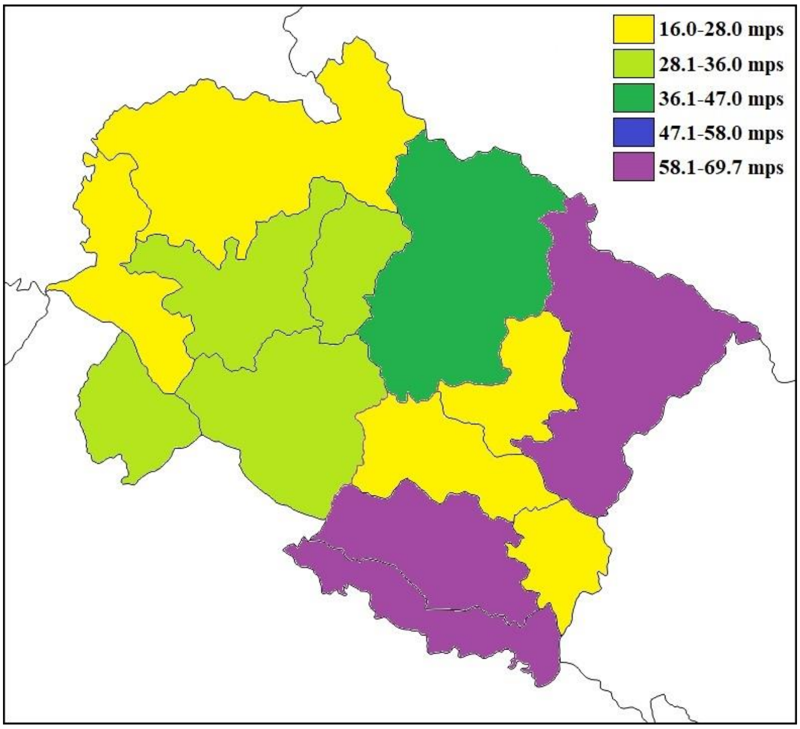

Fig. 6: Extreme annual wind speed (m/s) across all 13 districts of Uttarakhand (UK)

Fig. 7 represents the variation of annual thunderstorm normalized vulnerability index for all 12 districts of HP during 1981-2010.

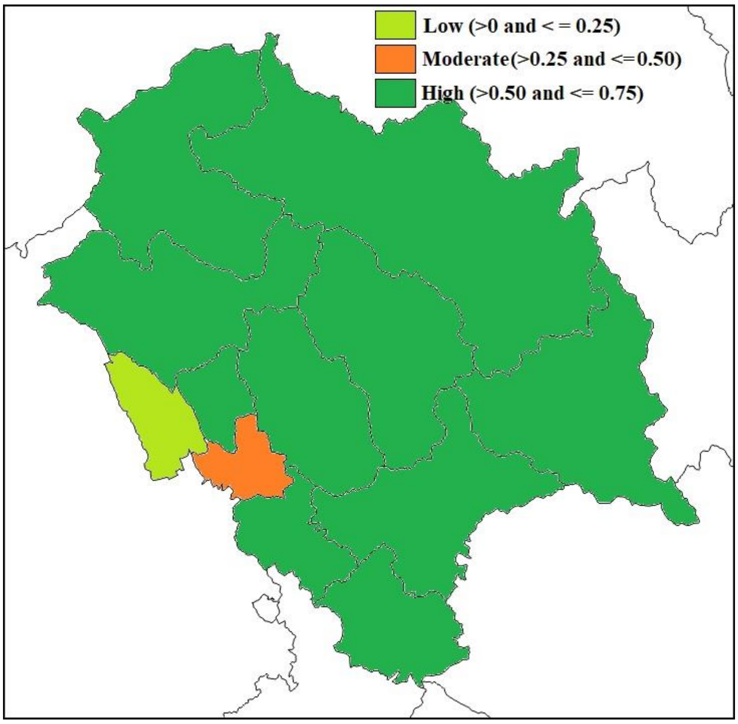

Fig. 7: Annual thunderstorm normalized vulnerability index for all 12 districts of HP during 1981-2010

Fig. 8 represents the variation of annual thunderstorm normalized vulnerability index for all 13 districts of Uttarakhand during 1981-2010.

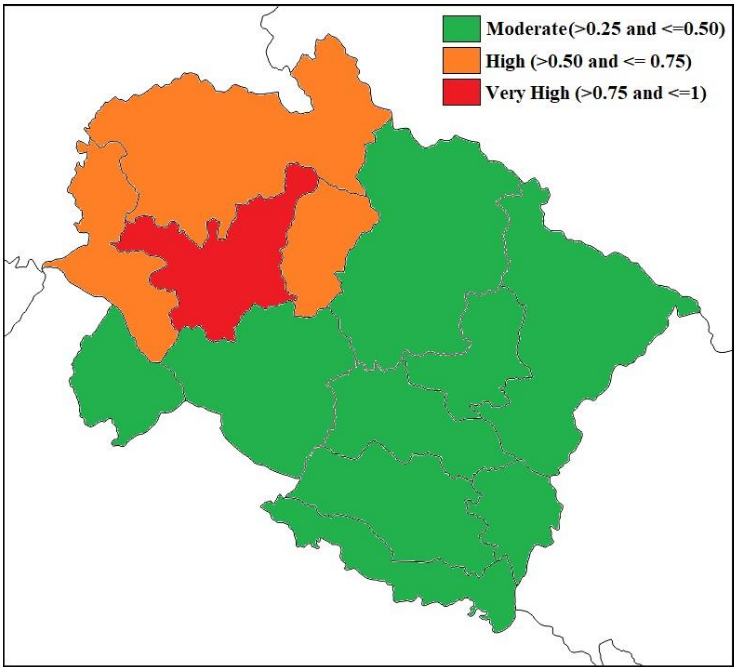

Fig. 8: Annual thunderstorm normalized vulnerability index for all 13 districts of UK during 1981-2010

Discussion:

Observed moderate to high vulnerability of selected EWEs across some of the HP and UK districts are to be treated very carefully as per the climatic consideration to avoid any sort of damage of livelihood and other properties. Proper prediction of weather conditions is very much essential is these vulnerable districts

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STATISTICAL STUDIES OF LIGHTNING HOTSPOTS OVER INDIA

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Abstract:

Gridded annual and monthly lightning climatological datasets for the period 1998- 2013 have been utilized to study and analyze lightning frequency and lightning flash density in India. Synoptic weather systems are found to be the major contributors of lightning in Indian regions. The study reveals that mainly the lightning hotspots are located in the Himalayan foothills, Himachal Pradesh, Jammu Kashmir, Uttarakhand, different states in the north-eastern India including Meghalaya, Assam, Tripura, West Bengal, Orissa, Jharkhand, Bihar and Kerala. Western disturbances were found to be the greatest contributor of lightning in the Himalayas, low-pressure systems and associated tropical cyclones from oceanic origin were found to be the key lightning contributors in parts of eastern India, and for the remaining regions lower tropospheric troughs were found to be the major contributors. Due to different localized climatological factors, there is variation in the occurrences of diurnal and seasonal lightning patterns across different lightning hotspots region. The study also examines the seasonal variation in lightning activity across India. These results are significant for understanding lightning climatology across India. Main focus of this study is on the systematic investigation and prediction of seasonal lightning over these Indian hotspot regions. Observations of lightning frequency indicate that the lightning density experiences a slight enhancement during both pre-monsoon and monsoon seasons for most of the regions in the country.

Keywords: Lightning Hotspots, Lightning Flash Density, Climatological Study

Introduction:

Lightning is an electrical discharge - a 'spark' or 'flash' as charged regions in the atmosphere instantly balance themselves through this discharge. When the collision between the hail particles with other smaller ice particles occurs because this smaller ice particle gains a positive charge and loses a negative charge, respectively. When the charge is built high enough, rapid electricity discharge occurs to equalize the charged region called lightning. In-cloud lightning is a cloud flash is lightning that connects regions with opposite polarity (+/-) within one cloud or between multiple clouds. While a cloud-to-ground flash consists of at least one cloud-to-ground stroke and is dangerous to life and property (Fig. 1). In-cloud and cloud-to-ground lightning, together are called total lightning. In-cloud pulses and cloud-to-ground strokes are collectively referred to as “lightning events”.

Fig. 1: Typical (a) in-cloud and (b) CG lightning discharges

Lightning Hotspots in India

The lightning hotspots region is mainly located in Jammu Kashmir, Himachal Pradesh, Uttarakhand, the north-eastern state of India, *i.e.*, Meghalaya, Assam, Tripura, West Bengal, Orissa, Jharkhand, Bihar, and Kerala [1-10]. The Foothills of the Himalayas also come under the lightning hotspots. According to the Indian Meteorological Department's (IMD) annual lighting report 2020-2021, lightning strikes in the country have increased by 34%. It increased by 4,683,989 strikes from 13,800,000 strikes in 2019-2020 to 18,544,367 strikes in 2020-2021. Himalayan region is one of the world's lightning prone areas. Due to the topology, varied surface temperature, moisture, and atmospheric circulation, lightning flash density (LFD) over this region have a tremendous spatiotemporal variability.

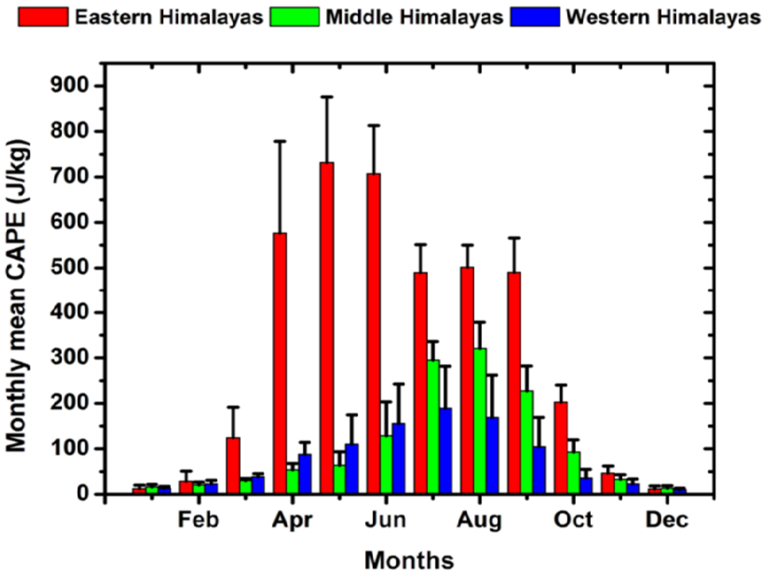

Fig. 2: Monthly variation of CAPE in the Himalayan zone

Fig. 2 shows the monthly variation of CAPE in the Himalayan zone. The variation of lightning activity over the Northeastern part of the Himalayan region is semiannual with primary maxima during April. At the same time, this maximum occurs during July in the North-West region.

Fig. 3 represents the frequency distribution of lightning flashes over all Indian districts. Fig. 4 represents average number of lightning flashes per sq. km per day (during 1998-2013) across all Indian states and union territories.

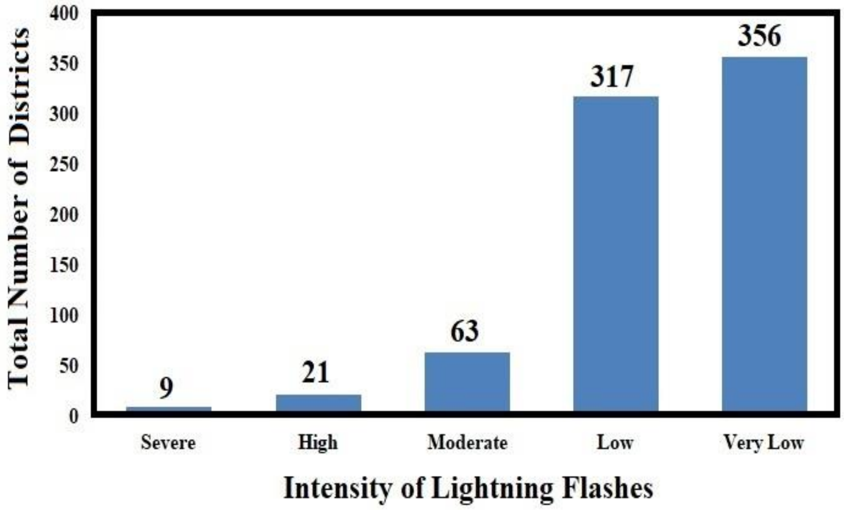

Fig. 3: Frequency distribution of lightning flashes over India

Districts which are veryvery highly prone to lightning are: Punch, Rajouri, Reasi, Jammu, Mirpur, Dhubri, Bongaigaon, Goalpara and Garo Hills.

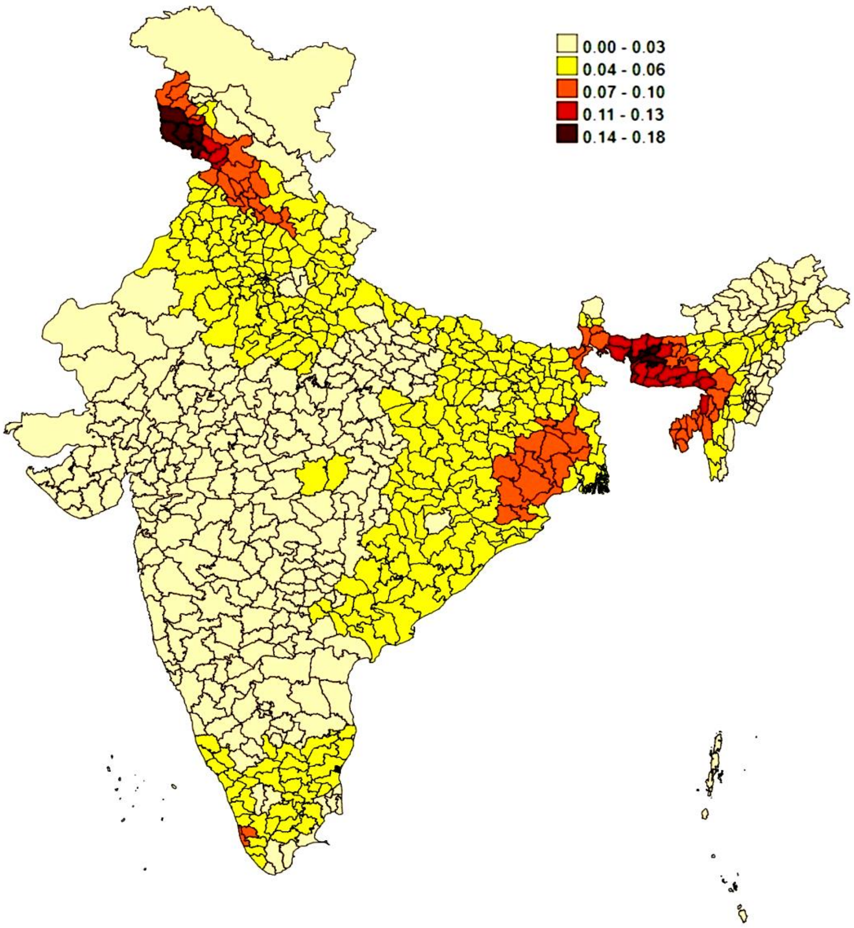

Fig. 4: Average number of lightning flashes per sq. km per day in India

Fig. 5 represents the frequency distribution of the severity of thunderstorm normalized vulnerability index (TNVI) over all Indian districts.

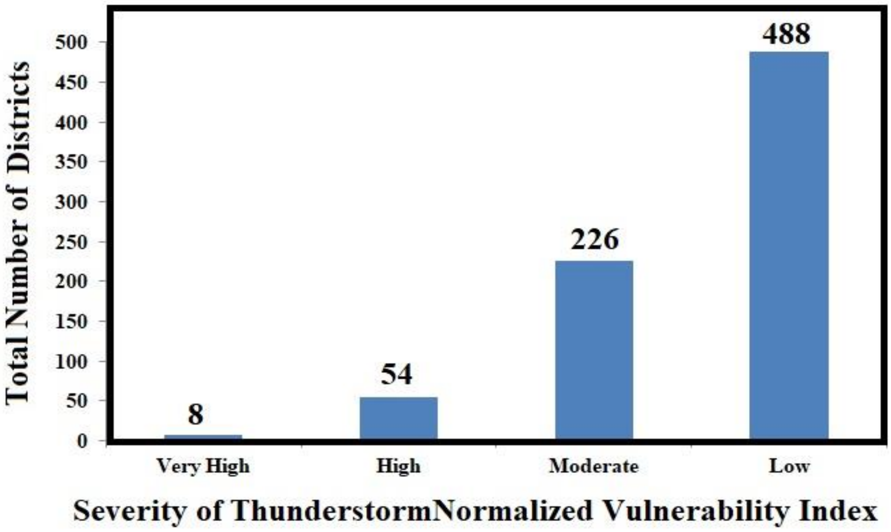

Fig. 5: Frequency distribution of lightning severity of thunderstorm normalized vulnerability index (TNVI) over India

Fig. 6 represents district wise TNVI across all Indian states and union territories. Districts which are very highly vulnerable to thunderstorms are: Tehri Garwal, Sonitpur, Nagaon, North Tripura, West Tripura, Unakoti, Khowai and Sepahijala.

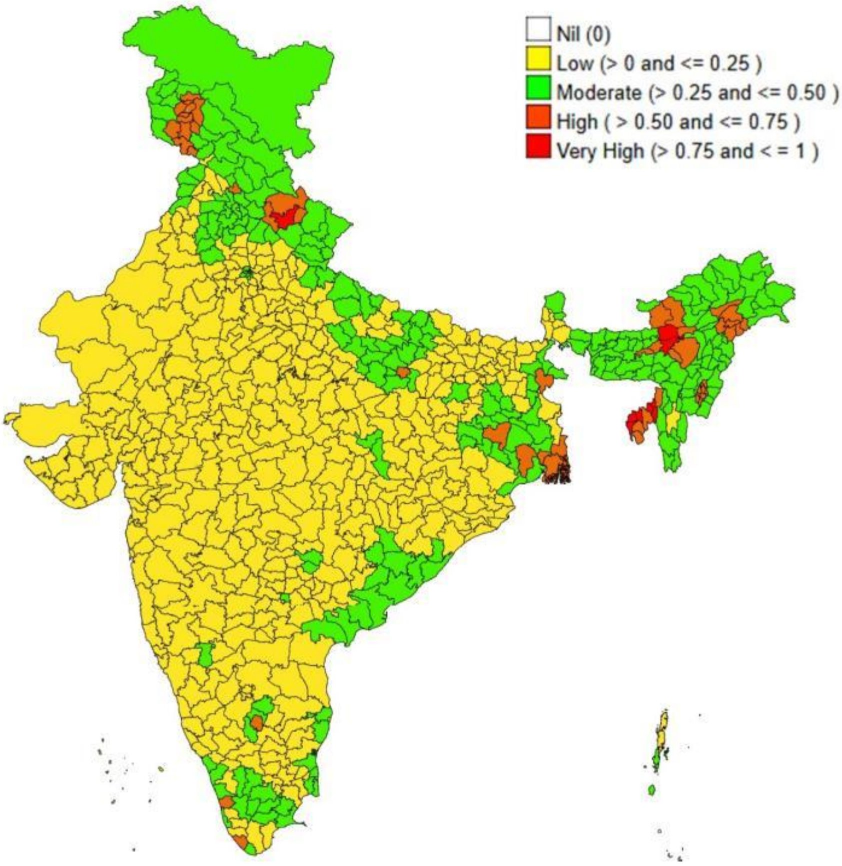

Fig. 6: District wise distribution of TNVI across India

Fig. 7 represents the frequency distribution of severity of thunderstorm days over all Indian districts.

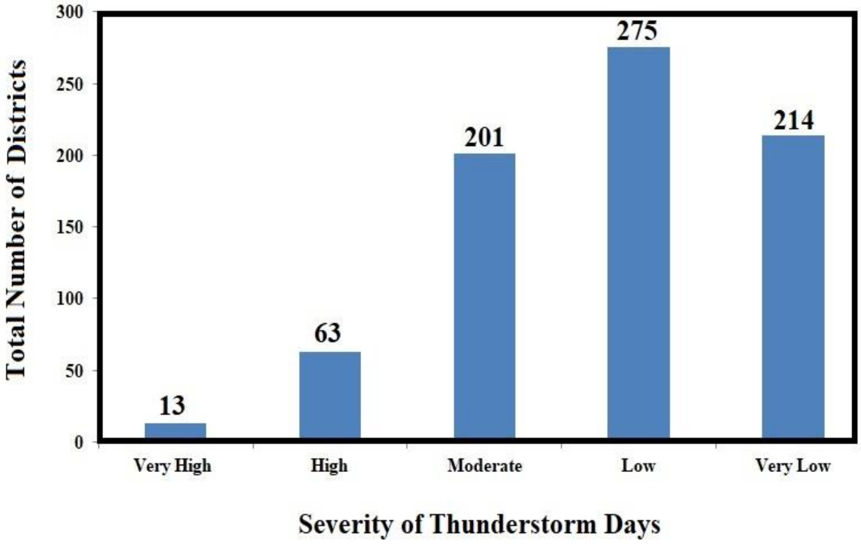

Fig. 7: Frequency distribution of lightning severity of thunderstorm days over all Indian districts

Districts which are very highly prone to thunderstorms are: Jammu, Dehradun, Tehri Garwal, Dibrugarh, Sonitpur, Nagaon, North Tripura, West Tripura, Unakoti, Dhalai, Khowai, Sepahijala and Thirivananthpuram. Fig. 8 represents annual average number of thunderstorm days (during 1981-2010) across all Indian states and union territories

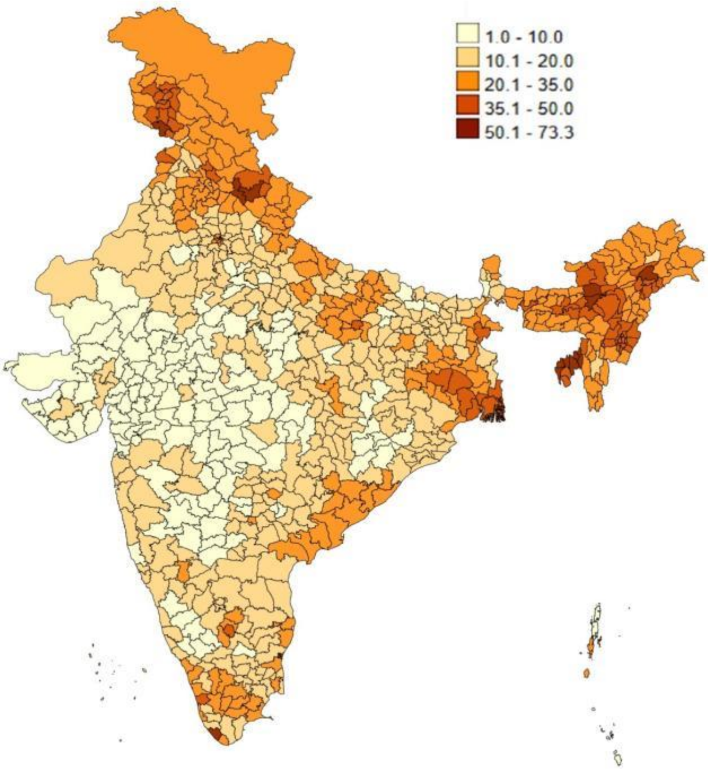

Fig. 8: Annual average number of thunderstorm days across India

Lightning fatalities in India

As per the study more than 2000 people die due to lightning per year in India, around 9 percent of deaths due to natural calamities.

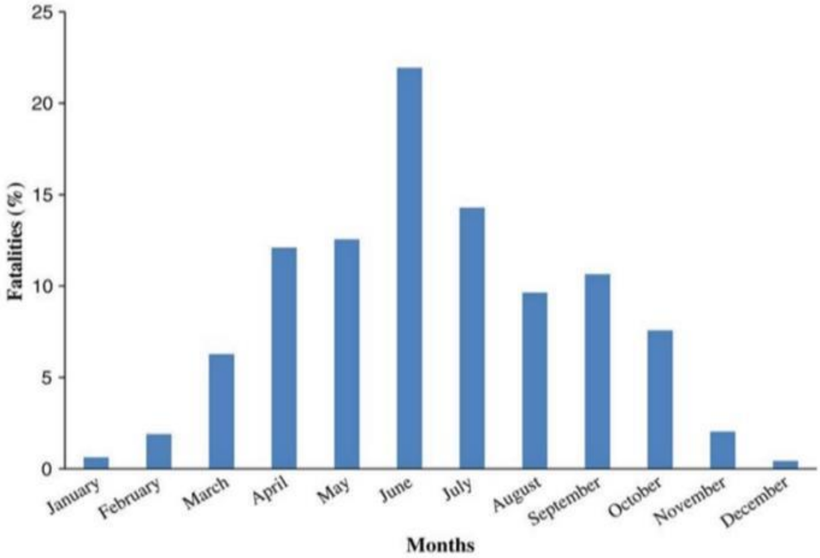

Fig. 9: Monthly Lightning Fatalities over India

The state-wise casualties' study reveals that maximum casualties are reported in Madhya Pradesh (313 deaths), Maharashtra (281 deaths) and Orissa (255 deaths) on an average per annum (Fig. 9). The favorable climatic conditions, such as availability of moisture content, unstable atmosphere and strong convection, cause severe cases of lightning over the regions of Orissa and Maharashtra. There are many effects of lightning such as visual effects, accidents caused by the lightning strikes over an area of the building resulting into fire which may also cause huge damage to property and cause loss of life (Fig. 10). Some indirect accidents also take place when lightning strikes.

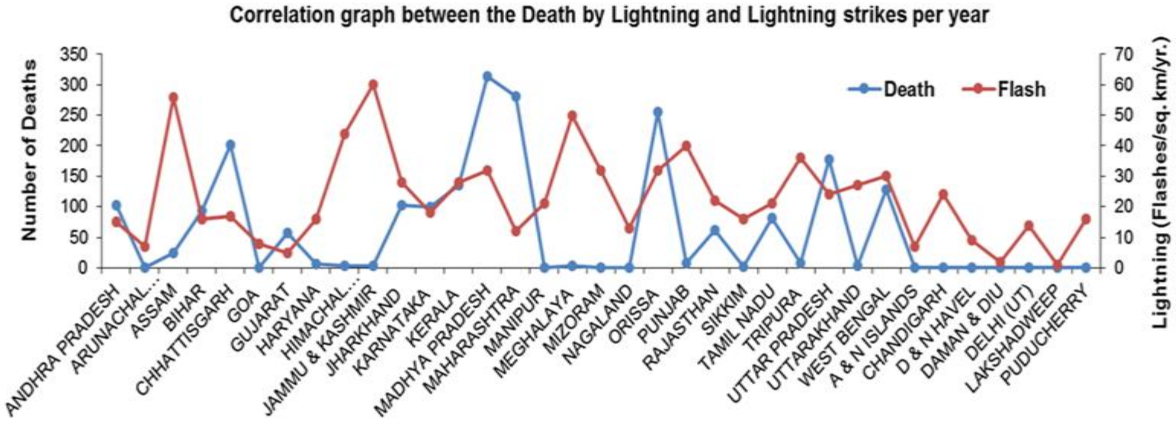

Fig. 10: Lightning Fatalities vs. Lightning Flashes over India

The study reveals that most lightning-dominant regions over India are Jammu and Kashmir, Assam, Meghalaya, Himachal Pradesh, Punjab and Tripura throughout the year.

A special Case Study on Western India

Figure 11 shows the annual average of lightning flashes per sq. km per day across all the districts of Western India. Figure 12 shows the annual average of thunderstorm normalized vulnerability index across all the districts of Western India.

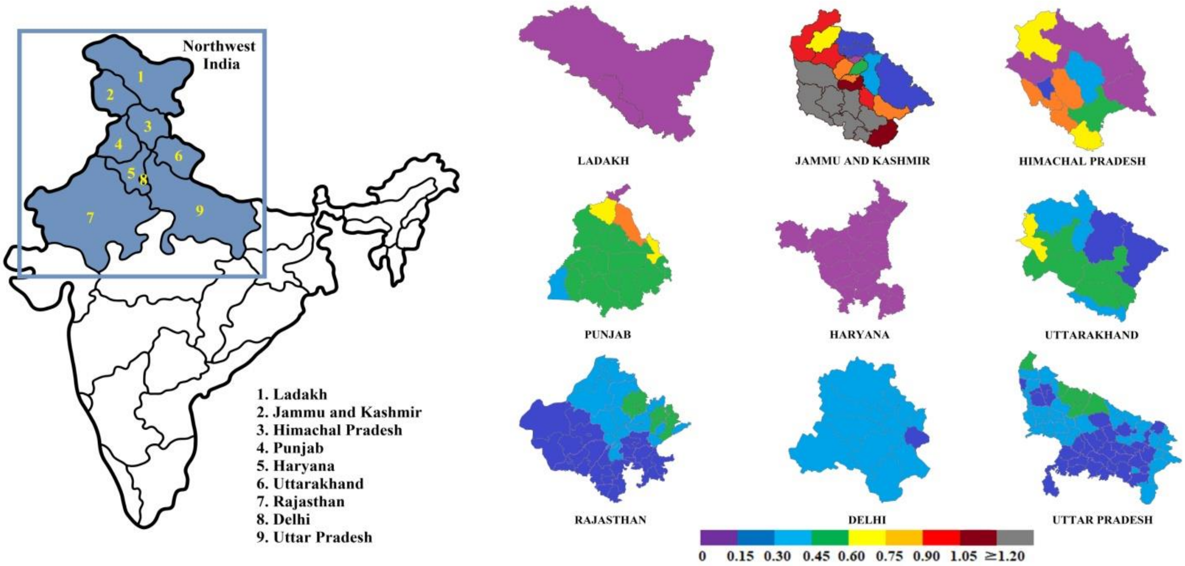

Fig. 11: Annual average of lightning flashes per sq. km per day across all the districts of Western India

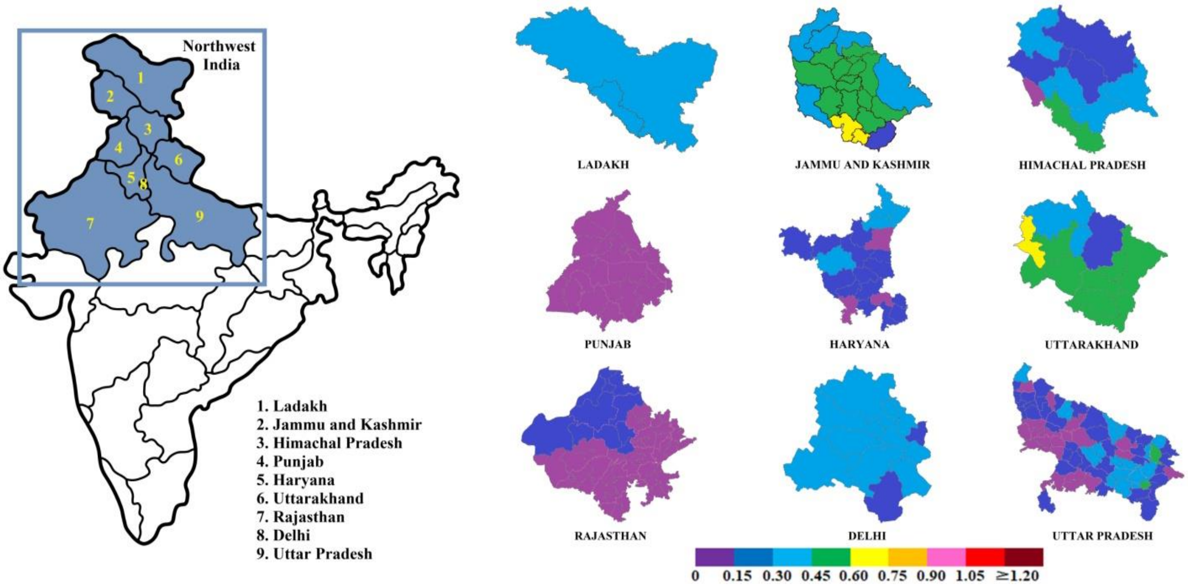

Fig. 12: Annual average of thunderstorm normalized vulnerability index across all the districts of Western India

Figure 13 shows the annual average number of thunderstorm days across all the districts of Western India. Figure 14, Figure 15 and Figure 16 respectively shows the seasonal (pre-monsoon, monsoon, post-monsoon and winter) variation of (A) lightning flashes per sq. km per day, (B) thunderstorm normalized vulnerability index and (C) thunderstorm days across all districts of Jammu and Kashmir, Uttarakhand and Delhi.

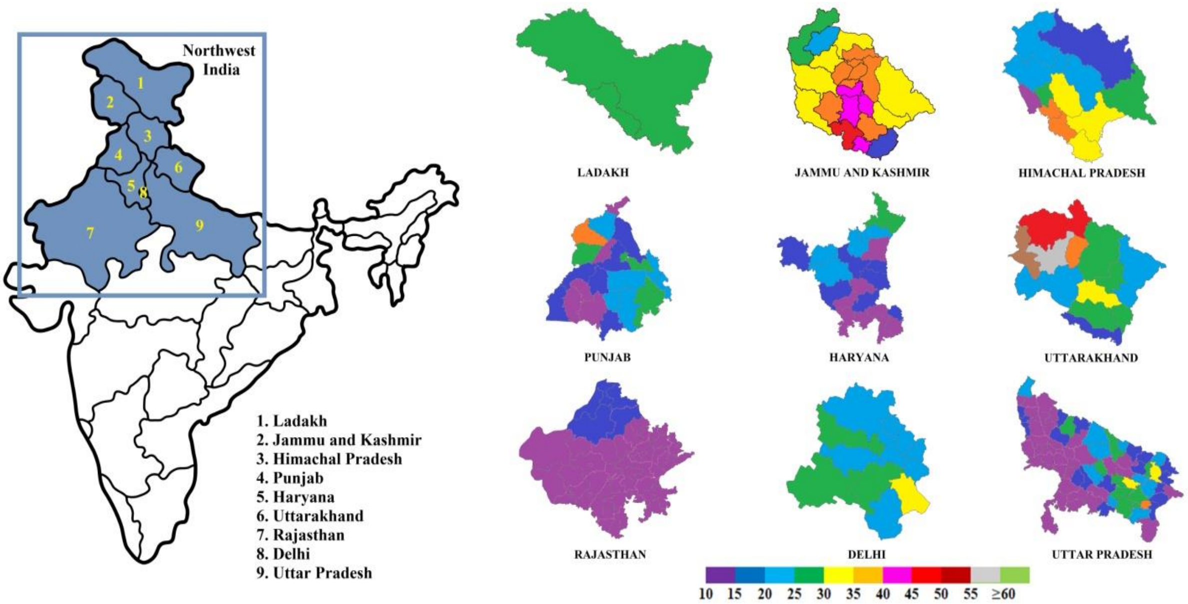

Fig. 13: Annual average number of thunderstorm days across all the districts of Western India

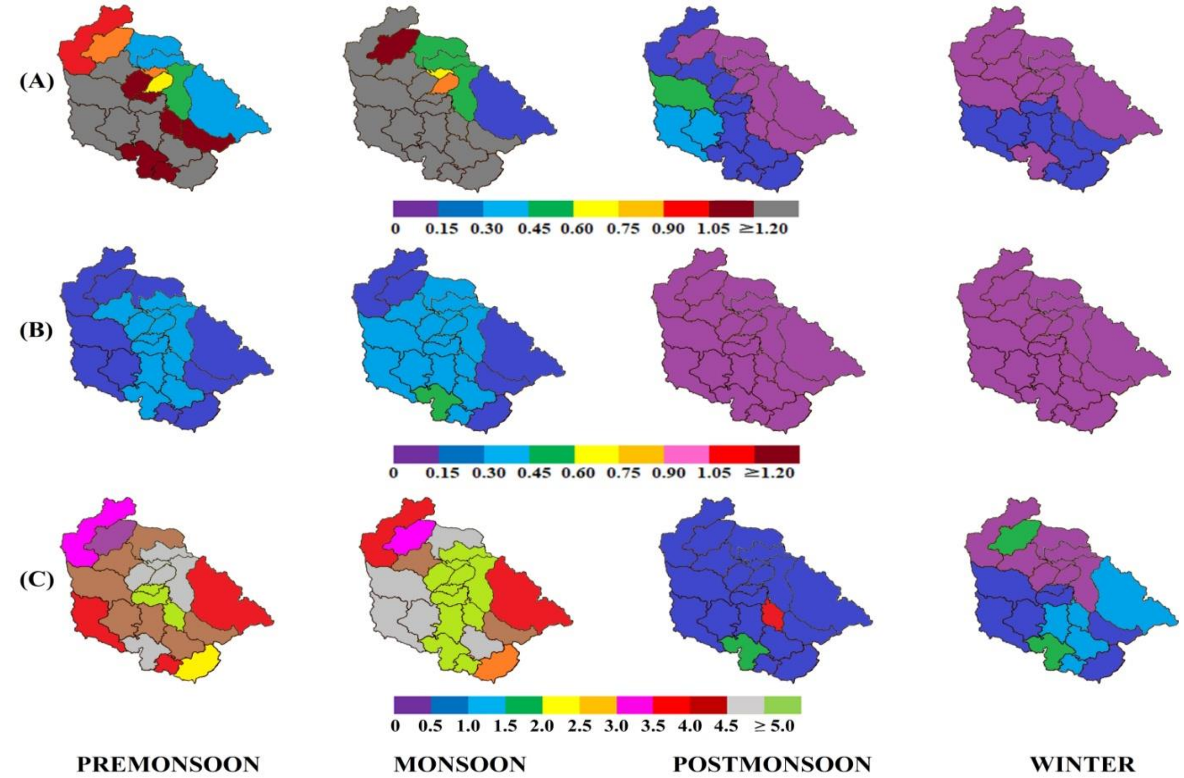

Fig. 14: Seasonal variation of (A) lightning flashes per sq. km per day, (B) thunderstorm normalized vulnerability index and (C) thunderstorm days across Jammu and Kashmir

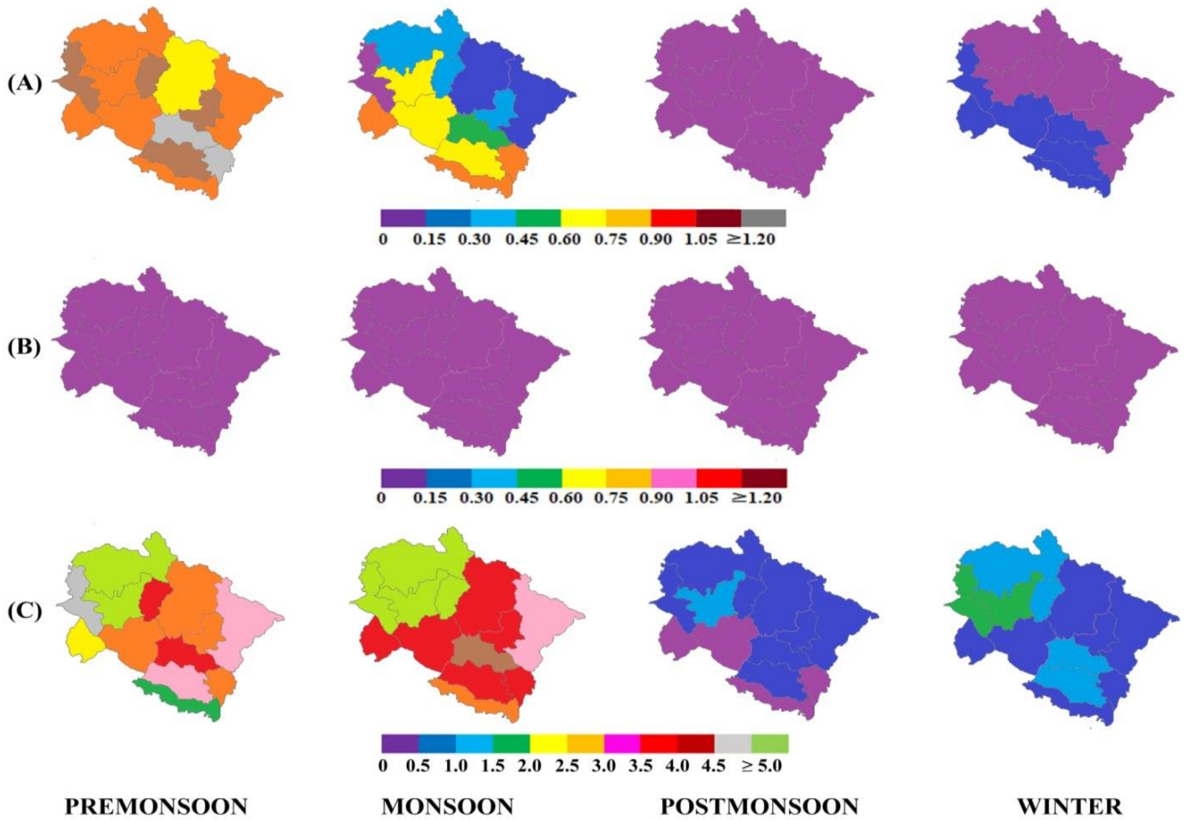

Fig. 15: Seasonal variation of (A) lightning flashes per sq. km per day, (B) thunderstorm normalized vulnerability index and (C) thunderstorm days across Uttarakhand

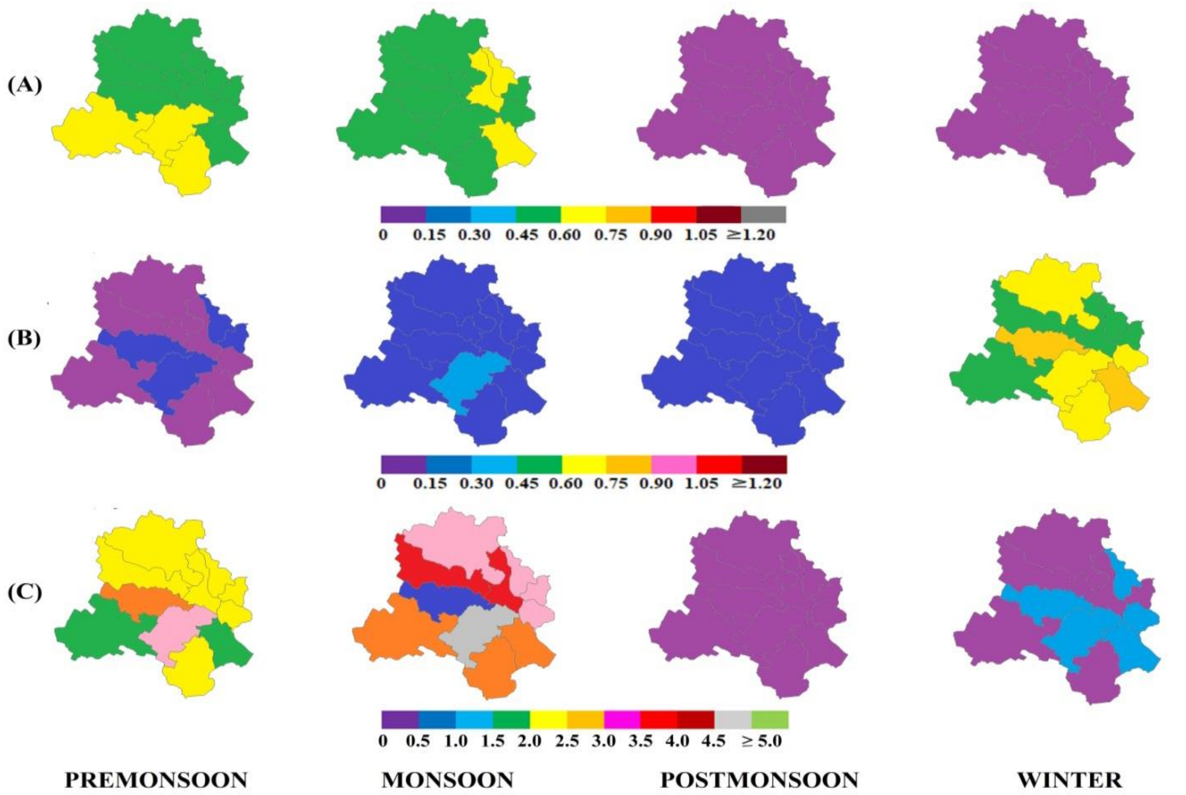

Fig. 16: Seasonal variation of (A) lightning flashes per sq. km per day, (B) thunderstorm normalized vulnerability index and (C) thunderstorm days across Delhi

Conclusion:

Lightning mainly occurs in the tropical region of the planet earth. India is situated in the tropical region and due to its location, some of the highest lightning events took place in this region. Probably, these are having the largest number of occurrence frequency amongst the various natural phenomena globally, as observed by humankind. Lightning activity constitute the major destructive component of thunderstorms over India. Intense thunderstorms form a very common climatological feature over the Indian subcontinent. Probably, lightning activity is found to be the greatest damage to life over the last few decades. There is also significant number of victims from those who are working in some open area during a lightning strike. The phenomenon of thunderstorms events causes massive destruction and loss of life and property. Because of lightning and thunderstorm every year many human fatalities happen in India.

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