ISSN 2278 - 6554

Conscientia

ACADEMIC JOURNAL OF

KRISHNAGAR GOVERNMENT COLLEGE

December 2022

Volume- X

CONSCIENTIA

December 2022

CONSCIENTIA

Vol. X

Academic Journal of

Krishnagar Government College

Krishnagar, Nadia

Nadia, West Bengal, India

December 2022

CONSCIENTIA

Vol. X, ISSN: 2278-6554

Published by

Officer-in-Charge
Krishnagar Government College
Krishnagar, Nadia, West Bengal, Pin-741101
TEL: 03472-252863; FAX: 03472-252810
e-mail: journalkgc@gmail.com
Website: www.krishnagargovtcollege.org

Printed at:
Maa Kali Artwork
Golapati, Krishnagar, Nadia, West Bengal, Pin-741101

December 2022

About the Journal:

The peer reviewed journal “Conscientia” is published annually to promote research in multidisciplinary fields and aims to facilitate discussions on important issues across varied disciplines, enfolding Science, Social Science and Humanities. It publishes original research papers, review works, short communication on subjects of academic as well as of popular interest. The journal also welcomes submissions on innovations in the teaching-learning process and/or learning experiences which focus on general dissemination of knowledge.

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CONSCIENTIA

ISSN-2278-6554

Volume-X, December-2022

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FOREWORD

Dr. Sobhan Niyogi
Associate Professor and Officer in Charge
Krishnagar Government College

*It gives me immense pleasure to announce that volume X of **Conscientia**, the academic journal of Krishnagar Government College is being published. Over the past 176 years- ever since the days of the East India Company rule to the present, this college has uninterruptedly carried forward the legacy of quality education in India. Today about 3,500 students enjoy the privilege of using and sharing the same abode of learning that greats such as D.L.Roy, Umesh Dutta, Jadunath Mukherjee, Jadunath Bhattacharjee, Lalit Kumar Banerjee, Satish Chandra Dey and a host of others have used in bygone decades. Teachers deliver lectures from the podium which had once been used by stalwarts like Pandit Madan Mohan Tarkalankar, Babu Ramtanu Lahiri, Suresh Chandra Sengupta and many other names remembered with reverence. I personally feel honoured at obtaining the opportunity to further promote the excellence of this heritage institution, which has witnessed more than 70 eminent Principals (like Roy Bahadur Jyoti Bhusan Bhaduri, Satish Chandra Dey, J.M. Sen and several others) over the course of its 176-year old history thus far. In less than the last ten years this College has secured "A" grade twice in NAAC evaluation and very recently the University of Kalyani has declared this College as the "Best Performing College" of Nadia District. The faculty members of the College have been contributing significantly in academic research through regular publications at various levels.*

***Conscientia,** the interdisciplinary journal of research findings launched by our College in 2011 strives to publish high quality articles, since the time of its inception. This journal is an interdisciplinary and multilingual publication and articles include scientific research findings, socially relevant issues as well as literary contributions from the various Humanities Departments. This volume is expected to evoke interest among myriad groups of readers, who will hopefully find the articles academically enriching and stimulants for intellectual discourse.*

*I wish to thank all the contributors from various Higher Educational Institutions for their submissions, the Editorial Board Members from our College, the Advisory Board Members from various well known Universities and Institutes of West Bengal and India for their active role for the publication of this particular volume. **Conscientia**, December 2022 Vol. X*

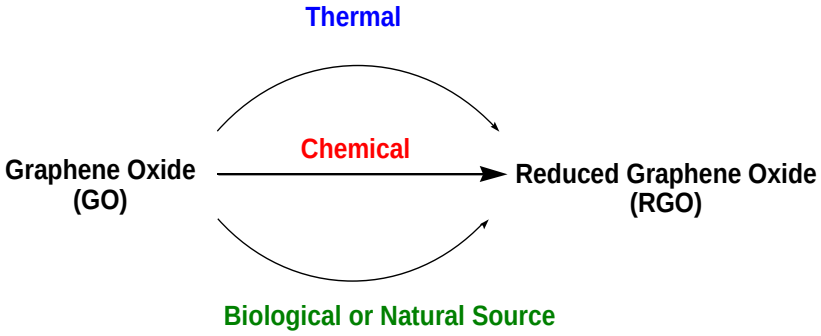
CONTENTS

Phytochemicals Derived from Indigenous Plants – An Incipient Alternative to the Conventional Reduction of Graphene Oxide (GO)

Suchandra Bhattacharya*

ABSTRACT

The isolation of single–layered 2D carbonaceous material graphene with sp^2–hybridized carbon atoms in 2004, subsequent modification, and functionalization has opened up an emerging field of research over the last decade. This carbonaceous nanomaterial has found numerous applications from optics to energy storage to organic catalysis. The two most important derivatives of graphene are reduced graphene oxide (RGO) and graphene oxide (GO). Despite being the most popular method to achieve RGO, the chemical reduction of graphene oxide has its disadvantages like the toxicity of reducing agents, high cost, high temperature, and harsh reaction conditions. Chemical reducing agents have their shortcomings and thus the search for greener synthetic routes and bio-reduction methods began, where plant extracts or microorganisms act as an eco-friendly reducing partner. Plentiful phytochemicals derived from plant parts, such as the roots, peels, leaves, seeds, and fruits, have been discovered. Biomolecules derived from these sources, which include proteins, polysaccharides, vitamins, pectins, amino acids, alkaloids, polyphenols, flavonoids, along with other nature-derived reducing agents including ascorbic acid, amino acids (L–cysteine, glycine, etc), chitosan, various tea extracts, bovine serum albumin, etc have been used for the greener reduction of RGO from GO.



Keywords: Biomolecules, Graphene, Greener, Nanomaterial, Phytochemical, Reduction

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Received: *1st November, 2022 / **Accepted:** 16th December, 2022*

1. Introduction:

Since the seminal discovery of graphene in 2004, (Novoselov et al., 2004; Allen et al., 2010; Dresselhaus & Araujo, 2010) a wide variety of carbonaceous nanomaterials have evolved for exploration by the scientific community. The promising thermal, mechanical, and electrical properties of graphene have gained immense recognition throughout these years (Loh et al., 2010; Soldano et al., 2010; Zhu et al., 2010). These graphene family congeners *viz*. graphene oxide (GO), reduced graphene oxide (RGO), etc. are extensively used in drug delivery to biosensing, photocatalysis, electrochemical charge storage, and dye removal, etc. (Plachá & Jampilek, 2019; Perumal et al., 2022).

A plethora of research articles have been published covering different ways of derivatization of graphene and consequent changes in structures and properties (Bai et al., 2009; Choi et al., 2010; Choi et al., 2010; Loh et al., 2010; Georgakilas et al., 2012). The chemistry of graphene (Dreyer et al., 2014; Eigler & Hirsch, 2014), its structure, and its properties have been studied immensely during the last decade (Dreyer et al., 2010). Materials like CNT, graphene, graphene oxide, reduced graphene oxide, etc. are some nanomaterials with interesting characteristics and applications in various fields of science. Graphene is composed of sp^2 hybridized carbons whereas GO is highly functionalized with diverse oxygenated groups e.g. OH, COOH, epoxy, etc. on the basal plane and edges (Dreyer et al., 2009, 2014).

RGO is considered to be an important class of nanomaterial. Though it is slightly different from pristine graphene as the former still may contain some oxygenated functional groups and the latter does not. RGO has occupied an important area in graphene research due to its diverse applications in the biomedical fields, supercapacitor, photocatalytic degradation, antioxidant, sensor, nanocomposite, organic catalysis, etc. (Perumal et al., 2022). To minimize the risk of toxic chemicals and other associated hazards, chemical reduction of GO highly demands environment-friendly approaches to reach the basic idea of green and sustainable methodologies.

2. Reduction of GO:

The reduction can be achieved by a thermal, chemical, electrochemical, and photochemical process (Pei & Cheng, 2012; Chua & Pumera, 2013; Singh et al., 2016). Thermal rather than hydrothermal or solvo–thermal methods entirely use temperature for the reduction whereas chemical methods chiefly involve reducing agents like hydrazine, $NaBH_4$, and hydrohalic acid. Apart from these, $LiAlH_4$, $PhNHNH_2$, NH_2OH, EtOH, CH_3OH, $^{i}PrOH$, BnOH, $NaHSO_3$, $Na_2S_2O_4$, M/HCl (M= Al, Zn, Fe), poly (amido amine), Dimethylketoxime and NH_3, hydroquinone, dextran, and NH_3, ethanethiol/ $AlCl_3$, thiourea dioxide/ NaOH and so many other mild to strong reducing agents have been reported till date (Pei & Cheng, 2012; Chua & Pumera, 2013; Singh et al., 2016). The reduction generally removes the functional groups from the GO surface but complete removal is difficult since all groups do not have the same binding energies to the plane. Epoxy and hydroxyl groups are easily removed whereas groups like COOH are present in the edges and are sometimes left even after reduction. NH_3BH_3 (ammonia borane) has been used as a mild reducing agent to prepare RGO from GO. The defects which are created by going from pristine graphene to GO can be removed in the process of GO to RGO production but the RGO is imperfect compared to that of the graphene. The carbon–oxygen ratio is one of the determining factors of how much the reduction is achieved. It has been found that this ratio is 12, 11.5, and 9.5 for $LiAlH_4$, hydrazine, and $NaBH_4$ respectively (Farah et al., 2020).

As mentioned earlier, chemical reduction method owing to its disadvantages like toxic and hazardous chemicals, and harsh reaction conditions is being swapped with bioreduction methods where the main target is to utilize the natural reducing components to minimize the engagement of toxic chemicals. Local availability, eco-friendly nature, and cost-effectiveness of plant extracts offer them as a decent alternative to harmful chemicals for the reduction of graphene oxide. Though there are numerous plant extracts that have been used in the reduction but global inaccessibility and not so efficient reduction capability restrict their usage. Owing to their great medicinal value and eco-friendly nature, the phytochemicals are attractive alternatives to orthodox toxic reducing agents. A wide range of such reductions can be found in the literature showing different parts of plants from diverse taxonomic groups contributing in this regard (Perumal et al., 2022). This includes components from orange peel, Indian gooseberries (*amla*) (Ansari et al.,

2019), green tea leaves (Vatandost et al., 2020), aloe vera (*gritakumari*) leaf gel (Bhattacharya et al., 2017), tamarind (Panicker & Sahu, 2021), Indian holy basil (*tulsi*) (Shubha et al., 2017) leave, myrobalan (*hortoki*) (Maddinedi et al., 2015), radish (Punniyakotti et al., 2021) and many others. These reported plants also include many indigenous Indian plants which are easily accessible making it a cost effective way. Hence the main idea behind the green reduction of graphene oxide using various natural resources is the presence of reducing chemicals in the phytochemicals.

3. Different phytochemicals from various parts of plants in the reduction of GO:

Studies have demonstrated that from fruits to roots of various plants contribute to the green reduction of GO to RGO or graphene sheet. Parts like peel, flower, leaf, seed, bark/stem, etc. have also been explored by the scientific community on demand of an environmentally benign methods. Biomolecules from these sources, which include proteins, polysaccharides, vitamins, pectins, amino acids, alkaloids, polyphenols, and flavonoids, may act as capping and reducing agents during the green reduction and formation of functional RGO from GO. Phenolics and flavonoids are the most abundant type of secondary metabolites and bioactive molecules found in plants, and they are excellent antioxidants. The components that have been utilized in the green reduction include polysaccharides, proteins, pectins, vitamins, amino acids, polyphenols, alkaloids, flavonoids (Perumal et al., 2022), and other nature-derived reducing agents including ascorbic acid, amino acids (L–cysteine, glycine), gallic acid, tannic acid, chitosan, bovine serum albumin, anti-septic, anti-inflammatory agents, anthrones, polymannans, acetylated mannans, anthraquinone C-glycosides, anthraquinones, emodin, and various lectins, etc. (Liu et al., 2010; Ansari et al., 2019; Panicker & Sahu, 2021). Reports show that phytochemicals do not always play the role of reductant only but they help to stabilize graphene sheets by preventing aggregation (Maddinedi et al., 2015).

Different parts of some plants like the taro or elephant ear (*Colocasia sp.*) (Thakur & Karak, 2012), *Ginkgo biloba* (Gurunathan et al., 2014), neem (*Azadirachta indica*) (Kumar et al., 2014), onion (*Allium cepa*) (Khanam & Hasan, 2019), ginger (*Zingiber officinale*) (Rai et al., 2021), coconut (*Cocos nucifera*) (Kartick et al., 2013), potato (*Solanum tuberosum*) (Sadhukhan et al., 2016), sweet lemon (*Citrus limetta*) (Hou et al., 2017), fig (*Ficus carica*) (Ansari & Siddiqui, 2018) etc.

have been used in the reduction of graphene oxide. These and some other derivatives from commonly available plants in their various forms helpful in graphene oxide reduction have been summarized in Table 1. A comprehensive list along with their potentiality of industrial usage has been prepared by Perumal et al. (Perumal et al., 2022).

Table 1. Summary of some commonly available plants and their derivatives utilized in the reduction of Graphene Oxide (GO)

Sl No.	**Plant Name & Part Used**	**Family**	**Reduction Method**	**Reduction time & Temperature**	**Reference**
1.	Elephant ear (*Colocasia sp.*) Leaf Extract	Araceae	Reflux	5h & 100**°C**	(Thakur & Karak, 2012)
2.	*Ginkgo biloba* Leaf Extract	Ginkgoaceae	Stir	24h & 37**°C**	(Gurunathan et al., 2014)
3.	Neem (*Azadirachta indica*) Leaf Extract	Meliaceae	Reflux	24h & 100**°C**	(Kumar et al., 2014)
4.	Onion (*Allium cepa*) Root Extract	Amaryllidaceae	Stir	6h & RT	(Khanam & Hasan, 2019)
5.	Ginger (*Zingiber officinale*) Root Extract	Zingiberaceae	Reflux	4h, 6h, 8h, 10h, 12h & 90**°C**	(Rai et al., 2021)
6.	Coconut (*Cocos nucifera*) Fruit Extract	Arecaceae	Oil Bath	12h, 24h, 36h & 80**°C**, 100**°C**	(Kartick et al., 2013)
7.	Potato (*Solanum tuberosum*) Root Extract	Solanaceae	Stir	12h & 60**°C**	(Sadhukhan et al., 2016)

8.	Sweet lemon (*Citrus limeta*) Fruit Extract	Rutaceae	Reflux	6h & 50**°C**	(Medha et al., 2017)
9.	Fig (*Ficus carica*) Fruit Extract	Moraceae	Stir	12h & 95**°C**	(Ansari et al., 2018)
10.	*Eucalyptus* Leaf Extract	Myrtaceae	Water bath	8h & 80**°C**	(Li et al., 2017)
11.	Peppermint (*Mentha piperita*) Leaf Extract	Lamiaceae	Autoclave	12h & 180**°C**	(Khojasteh et al., 2019)
12.	Tea plant (*Camellia sinensis*) Leaf Extract	Theaceae	Water bath	8h & 80**°C**	(Moosa & Jaafar, 2017)
13.	Pink periwinkle (*Catharanthus roseus*) Root Extract	Apocynaceae	Precipitation	24h & RT	(Andrianiaina et al., 2021)
14.	Radish (*Raphanus sativus*) Root Extract	Brassicaceae	Autoclave	12h & 100**°C**	(Punniyakotti et al., 2021)
15.	Sugarcane (*Saccharum officinarum*) Bark/Stem Extract	Poaceae	Autoclave	12h & 150**°C**	(Singh et al., 2018)
16.	Chandramallika (*Chrysanthemum morifolium*) Flower Extract	Asteraceae	Water bath	24h & 95**°C**	(Hou et al., 2016)

17.	Indian acalypha (*Acalypha indica*) Leaf Extract	Euphorbiaceae	Autoclave	12h & 100**°C**	(Punniyakotti et al., 2021)
18.	Mango (*Mangifera indica*) Leaf Extract	Anacardiaceae	Reflux	8h & 60-70**°C**	(Sadhukhan et al., 2016)
19.	Common lantana or Putush (*Lantana camara*) Leaf Extract	Verbenaceae	Reflux	6h & 50**°C**	(Medha et al., 2017)
20.	Tulsi (*Ocimum sanctum)* Leaf Extract	Lamiaceae	Stir	4h & 70**°C**	(Shubha et al., 2017)

4. Characterization of the reduced graphene oxide (RGO):

To study the morphology of the reduced graphene oxide (RGO), different characterization tools have been utilized including UV-Vis, Raman spectroscopy, XRD, FT-IR, SEM, TEM etc. (Thakur & Karak, 2012; Maddinedi et al., 2015; Bhattacharya et al., 2017; Roy et al., 2017; Shubha et al., 2017; Lingaraju et al., 2019; Panicker & Sahu, 2021; Punniyakotti et al., 2021). In the UV-Vis spectroscopy, a clear indication of π-π interaction and n-π interaction can be observed at respective wavelengths. Since the incorporation of oxygenated functional groups can be well observed through FT-IR spectra of GO and graphene, the reduction of intensities of various peaks or total elimination of the peaks related to the oxygen functionalities are also noticed (Ansari et al., 2019; Panicker & Sahu, 2021). This is attributed to the fact that the reduction of GO partially removes many of the oxygen functionalities from the surface and edges. In the XRD pattern, the disappearance of the characteristic diffraction peak ($2\theta = 10.5^0$) after the reduction GO to RGO and the appearance of a new peak at $2\theta = 26.6^o$ indicate an inter-layer distance value of RGO which is in good agreement with the reported value for graphene (Lingaraju et al., 2019). In Raman spectra, comparing the D/G intensity ratio of GO and RGO, the morphological change can be witnessed. The catalytic activity of the plant extract-derived RGO can vary depending on the

process and reducing source. It is worth mentioning that few plant extracts are equally efficient as chemical reducing agents (Roy et al., 2017).

5. Conclusion:

In the era of diverse catalytic systems starting from nanoparticles (NPs) to solid-supported NPs, metal salts, complexes, metal-ligand systems, organocatalysts, etc, it is difficult to find out greener and mild reagents that can serve the purpose with similar reactivity under greener reaction conditions and shorter reaction time. Utilization of natural resources like plant extracts involving their roots, bark, stem, fruits, leaves, peels, seeds, etc. has been well established due to their benefits. Availability and accessibility of such plants can be well utilized in their application in organic reactions over conventional catalytic systems. Hence, with the native plants within reach, it is an enriched area of research which has already been explored widely and is yet to be unfolded further by future scientists.

Acknowledgment:

The contribution of Sri Satadal Adhikary, Assistant Professor, Post Graduate Department of Zoology, ABN Seal College, and Sri Hemen Biswas, Assistant Professor, Post Graduate Department of Zoology, ABN Seal College is duly acknowledged.

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Lanthanide Nano-Particles: Synthetic Strategies

Swarna Kamal Samanta*

ABSTRACT

Lanthanide compounds form a large number of functional materials with several applications in optical, electrical, magnetic and catalytic fields due to their unique 4f electrons. While due to unforeseen changes in surface properties, nanoparticles become very popular in the field of material science and technology. This short review highlights the synthetic strategies used for the designing of lanthanide based nano particles. In most of the cases, these particles are synthesized through solution-based routes such as hydrothermal/solvothermal methods and precipitation/coprecipitation methods both in aqueous and organic solvents. A series of novel nanostructured lanthanide compounds are designed by controlling the synthetic parameters and reaction kinetics.

Keywords: Nanoparticle, lanthanide, hydrothermal, ionic liquid, microemulsion.

1. Introduction

With the progress of lanthanide chemistry for more than two centuries, lanthanides have found assets of applications in chemical industry, military, agriculture and biomedicine. Trivalent lanthanide ions (Ln^{3+}) are the most common and stable oxidation state of lanthanides. Due to their 4f electrons lanthanides are unique in properties. The magnetic susceptibilities, magnetic moments and electronic relaxation time of Ln^{3+} are determined by their 4f electronic configurations [1−3]. Symmetric electronic ground state of Gd^{3+} favors weak spin−orbit coupling and long electronic relaxation time, whereas the asymmetric electronic ground states of Tb^{3+}, Ho^{3+}, Dy^{3+} and Er^{3+} offers short electronic relaxation time but larger magnetic moments and magnetic susceptibilities. These are utilized in nuclear relaxation acceleration and resonant frequency shifting [4].

In addition, the lanthanides are useful for optical applications. The sensitization of lanthanide (Ln^{3+}) emission in various medium is an active field of research. The Ln^{3+} emission is

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Received: 10th October, 2022 / **Accepted:** 3rd December, 2022

characterised by the narrow band width, the large Stoke's shift from the excitation source and the longer life time. Therefore, Ln^{3+} are considered as high-quality luminescent materials for applications in the field of sensing,[5] therapy,[6-8] lighting, displays,[9] and photovoltaic devices[10].

With the rapid developments of nanoscience and nanotechnology over the past few decades, Ln^{3+}-based nanoparticles are currently investigated as probes in nanomedicine for the development of optical diagnostic techniques [11]. The tunable size and morphology have been developed to meet the in vivo studies. In addition, through surface functionalization and doping, such nanoparticles could provide as multifunctional stages for promising bioapplications.

This review takes a close look on controlled synthesis of monodispersed Ln^{3+}-based nanoparticles which is essential for extended bioimaging and therapeutic applications. In the past decade, solution-based synthetic methods have been carried out to prepare various Ln^{3+}- based nanoparticles. In these methods, synthetic parameters like pH, reaction temperature, duration time, concentration of precursors and surfactants etc can be adjusted in such a way that the morphology and size distribution of nanoparticles were managed to be controlled. To date some chemical synthetic methods including thermal decomposition, hydrothermal/solvothermal method, microwave and microemulsion- assisted approaches etc have been developed. Among these synthetic methods, thermal decomposition and hydrothermal/solvothermal methods are considered as the most popular and effective procedure to prepare high-quality target nanoparticles. Some typical synthetic procedures for preparation of Ln^{3+}-based nanoparticles have been discussed. The emerging applications of Ln^{3+}-based nanoparticles in the field of medicine have also been demonstrated.

2. Synthetic Procedures for Lanthanide Nanoparticles

2.1. Thermal Decomposition

The thermal decomposition involves the oxygen-free decomposition of the organometallic precursors in high-boiling point organic solvents. The organometallic precursors are Ln^{3+}-based organic salts like acetates, trifluoroacetates etc. Octadecene (ODE) is generelly used as high-boiling-point organic solvent. Oleylamine (OM) and oleic acid (OA) are also used as capping

reagents to govern the size and morphology of nanoparticles. The crystal nucleation and growth process, the two key steps for formation of uniform nanoparticles, can be precisely adjusted by modulating the synthetic parameters like concentration of precursors, temperature, heating rate etc.

In 2005, Yan and co-workers reported the synthesis of LaF_3 nanoplates with the decomposition of $La(CF_3COO)_3$ using OA/ODE as the organic solvents[12]. It was reported that a mixture of OA and ODE (molar ratio 1:1) led to uniform LaF_3 triangular nanoplates. Nanoparticles with diverse morphology (truncated-triangular, quadrilateral, hexagonal, polygonal, nanopolyhedra and nanorods) using the thermolysis of trifluoroacetates with lanthanide fluoride and oxyfluoride are also reported [13]. Monodispersed lanthanide oxyfluoride nanoparticles were synthesized via the decomposition of $Ln(CF_3COO)_3$ in OA and OM[14]. LaOCl nanoplates were synthesized using $La(CCl_3COO)_3$ in OM and ODE[15]. Yan and co-workers developed a general synthetic strategy for getting $NaREF_4$ (RE = Pr to Lu, Y) nanoparticles (cubic/ hexagonal phased nanopolyhedra, nanoplates, nanorods) via thermolysis of $RE(CF_3COO)_3$ and $Na(CF_3COO)$[16]. The molar ratio of [Na]/[RE] is important for the phase transition from cubic to hexagonal. Recently, Yan et al. have successfully synthesized Ln^{3+}-based oxysulfides nanoplates via sulfur powder and lanthanide acetylacetonate [17]. In a similar way, monodisperse Ln^{3+}-based $LnSe_2$ nanosheets [18], $NaLnS_2$ particles[19] and $Ln_4O_4Se_3$ nanoplates[18] have been synthesized. Murray and co-workers reported the synthesis of LnF_3, $NaLnF_4$ nanoparticles [20] and nanoplates[21] with uniform morphology. Colvin and co-workers developed the synthesis of CeO_2 nanoparticles with variable trivalent cerium content via the thermal decomposition of cerium oleylamine, cerium acetylacetonate hydrate and cerium nitrate hexahydrate in ODE [22]. The particle size can be adjusted by controlling the molar ratio of cerium to surfactants as well as water and cosurfactants.

2.2. Hydrothermal/Solvothermal Synthesis

In hydrothermal/solvothermal synthesis the preparation of nanoparticles are carried out using the superheated solvents and the concomitant high pressure in autoclaves. In high pressure, the enhanced solubility and reactivity of reactants offer the key point for getting better crystalline nanoparticles. By adjusting experimental parameters, high-quality Ln^{3+}-based nanoparticles are

synthesized using this method. In general, Ln^{3+}based oxides, nitrates, chlorides and acetylacetonates are frequently used as precursors.

Qian and co-workers synthesized[23] Ln^{3+}-doped YF_3 nanospindles with the hydrothermal method where EDTA was used to control the growth of the nanospindles. The morphology and size was controlled by changing reaction temperature, concentration of EDTA as well as duration time. Synthesis of LaF_3 nanoplates[24] was reported by Chen and co-workers where they used $Ln(CF_3COO)_3$ as precursors. The morphology of the nanoplates was controlled by the amount of sodium oleate and oleylamine added. Using hydrothermal strategies, Lin et al. synthesized a series of $NaLnF_4$ and LnF_3 nano-particles[25-29] where trisodium citrate and EDTA have a clear impact on the morphologies of the particles. Using liquid−solid solution (LSS)-based hydrothermal synthetic route, lanthanide doped $NaYF_4$ single-crystal nanorods, hexagonal nanoplates, and nanoparticles have also been synthesized [30]. This process involves a phase transfer and separation mechanism occurring at the interfaces of the liquid and solid phases. Yan and co-workers reported the synthesis of CeO_2 nanopolyhedra, nanocubes and nanorods by reacting $Ce(NO_3)_3$ with NaOH employing hydrothermal method [31]. The NaOH concentration was the key factor responsible for the morphology evolution. Kaneko and co-workers also reported CeO_2 nanoparticles[32] where decanoic acid was added to $Ce(NO_3)_3$ for anisotropic growth of the nanoparticles. Qian and co-workers developed an improved toluene solvothermal synthetic route where CeO_2 nanoparticles were prepared using $CeCl_3$ as the precursor and hexadecylamine as the surfactant[33]. It was found that the water content, concentration of surfactants and types of aliphatic amine played an important role in determining the morphology of nanoparticles. Nanoparticles[34] of sodium lanthanum (III) fluoride-doped and co-doped with Eu^{3+}/Tb^{3+} were prepared by Haq Nawaz Sheikh et al. using the hydrothermal method by citric acid as structure-directing agent.

2.3. Precipitation/Coprecipitation

In precipitation/Coprecipitation method, simultaneous precipitation process of several ions is carried out with the formation of nano-sized particles. Due to precipitation rate difference of various ions, coordinating surfactants and cosolvents are usually added into the reaction systems.

Precipitation/ coprecipitation synthesis can be performed both in aqueous as well as in organic medium.

A series of nanocrystalline (≈5–10 nm) lanthanide doped fluorides – CeF_3:Gd^{3+}, Sm^{3+} were prepared by Marcin Runowski and Stefan Lis using a simple coprecipitation method. The nanoparticles were further hydrothermally treated, which resulted in increased crystallinity and size of the nanocrystals[35]. Haase and co-workers reporteded a coprecipitation method where lanthanide doped $NaYF_4$ nanoparticles[36] were obtained by reacting sodium alkoxide, $LnCl_3$, and NH_4F in high-boiling point organic solvent N-(2-hydroxyethey)ethylendiamine. The average particle size was tuned from 37 to 166 nm by varying the molar ratio of EDTA to total lanthanides. EDTA plays the key role to prevent the particle coagulation by shielding the Ln^{3+} ions. Van Veggel and his co-workers have synthesized the lanthanide doped LaF_3 nanoparticles with coprecipitation method in ethanol and water mixture, using $Ln(NO_3)_3$ and NaF[37]. In this process, ammonium di- octadecyldithioposhate was added to control the growth of nanoparticles. The average size of the particles formed was 10 nm.

Karakoti and co-workers synthesized CeO_2 nanoparticles by dissolving cerium nitrate in polyethylene glycol solution [38]. Nitric acid was used to adjust the pH value of the solution. After adjustment of pH, the solution was oxidized using hydrogen peroxide to produce CeO_2 nanoparticles. Kar and co-workers also synthesized CeO_2 nanoparticles[39] where ethylenediamine was act as the catalyst as well as capping agent. CeO_2 nanoparticles were obtained by dissolving cerium nitrate in ethylenediamine with continuous stirring at room temperature.

Zhang et al. employed the synthesis of hexagonal phased $NaYF_4$: Yb,Er nanoparticles in organic medium with controllable morphology using Ln^{3+}-based oleates, acetates, chlorides, and nitrates[40]. Chen and coworkers reported Ln^{3+}-based oleates and NaF to synthesize $NaGdF_4$-based nanoparticles in OA and ODE[41]. Higher temperature favors the formation of hexagonal $NaGdF_4$ nanoparticles, while lower temperature leads to cubic nanoparticles.

2.4. Ionic liquid based synthesis

Ionic liquids are non-volatile, non-flammable and thermally stable organic salts having low melting point. These have been recently suggested as a ‘green’ alternative to the conventional

organic solvents for the synthesis of nanoparticles. Due to their superior capability for the solvation and stabilization of metal cations, ionic liquids are acting as capping agents or surfactants.

Nuria O Nu˜nez and Manuel Oca˜na have reported[42] a facile procedure for the synthesis of uniform lanthanide fluoride nanophosphors using an ionic liquid (1-butyl, 2-methylimidazolium tetrafluoroborate). This method was applied for the preparation of pure YF_3, EuF_3 and TbF_3 nanoparticles as well as of Eu-doped YF_3 and Tb-doped YF_3. In most of the cases, highly uniformed nanoparticles were obtained. The size of nanoparticles could be tuned in the nanometer range by adjusting the nature and concentration of the starting lanthanide precursor. A synthetic procedure for the preparation of LnF_3 nanocrystals using three ionic liquids ($OmimPF_6$, $OmimBF_4$, and $BmimPF_{6)}$ also reported [43]. The partial hydrolysis of PF_6^- and BF_4^- was utilized to introduce a new fluoride source. Uniform LnF_3 (Ln = La, Ce, Pr, Nd, Sm, Eu, Er), Tb^{3+}-doped CeF_3 and Eu^{3+}-doped LaF_3 nanocrystals were obtained in a large scale. Manuel Ocana et al. have developed [44] a procedure for the synthesis of multifunctional europium(III)-doped gadolinium(III) fluoride ($Eu:GdF_3$) nanoparticles having quasispherical shape (~85 nm) by precipitation using diethylene glycol solution containing lanthanide chlorides and an ionic liquid (1-Butyl, 2-methylimidazolium tetrafluoroborate) as fluoride source.

2.5. Microwave Assisted

In microwave assisted synthesis, chemical reactions are often faster than traditional convection heating methods. Microwave reactors provide excellent control over reaction mixture, withstanding high temperatures and pressures from reaction to reaction. This technique provides improved engineering for the separation of the nucleation and growth stages of nanomaterials. Kristina Djanashvili and co-workers [45] have developed a facile, highly reproducible method for the preparation of Ln-based nanoparticles with predefined diameters in the range of 20 to 200 nm. A defined amount of dispersion of the lanthanide oxide was added directly to an aqueous solution of urea and the corresponding lanthanide chloride. Finally, the mixture was heated in a microwave oven to induce hydrolysis of the urea. As soon as the solubility product was reached, the nano particles were started to form. Elson Longo et al. discussed [46] a simple approach for good quality nano sized calcium titanate crystals doped with trivalent Tm and Yb lanthanide ions. The

nanoparticles had a microcube-like structure in the range of 47 nm. A europium-doped calcium hydroxyapatite and fluoroapatite nanophosphors[47] functionalized with poly(acrylic acid) (PAA) have been synthesized by Manuel Ocaña et al. through a microwave-assisted hydrothermal method from aqueous basic solutions containing sodium phosphate, calcium nitrate, PAA as well as sodium fluoride in the case of the fluoroapatite particles. In both cases a spindlelike morphology was obtained. The size of the nanospindles was 191 (32) × 40 (5) nm for calcium hydroxyapatite and 152 (24) × 38 (6) nm for calcium fluoroapatite. Venkata Krishnan and co-workers[48]effectively synthesized acetate-capped hydrophilic cubic phase $NaYF_4$:Yb/Er upconversion nanophosphors having a size of about 25 nm employing a microwave-assisted synthesis route at relatively low temperatures.

2.6. Microemulsion Based

In addition to the aforesaid well-developed synthetic procedures, microemulsion based procedures have also been utilized to synthesize Ln^{3+}-based nanoparticles. Ritcey and co-workers developed the synthesis of LnF_3 nanoparticles with reverse microemulsions of water in cyclohexane stabilized with Igepal CO-520[49]. By mixing two microemulsions containing $LnCl_3$ and NH_4HF_2, monodisperse amorphous LnF_3 nanospheres were obtained. Seal and co-workers synthesized monodisperse, nonagglomerated nanocrystalline CeO_2 nanoparticles in the range of 5 nm using microemulsions of water and toluene[50]. They used cerium nitrate and NH_4OH as precursors and sodium bis(2-ethylhexyl) sulfosuccinate as surfactant to control the size of the CeO_2 nanoparticles. Yuxiu Sun and coworkers have successfully fabricated luminescent lanthanide-doped hydroxyapatites (Eu:HA and Eu–La:HA) via the (cyclohexane/polyxyethylene (TX-100)/*n*-butanol/water solution) microemulsion mediated hydrothermal process[51].

3. Discussion

As the properties of nanoparticles are size-dependent, the main hurdle for research community in nanoscience especially those who working in medicine or health care is the confinement of chemical methodologies that can produce cost-effectively the desired nanoparticles with proper particle size, distribution, uniformity and purity in terms of both structure and composition. A variety of synthetic methods for the preparation of lanthanide nanoparticles have

been discussed in the earlier section. Considering these synthetic procedures, a comparative study (Table-1) has been made in terms of cost of the process, reaction time, degree of complication and shape control of the nanoparticles. From the literature survey, it has been found that in most of the cases, these particles are synthesized through thermal decomposition [12-22] and solution-based routes such as hydrothermal/solvothermal [23-34] methods and precipitation/coprecipitation [35-41] methods both in aqueous and organic solvents. Among these processes coprecipitation method is considered as the most cost effective process. The coprecipitation method is one of the most easiest, and convenient route due to its mild reaction conditions, low costs for necessary equipments, simple protocols and fast reaction times. In hydro(solvo)thermal synthesis, water is compatible as reaction media with a wide variety of inorganic metal salts, thereby allowing cost-effective and environmentally useful method for synthesis of lanthanide nanoparticles. This method (needs expensive autoclaves) is expensive compared to coprecipitation method. Though thermal decomposition is much expensive, it is generally accompanied in order to get precise particle size and shape.

Table 1: A summary comparison of the synthesis methods.

Method	**Degree of Complication**	**Reaction Period**	**Cost**	**Shape Control**	**Yield**
Thermal Decomposition	Complicated	Hours-Days	High	Very Good	High
Hydrothermal/ Solvothermal	Complicated	Hours-Days	High	Very Good	Medium
Precipitation/ coprecipitation	Very Simple	Minuets	Low	Not good	High
Ionic Liquid Based	Complicated	Hours	Medium	Good	Medium
Microwave Assisted	Simple	Few minuets	Medium	Good	Medium
Microemulsion Based	Complicated	Hours	Medium	Good	Low

4. Emerging applications of lanthanide nanoparticles

Scientific interest in Ln^{3+}-based nanoparticles has rapidly increased over the past few decades. Researchers have made significant progress in utilizing polymers and surfactants to modify the surface of lanthanide nanoparticles to increase its biocompatibility. Some emerging applications of Ln^{3+}-based nanoparticles in the field of diagnosis and radiation therapy have been summarized here.

4.1. Bioimaging

The lanthanide based near infrared nanoprobes having higher tissue penetration ability than short-wavelength UV or Vis light are useful to avoid the interference from organism background fluorescence[52-56] . Li's group [52] have designed phosphatidylcholine (PC) based nanocomposite for biological imaging. A sulfonic functionalized cyanine dye derivative was used as the antenna dye, which could broadly gather NIR energy and enhance the luminescence. Li et al. [57] have developed $NaLuF_4$:Yb,Tm@$NaGdF_4$:^{153}Sm as an optimized multi-modal imaging probe, where, Tm was used for luminescence imaging; Lu was used for Charge transfer imaging, Gd was used for magnetic resonance imaging (MRI) and radioisotope ^{153}Sm for improving single-photon emission computed tomography imaging. The desired sensitivity and resolution have been greatly improved by combining MRI and luminescence imaging [58–62].

4.2. Chemotherapy

Chemotherapy is a cancer treatment where one or more anti-cancer drugs are used to kill cancer cells. Chemotherapeutic applications of Ln^{3+}-based nanoparticles have been studied extensively [63-71]. Hongjie Zhang and their group[72] have developed a multifunctional nano-theranostic agent with ($NaYF_4$: 20%Yb^{3+}, 2%Er^{3+}/ $NaGdF_4$: 2%Yb^{3+}) as the core for the luminescence imaging, and a mesoporous silica layer as the outer shell with ZnO for pH-triggered drug delivery. Chen, Y. et al. [68] have prepared NIR-light-activated ratiometric fluorescent hybrid micelles (RFHM) based on lanthanide nanoparticles where doxorubicin (DOX) and photoreactive fluorescent amphiphilic block copolymer (BCP) containing the 1, 8-naphthalimide-based

fluorescent group as well as 2-nitrobenzyl group were used for biological imaging and chemotherapy.

4.3. Photothermal therapy

Photothermal therapy (PTT) is based on the photothermal conversion effect of photothermal agents to enhance the temperature of tumor site and destroy the tumor cells under the irradiation of external light. NIR light-activated nanocomposites combining with photothermal agents confirm great prospects in PTT of tumor[72-79]. Du, K. M. et al. have reported [80] multifunctional nanocomposites for multi-modal imaging-guided PTT of tumor. Zhao, S. et al.[72] have reported Bi_2Se_3 nanohybrid for imaging-guided PTT where Bi_2Se_3 nanodots possess strong NIR absorption and distinct cancer cell ablation using single-wavelength NIR laser irradiation.

4.4. Photodynamic therapy

Photodynamic therapy (PDT) is a site specific cancer treatment which involves three major elements: suitable excitation of light, photosensitizer and oxygen molecules at the site of the disease tissue. Upon light excitation, photosensitizer becomes activated to produce reactive oxygen species (ROS), which are responsible to destroy the cancer cells. Kong et al. [81] have reported NIR light switchable lanthanide nanopartcicle mediated TiO_2 nanocomposites to understand imaging guided accurate PDT of tumor. Tang et al. [82] developed switchable DNA/nanocomposite, which could produce singlet oxygen ($^1O_2$) and carry out effective PDT for cancer. To optimize the diagnosis performance, Tang et al. [83] has developed tumor microenvironment-responsive multifunctional nanoplatform. The fluorescence resonance energy transfer (FRET) could widen the wavelength of excitation light from UV–Vis to NIR region, which really improves the tissue penetration depth.

5. Conclusion

Nanotechnology is improving our everyday life by enhancing the performance and efficiency of daily applications. It provides a clean environment and renewable energy for a sustainable future. A critical need in the field of nanotechnology is the development of a reliable and ecofriendly process for synthesis of lanthanide nanoparticles. This review provides a

comprehensive overview of the commonly employed strategies for the synthesis of nano particles. The key desirables during nanoparticle synthesis are to find out the optimum conditions for precise size with specified surface characteristics.

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Nesting Behaviour of Wasps: A Sociobiological Approach

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ABSTRACT

Among the numerous factors that contribute to the success of social wasps, colony productivity is the most important and depends on ecological and environmental factors, such as the nest site. Consequently, nest-site choice should be determined by nest-site characteristics. A waspnest colony is an incredible superorganism, consisting of thousands of interdependent wasp individuals, all serving the common good of the colony. Social wasps (Hymenoptera: Vespidae) have received less attention than social bees and ants, and our understanding of fundamental aspects of their ecology remains limited. The nests these wasps create are in my view, every bit as amazing in structure as the honey combs. My thesis is aimed to contribute to a better understanding of the nesting ecology and labour organisation of the social wasps. The objective of this study is to determine the factors affecting the nesting behaviour of the wasps. Some special findings related to the nesting in different wasp colonies are also noted.

Keywords: Hymenoptera, Vespidae, *Polybia occidentalis*, nesting ecology, sociality, brood care, behaviour, colony productivity, camouflage, nest consistency.

Introduction

Individuals build the nest in the case of social wasps by carrying out a variety of distinct inherent building acts. Each act adds a new load of material to the nest, directed in response to cues both internal and external to the nest. Individual workers do not, as far as we are aware, specialise in just one type of building activity throughout their careers in any social insect species. That is, every

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Received: *26th August, 2022 / **Accepted:** 2nd October, 2022*

member of the colony is equipped with the entire repertoire of behaviours needed to construct the nest. Thus, given enough time and effort, a lone individual might theoretically build even the most intricate nests of colonial species.According to this

theory, the construction process is controlled by a system whereby builders react to stimuli resulting from the nest's structural features. The building that builders are working together to construct serves as a conduit for only indirect interactions, known as stigmergy (Grasse, 1959; Theraulaz and Bonabeau, 1995; Camazine *et al*., 2001). But are there any patterns in the nest of a social species that are under the more direct influence of the social group? Here, we offer proof that the affirmative is true. We demonstrate that nests of various sizes scale in ways that suggest a quantitative modification of the construction rules in response to feedback about the size of the swarm for the swarm-founding social wasp *Polybia occidentalis*.

The key objective of this study is to prepare a brief draft on insect behaviour which will facilitate the further study in this field with new research. Topics include characterizing how insects like wasp find and defend their resources, what they forage upon, factors affecting their foraging behaviour etc. Many of the topics are supported with case studies related to communication, foraging behaviour, behaviour and environment, types and mechanism of behaviour and so on.

Behaviour patterns in insects

Behaviour is considered the most important property for any living organism due to its role in biological adaptations. It is an essential component of an organism for interacting with its surroundings. In addition to being important as a field of study in and of itself, the study of insect behaviour has also made contributions to other scientific fields with implications for the study of human behaviour, the neurosciences, the environment and resource management, the welfare of animals, and the training of future generations of scientists. Insect behaviour is more interesting to human curiosity than the behaviour of neutrons and neurons. People are certainly more interested in learning about insects than ever before, as seen by the time and money spent on bug movies, documentaries, and nature literature.

Despite the fact that there are less funds available for research in this area, research on insect behaviour and behavioural ecology is expanding. Insect behaviour is related to biological and ecological properties at the molecular and physiological levels. This is crucial because, like the nervous system and ecosystem, the environment and organisms are linked through behaviour.

Behaviour, in general, refers to an insect's ability to adapt to its environment. The behaviour of the insect alters in response to anything harmful to it and the opposite is true for anything beneficial to it. As with other species, internal circumstances and processes play just as important a role in controlling behaviour in insects. Both of these aspects can result from environmental factors and typically do.

Insects show varied behavioural response to different stimulus. Some of them include innate (which can be heritable or intrinsic or stereotypic), learned (includes orientation behaviour as in walking, swimming. Also Alloway (1972) identifies conditioning, Instrumental learning, shock avoidance learning and olfactory conditioning as four examples of learned behaviour experimentally demonstrated among insects), apetite behaviour, instrumental learning, (learning by trial and error), latent learning(Tinbergan and Kruyt, 1938) and other specified behaviour like foraging, reproductive behaviour etc.

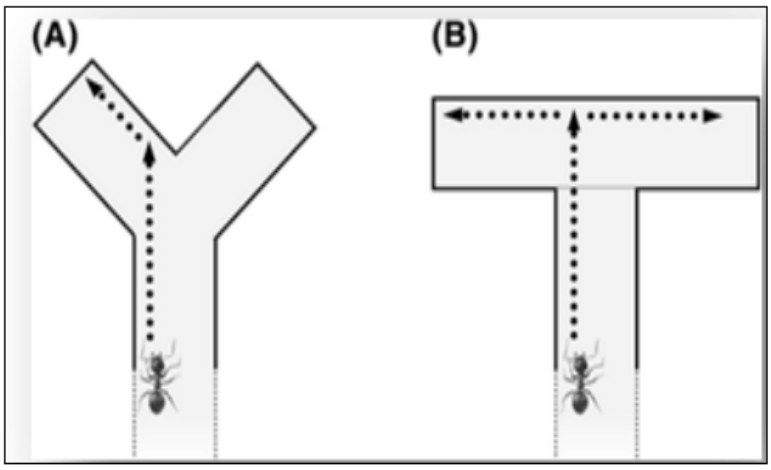

Fig 1: Instrumental learning as shown by an ant

Family Vespidae:

The Vespids are a large (nearly 5000 species), diverse, and cosmopolitan family of wasps, including nearly all the known eusocial wasps (Pickett and Wenzel 2004). The family Vespidae,

includes the subfamilies Euparagiinae, Masarinae, Eumeninae, Stenogastrinae,Vespinae and Polistinae, contains social aculeate wasps with a few notable excetions (Matthews *et al*., 1978; Carpenter 1991). The focus of this review is on the last two subfamilies, which include eusocial species (Carpenter 1991). Within the family, the subfamily Vespinae includes hornets(*Vespa* and *Provespa*) and yellowjackets (*Dolichovespula*, and *Vespula*) (Figures: 1 and 2).

Figure 2: Hornets

Figure 3: Yellow jackets

About 60 known species of the vespine group were formerly found throughout the Holoarctic and Oriental tropics (Greene 1991). The 40–48 species of yellowjackets that are now described are widespread in the Northern Hemisphere (Lopez-Osorio et al. 2014), but humans have unintentionally brought them too many non-native places, including in the Southern Hemisphere (Beggs et al. 2011). Invading nations like Hawaii, Argentina, South Africa, Australia, Tasmania, and New Zealand, these social wasps have had significant ecological effects (Beggs 2001; Lester et al.2014).

Yellowjackets have relatively little physical variation between species (Archer 1989; Archer 2008), and if coloration patterns and male genitalia characteristics are omitted, they are essentially identical (Yamane *et al*. 1980; Akre *et al*. 1981). Moreover, the life history within this group of social wasps is remarkably stable. Despite these shared characteristics, yellowjackets have a very unique behavioural difference (Greene 1991; Lopez-Osorio *et al*. 2014). Yellowjackets are typically split into two distinct groups based mostly on the size of their colonies: small colony yellowjackets (species groups *Dolichovespula* and *V. rufa*) and large colony yellowjackets (species groups *V. vulgaris, V. koreensis*, and *V. squamosa*) (Akre *et al*., 1981; Archer, 2008; Greene, 1991)

Eusocial vespids like *V. vulgaris* can survive in a variety of habitats, from extremely humid regions to man-made environments like gardens and buildings, thanks to its exceptional adaptability. This species, along with other wasp species like *V. germanica*, have had an effect on the ecosystem, particularly in New Zealand and Australia, where they were brought by humans. They frequently harm fruit harvests and put the lives of people and other animals in danger (Clapperton *et al*, 1989)

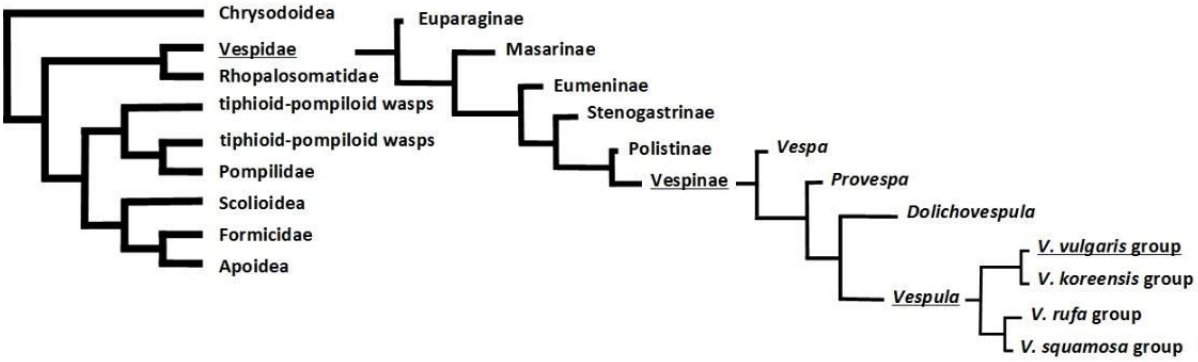

Figure 4: Relationships among the Aculeate Hymenoptera resolved by next generation sequencing (redrawn fromJohnson *et al*. 2013) and morphological analysis of the subfamilies of Vespidae and genera of Vespinae, showing also the interrelationships of the species groups in Vespula (redrawn from Carpenter, 1991). Phylogenetic relationships within Vespinae are not yet clearly resolved, but morphological and molecular studies concord on themonophyly of the *Vespula vulgaris* species group and the sister relationship between the *V. rufa* and *V. squamosa* groups (Loope *et al*. 2014; Lopez-Osorio *et al*. 2014)

Another subfamily of eusocial wasps in the Vespidae family is the Polistinae, sometimes referred to as paper wasps. They have a strong kinship with the more well-known wasps (also known as "yellowjackets" in North America) and real hornets of the subfamily Vespinae, which has four tribes. It is the second-most varied subfamily of the Vespidae, with around 1,100 species overall, and while the majority of its species are tropical or subtropical, they do include some of the most frequently seen giant wasps in temperate climates.

Paper is a common material used by many polistine species, including *Polistes fuscatus, Polistes annularis,* and *Polistes exclamans*. The pedicel used by *Polistes annularis* to suspend its

paper nests from cliff overhangs triggers the necrophobic response in ants, causing them to avoid it rather than cross and feed on the nest's occupants. Like the comb structure in a honey bee nest, the arrangement of polistine brood cells is in a hexagonal pattern.

The evolutionary significance of insect behaviour patterns

Brady and Danforth reviewed recent progress toward understanding the evolutionary history of eusocial insect societies. The repeated origins of eusocial organisms can be considered one of the major evolutionary transitions in the history of life (Maynard Smith and Szathmáry 1995).

Social vertebrates have been at the forefront of research on social learning, but studies using small-brained and short-lived social invertebrates are increasing in number. In an exceptional experiment with *Bombus terrestris* bumblebees, Alem *et al*. (Alem, 2016) showed that some individuals can innovate by acquiring a non-natural, novel behaviour for feeding: string pulling. Once demonstrator individuals (previously trained to pull a string to reach a sugar source) were observed by inexperienced individuals, these bees learned how to perform string pulling them. The authors further showed that string pulling behaviour could spread from a single experienced individual (i.e., that perceived a social cue leading to a behavioural change) to other bees, even when the original demonstrator was no longer present). For invertebrates, most work has been done with social insects and recent findings support the idea that insects have the cognitive abilities necessary for transmission of socially learned behaviours.

Most of the insects show two kinds of behavioural patterns ie, innate and learned. Most behavioural patterns are innate, steriotyped and genetically programmed in their nervous system. Learned behavioural patterns are very less in insect because their learning capacity is very less as compared to other organisms due to very less number of neurons in their nervous system.

Within wasps of the family Vespidae, eusociality occurs in the Polistinae (paper wasps), Vespinae (yellowjackets), and Stenogastrinae (hover wasps) (Ross and Matthews 1991). Morphological and behavioral characters argue that these three groups form an exclusive clade, indicating a single origin of eusociality (Carpenter, 1991). A recent molecular phylogeny, however, suggests that Stenogastrinae is only distantly related to the other two eusocial groups,

implying two eusocial origins (Hines *et al*. 2007). Several trace fossils of wasp nests are preserved throughout the Cenozoic, the oldest of which is a presumed nest of Polistinae or Vespinae at least 63 Ma, establishing a minimum age for a eusocial origin in this group.

Nesting behaviour

Social wasps build communal nests by mixing wood fibres with saliva to form a paper-like material that can be moulded into brood cells and other nest components. When raising larvae, the brood comb is always built like an upside-down umbrella with the open ends of the hexagonal cells facing downward. In order to protect the nest, feed the larvae, and take care of other household duties, workers frequently cling to the bottom of the comb. All social wasps are carnivores, and the majority of their prey is flies and caterpillars. The wasps transform the carcasses of their victims into a paste that they may feed to their larvae, and in exchange, the larvae make nourishing syrup that the adults devour.

Over the course of a summer, a tiny colony of 200 yellowjackets may kill and consume roughly 5000 caterpillars. Wasps exhibit a change from a solitary (non-social) lifestyle to a sociable one. Various stages of evolution from solitary to social existence would have occurred in different animals.

1. Huddling close together without interacting much

2. Interaction and some division of labour while nesting together

3. Nesting with a single morphologically specialised queen or a small group of such queens, each of which is capable of independent reproduction.

In close proximity to populated areas, wasps prepare their nests on walls, ceilings, and trees. The Indian wasp (Ropalidia) and French wasp (Polistes) nests both include a few hexagonal chambers where the larvae are raised. Wasps are active year-round, although they hibernate in the winter.

Social wasps are active year-round in tropical regions. It is common for new colonies to arise by fission or swarming, in which a fertile queen and a number of workers depart from a

sizable parent nest and establish a home for themselves. In temperate climates, one or more queens who mated the previous summer and hibernated during the winter establish wasp colonies in the early spring. A modest nest with only a few brood cells is built by the foundress queen. She lays a modest number of eggs, then feeds and tends to her young until they become adults. These people—all women—become her employees. They take on the responsibility for all household chores, foraging, and brood care. Throughout the colony's growth, the queen continues to lay eggs throughout the summer. The colony's structure starts to deteriorate in the early fall. Males are produced from unfertilized eggs, which mate with newly emerging females to create new colonies the next year (Richard, 1977; Davies, 1977).

Water and pulp foraging: A mandate for nest construction

In addition to imbibing water or passing it along to larvae, social wasps mix water with masticated plant fibre in processing material for nest construction and also use water in conjunction with wing fanning in evaporative cooling of the nest (Akre, 1982). Wasps imbibe water at sources such as standing water or rain droplets on vegetation, and water is carried to the nest in the forager's crop. At the nest, the water is regurgitated from the crop and transferred to nest mates (Jeanne, 1986). The forager may then take off from the surface of the nest and resume water collection in the field. Water can be a limiting resource for wasps. In areas or during seasons in which fresh water is scarce, social wasp foragers are frequent visitors to sinks and dripping water spigots.

Plant fibers such as scrapings from dead branches or weathered, unpainted wood are collected by social wasps and serve as the major structural components of their nests. In plant fibre collection by *Polybia occidentalis*, a forager lands on a piece of wood, regurgitates water from her crop onto the surface of the wood, and scrapes her mandibles across the surface of the wood until she forms a ball of pulp, which she carries in her mandibles as she flies back to her nest. Upon arriving at the nest, foragers typically transfer the pulp to nestmates and may resume foraging for additional loads of pulp (Jeanne, 1986).

Nest construction in *Polybia:* a unique phenomenon

A Neotropical wasp known as *Polybia occidentalis* has been studied for its intricately detailed nesting behaviour (Forsyth, 1978; Jeanne, 1986, 1996). A limited number of queens and a big number of workers make up colony-founding swarms. The initial downward-oriented, hexagonal cells are instantly built as a swarm arrives at the nest site it has selected. These are firmly fastened to the substrate, which is often a twig. The emerging comb becomes a discoid shape and spreads freely from both sides of the twig as more cells are added radially. There is room for more personnel to start working on construction as the comb expands. The queens start laying eggs in the cells in the meantime. The constructors' behaviour changes in terms of quality as the first comb reaches a specific size (qualitative stigmergy; Camazine *et al*., 2001). Workers begin expanding the peripheral cells' outer walls downward and outward to initiate the envelope, starting from the back and sides of the comb, as opposed to adding more cells to the comb's borders. A dome-shaped covering about 2 cm below the comb is formed when this sheet expands and becomes bent toward the centre. However, a 1-cm aperture is left in the front of the envelope to serve as a comb entrance, and the construction of combs and envelopes alternate until the nest is large enough to house the adult wasps of the swarm and the brood they will rear.

The complete building procedure usually lasts a week to ten days. Thus, *P. occidentalis* nests are divided into modules, each of which consists of a comb and its associated envelope. Each comb and envelope module is built to its final size before the next one is started, and it is uncommon for a founding swarm to start a new comb and leave it unfinished or exposed.

Although *P. occidentalis* swarms come in a variety of sizes, each one can build a nest with a number of cells that closely matches the number of wasps in the founding group (Forsyth, 1978; Jeanne and Nordheim, 1996). The founding groups of Polistes exhibit a comparable trend (Wenzel, 1996).The size of the nest the swarm constructs might optimally balance the trade-off of opposing costs such that the output of the colony is maximised. On the one hand, the rate of colony expansion will be constrained if the swarm produces too few cells, as it won't have enough room to accommodate the brood it can rear. On the other hand, if the nest is significantly larger than what is necessary to house the brood population, forager mortality may be high as a result of the

increased foraging requirements for nest material, leaving too few workers to effectively nurse the brood (O'Donnell and Jeanne, 1992).

Two different sets of decision-making procedures are used by individual nest builders in the colony to determine the shape of the nest. One is a worker choosing the type of construction activity to carry out. Construction of brood-cell walls, envelope construction, and surface thickening for reinforcement of the upper nest walls are the three main building activities that *P. occidentalis* workers carry out (Jeanne, 1986). The orientation of the material added to the nest during a certain type of building act is the subject of the second set of operations. The most crucial orienting cues are stigmergic, meaning they originate from the nest itself (Grasse, 1959; Camazine *et al*., 2001), and the species-typical nest structure is determined by the inherent response to these cues.Gravity is an important external orienting cue.

Why is nesting behaviour of *Polybia occidentalis* interesting?

Overall, *P. occidentalis* has a very high relatedness,[1] primarily due to the number of queens in the colony over time. As the colony grows, the number of queens decreases. *P. occidentalis* follows cyclic oligogyny, which increases genetic relatedness among the colony members because over time, as the queens die, fewer queens produce offspring. The fewer the reproducers, are the higher the relatedness. Therefore, the queens are essentially true sisters. The workers and males are also very high in relatedness, though no inbreeding occurs. (O'Donnell and R. L. Jeanne, 1995)

On measuring patterns of individual forager specialization and colony-wide rates of material input during periods of response to experimental nest damage and during control periods in three colonies of the tropcial social wasp Polybia occidentalis, it was found that (1) Most foragers specialized on gathering a single material. While active, foragers rarely switched materials, and most switching that did occur was between functionally related materials - prey and nectar (food materials) or wood pulp and water (nest materials). (2) Individuals differed greatly in activity level, here expressed as rate of foraging. Workers that foraged at high rates specialized on a single material in almost all cases. Specialized, highly active foragers comprised a minority (about 33%) of the working foragers in each colony, yet provided most of the material input. (3) Individual wasps that responded to experimental

nest damage by foraging for nest materials did not gather food on days preceding or following manipulation. (4) On the colony level, nectar and prey foraging rates were not affected by foraging effort allocated to nest repair within days, or when comparing control days with days when damage was imposed. The emergency foraging response to nest damage in P. occidentalis did not depend on effort recruited away from food foraging.(Jeanne,1986). These unique features make *Polybia occidentalis* an apt subject to study.

Factors affecting nesting behaviour

- Among the numerous factors that contribute to the success of social wasps, colony productivity is the most important. Productivity is influenced by ecological elements like temperature, the availability of prey, and the number of founders (Gamboa *et al*., 2005). According to Inagawa *et al*. (2001) and Nadeau & Stamp (2003), environmental factors like the nesting site may also have an impact on the productivity and success of colonies. Due to its impact on the number of offspring produced, nest-site selection is strongly correlated with fitness. As a result, specific nest-site qualities should be taken into account while choosing a nest-site. Because nest predation is frequently the main cause of nest mortality in social wasps, habitat variables that affect the chance of nest predation may therefore be especially significant (Cervo & Turillazzi, 1985).

- Another aspect that influences colony formation is the availability of prey. The opportunistic, generalist foragers known as eusocial vespids. Arthropod distribution and abundance may be impacted by plant structural variability and architecture, as is well documented. Increased structural variability of vegetation, according to Root (1973), may increase the number of niches open to consumers and hence increase the richness of local species. One of the primary prey species (caterpillars) of wasps, butterflies (Collinge *et al*., 2003), have been used as examples to illustrate the relationship between plant species variety and vegetation structure on invertebrate diversity. According to these experts, habitat quality has an impact on the diversity and composition of butterfly species.

- According to Kozyra *et al*. (2016*), P. nimpha* foundresses prefer to build their nests in specific plant species, at a specific height above the ground, and with the combs oriented in a specific geographic direction (azimuth). The azimuth is likely crucial for nest thermoregulation while the surrounding vegetation is still sparse and the nest is directly exposed to sunlight. The first two criteria are crucial for increasing colony survival in the pre-emergence phase, the most perilous early stage of a colony's life cycle. According to these writers, *Hypericum, Tanacetum, Daucus, and Achillea* plants are the ones that start nests the most frequently.

Several observations and discussion

Prior to constructing a nest, the foundress of social wasps must decide on the location in which to construct it. The selection of a suitable nest site is determined by a combination of five main factors: the availability of food, risk of predation, presence and behaviour of conspecifics, availability of suitable nest material and a suitable ambient climate for raising offspring

It is unknown why a wasp chooses a particular plant, however a number of things could influence the decision:

(A) The availability of plants during the late winter emergence of foundresses: According to Kozyra *et al*. (2016), young trees, shrubs, lignified sections of herbaceous plants, or grass culms that are still standing after the winter are the only available nesting locations for wasps.

(B) Protection: A third (33.33%) of the wasp-selected plants at the study site possessed some kind of passive defence (spines, thorns).

(C) Occultation/camouflage: The nests of *P. gallicus* are beige and grey, with dark grey linings, similar to those of *P. dominula* and *P. nimpha* (Bagriaik, 2012). This pattern may help conceal the nest on the majority of the plants that wasps choose, particularly in the late spring and summer when the majority of plants dry up due to high temperatures.

(D) Nest consistency: Polistes use chewed plant fibres from weathered wood and other sources to construct their nest (Jeanne, 1975). Furthermore, long vegetative fibres and plant hairs are preferred by some species of Polistes as nesting materials (Bagriaik, 2012).

Nevertheless, we concur with Kozyra *et al*. (2016) that nest height is crucial for safeguarding the nest from predators. We hypothesise that they build their nests at different heights in reaction to predators, higher from the ground in response to mammalian and ant predators and lower in response to avian predators, as is the case with birds (Mainwaring *et al*., 2014).

Polistes wasps construct unprotected combs with no shelter or safety. As a result, the thermoregulation of their nests is largely dependent on the environment (Höcherl *et al*., 2016). All techniques used to optimise internal temperatures, such as location selection, fall under the category of passive processes of thermoregulation. The ability of social insect colonies to maintain constant nest temperatures is significantly influenced by nest-site selection. There are two main types of nesting sites. For many species, physical protection from environmental disturbances is the primary factor in nest site selection; other species choose locations where the microclimate offers a reasonably consistent temperature (Jones & Oldroyd, 2007).

Research status in India regarding the behaviour of insects

Growing interest in insect behaviour has seen an increasing number of research in this field in India. By using different stimuli insect behaviour can be manipulated for the purpose of pest management. The recent development in the field of behavioural study is the extraction of green fluorescent protein which are incorporated into genes of insects to study the expression of various proteins. Such practices are eco-friendly and safe for human and animal health.

Another important study is in the field of DNA barcoding. Since its proposal in 2003, DNA barcoding is a useful tool to quickly identify species and is used as a complementary approach to traditional Taxonomy in biodiversity studies (Sreedevi *et al*, 2015). DNA barcoding, the method of characterizing species using one or a few con-served and standardized regions of DNA, has become an effective tool in species identifcation or delineation

DNA barcoding hasits application in cryptic species identifcation, identifcation of immature life stages, rapid identifcation in quarantine, host-parasitoid inter-actions, herbivore diet analysis, disentangling food webs, understanding pollinator communities and their interactions using environmental DNA barcodes, identification of species from different environments and in seasonal diversity shifts with the wide use of Sanger sequencing and next-generation sequencing (NGS) technologies, the cost of obtaining each sequence read of a target region has come down drastically.

The advantage of low-cost sequencing technologies encouraged a positive growth in the use of DNA barcoding in scientific studies from India.

Conclusion

Both benefits and drawbacks of living in social groupings can be found. Large colonies are particularly susceptible to the transmission of contagious illnesses, and member individuals must compete with one another for resources and space. Nest sites may also be used by social parasites that steal food or harm the young. On the other hand, collaboration among the members might enable them to carry out tasks that are unfeasible for solitary insects, such as building enormous nests, dispersed food gathering, and constant vigilance against parasitism. An adaptation that helps the species survive and reproduce is social behaviour. Without any personal jealousy or avarice, each social insect colony member continuously contributes to the well-being of the community and the survival of the race.

The nest building behaviour in wasps is very advanced as compared to the other arthropods. The worker wasps collected building materials from far distance due to perception of availability of the construction materials in the surrounding. Nests of wasps are different in size,shape ,structure,and building pattern and provide immense scope for further studies and research.

Variability in nesting behaviour patterns within and among social wasp species must still be investigated.

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Template Synthesis of Closed Packed Polymer Nanostructures: A Superior Material for Photovoltaic Application

Uday Das*

ABSTRACT

The performance of conjugated polymers in photovoltaic devices is primarily constrained due to their small exciton lifetime, inefficient charge transport and narrow absorption cross-section. Further, loose packing in solid films of conjugated polymers leads to low chain overlap (both interchain and intrachain) and a wider energy bandgap. It is envisaged that the improvement in polymer chain packing would therefore help reduce its energy bandgap and increase the carrier transport properties by lowering the hopping length. I use the porous Anodic Alumina membrane to develop closely pack Poly [2-methoxy-5-(2'-ethylhexyloxy)-1,4-phenylene vinylene] (MEH-PPV) nanotubes and nanorods using a wet chemical synthesis approach. MEH-PPV is a widely used conjugated polymer in organic solar cells and light-emitting diode applications. It is observed that the absorption spectra red-shifts to higher wavelengths in MEH-PPV nanotubes and nanorods, indicating their reduction in the bandgap. Exciton lifetime measurements show increased lifetimes for photogenerated excitons, which suggests that in MEH-PPV nanotubes and nanorods the excitons may migrate a longer distance before recombination in comparison to their thin films. Due to the better packing of polymer chains, it is claimed that nanotubes/nanorods may also show improved carrier transport properties which will be beneficial for photovoltaic and other optoelectronic applications.

Introduction

Due to ever-increasing global warming issues, renewable energy source stimulates scientific research for efficient and low-cost photovoltaic devices to create non-CO2 releasing ways for transport and electricity [1,2,3]. Tuning of material properties through chemical manipulation, together with easy and cheap processing techniques, make conjugated polymers potential

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Received: *21 st November, 2022* / ***Accepted:*** *22nd December, 2022*

candidates for the semiconductor industry. Conjugated polymers with a delocalized π-electron system can absorb visible range solar energy to create photogenerated charge carriers and transport them through the π -conjugated backbone in photovoltaic devices [4,5,6,7].

One of the key challenges for organic polymers is solar cell application is rooted in their relatively high energy bandgap (>1.5eV) [8]. Lack of long range ordering, lose packing, and amorphous nature of polymer films gives rise to discrete energy levels with high HOMO-LUMO energy gap [9]. To efficiently absorb the polychromatic solar radiation in solar cells, reduction of the energy band gap of polymers is critically important. Increase in conjugation in the chemical structure through advance synthetic strategy is historically investigated to lowering the energy band gap of polymers [10,11,12,13]. One of the popular ways to tune the HOMO-LUMO gap in polymers is to attach optically sensitive dye molecules to their repeating monomers. Metal-free organic dye Indoline has been successfully linked to the backbone of conjugated polymers to redshift their absorption spectra [14,15,16]. Alternatively, one can significantly reduce the energy band gap of polymers by increasing the chain-chain interaction through morphological ordering. It is observed that π -electron delocalization increases as the overlapping portion of two chain segments increases. For example, if two chains cross each other perpendicularly, the overlapping is minimum whereas, if they are parallel to each other, the overlapping is maximum [17]. In polymers, energy band gap modulation through chain ordering is rare in the literature.

Herein I synthesized nanotubes and nanorods of MEH-PPV polymer using porous Anodic Alumina membrane. The as-synthesized nanotubes and nanorods show redshifts in their absorption spectra due to an increase in overlapping of the p-conjugated chain through ordered close packing. Their absorption spectra are further tuned by controlling the diameter, wall thickness, conjugation length of the polymer chain. The nanotubes and nanorods show a higher exciton lifetime compared to the reported thin film of MEH-PPV. Conjugated polymer nanotubes and nanorods could be a better choice for solar cell application due to their broader absorption cross-section, increased exciton lifetime and improved charge transport along the p-conjugated backbone parallel to the tube axis.

Experimental:

MEH-PPV is dissolved in dichloroethane (DCE) at different concentrations (0.5mg/ml to 2mg/ml), and the solution is stirred with a magnetic stirrer. Anodic Alumina template heated to

about 393K in an oven is suddenly dipped into the MEH-PPV solution kept at room temperature for 10 minutes. Due to capillary action, the solution is entered into the nanochannel of the template. The Anodic Alumina templates are then dried at 343K for 15 minutes to evaporate the solvent. Finally, the Anodic Alumina templates filled with MEH-PPV are dipped in the 0.1M NaOH solution for 30 minutes to dissolve the templates. The solution is then filtered using a nanoporous polymeric membrane. The filtrate is then dispersed in methanol and used for film formation. The MEH-PPV nanotubes and nanorods synthesized using the above methods are characterized using Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), UV-ViS absorption spectroscopy. The exciton lifetime is measured by Time-Correlated Single Photon Counting (TCSPC) decay profiling.

RESULTS AND DISCUSSIONS:

Fig.1(a) shows the SEM images of the MEH-PPV nanorods synthesized using Anodic Alumina templates of 100 nm pore size. The concentration of MEH-PPV solution was used as 2mg/mL for nanorod formation. The magnified view of individual rods is shown in Fig.1(b). By varying the concentration of MEH-PPV, we managed to control the morphology of MEH-PPV nanostructures. At low concentration (0.5mg/ml) holo nanotubes are formed and at high concentration (2mg/ml) solid nanorods are formed.

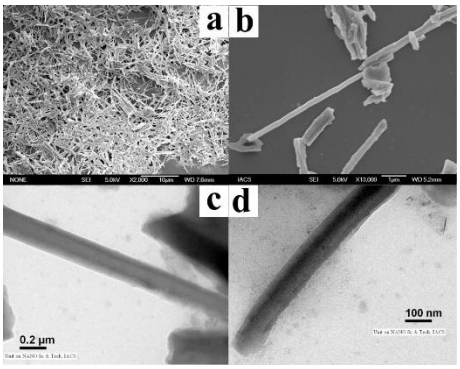

FIGURE 1. 1**(**a**)** SEM micrograph of polymer nanorods, 1(b) Magnified view of single nanorod/nanotube, 1(c) TEM micrograph of single polymer nanotube, 1(d) TEM micrograph of single polymer nanorod

Fig.1(c) and Fig.1(d) show the TEM images of MEH-PPV holo nanotubes and solid rod-like structures depending on the concentration of MEH-PPV. The diameter and length of the nanotubes

and nanorods are determined by the pore diameter and pore length of the Anodic Alumina templates. The average diameter and length of the nanotubes/nanorods are found to be 100 nm and 10 μm, respectively.

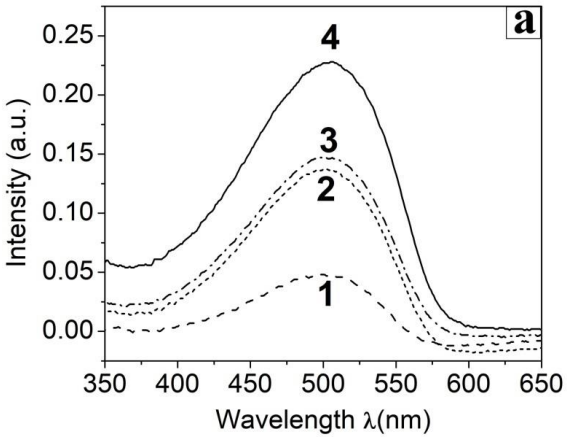

FIGURE 2(a). UV-Vis absorption of different samples. Curve 1 indicates sample 1, curve 2 sample 2, curve 3 sample 3 and curve 4 indicates sample 4

Sample No	Amount of MEH-PPV(mg)	Amount of DCE (ml)	UV-VIS abs(nm)
1	0.5	20	497
2	1.0	20	501
3	1.5	20	506
4	2.0	20	507

TABLE 1. Different concentration of MEHPPV in DCE and their absorption peak position.

Fig. 2(a) gives the UV-VIS absorption spectra of MEH-PPV nanotubes and nanorods synthesized by varying the concentration of MEH-PPV solutions. Four different concentrations used in this study are given in table-1. From the TEM micrograph, it is seen that for the highest concentration of MEH-PPV (2mg/ml), the resultant structure is a solid nanorod, and for the lowest concentration (0.5mg/ml), it is a thin-walled tube. Table-1 shows that for the lowest concentration,

the peak is at 497 nm, and there is a redshift of 10 nm for the highest concentration of MEH-PPV. This is because for the lowest concentration, the tube wall is very thin, and π electron delocalization is small, whereas in the case of solid rods, due to close packing and a large number of polymer chains, a redshift of 10 nm is observed. Alivisatos [10] and others [18,19] in their early work reported the peak wavelength of UV absorption spectra for the bulk film of MEH-PPV as ~ 494 nm. Usually, this value decreases in the case of nanoscale materials due to the special confinement effect. However, in the present work, the absorption peak for MEH-PPV redshifts for both nanotubes and nanorod structures. In the case of nanotubes, the absorption peak appears at 497 nm. The redshift is more pronounced in the case of nanorods, for which the absorption peak appears at 507 nm. This is due to better alignment and close packing of the polymer chains.

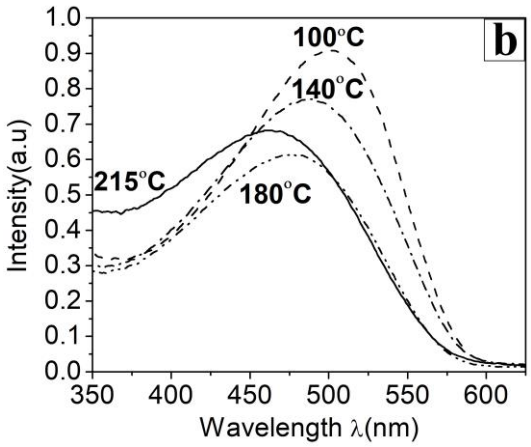

FIGURE 2(b). Annealing effect at different temperatures in ordinary atmosphere

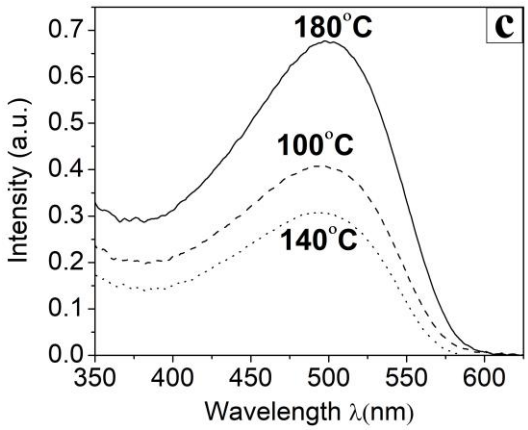

FIGURE 2(c). Annealing effect at different temperatures under Nitrogen atmosphere

Figs 2(b) shows the absorption spectra of sample-4 (2mg/ml MEH-PPV concentration) annealed at different temperatures in the ambient atmosphere. The absorption peak position of MEH-PPV nanorods blue-shifts with the increase in annealing temperatures in ambient conditions. This could be due to oxidation of the MEH-PPV, which leads to a decrease in conjugation length at higher annealing temperatures. To avoid oxidation, the samples are annealed under a nitrogen atmosphere, and no apparent change in absorption peak position is observed (Fig. 2(c)). Annealing of polymer films under an inert nitrogen environment usually leads to a redshift (lower energy) in their energy peak position. This is due to the fact that polymer chains are entangled at room

temperature but becomes uncoiled and closely packed at the expense of heat energy when annealed at higher temperature [20]. This causes a redshift of the annealed film due to better π electron delocalization. In the case of nanorods, the polymer chains are already aligned and closely packed along the growth axis. Therefore, no redshift in the absorption peak is observed in the nitrogen annealed nanorods samples.

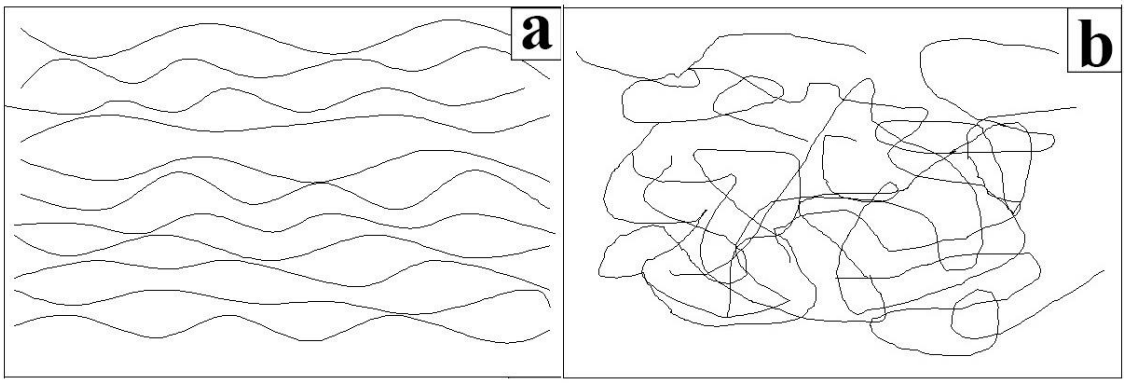

FIGURE 3. Schematic diagram of (a) Uncoiled Polymer chains (b) Coiled Polymer chains

In the present work, commercially available MEH-PPV from Sigma-Aldrich is used to synthesize the nanotubes/nanorods. I believe that the conjugation length of MEH-PPV for all the studied samples remains constant. In view of the redshift in absorption spectra of the nanotubes and nanorods in comparison to reported MEH-PPV film, I proposed that increased conjugation and close packing is the root cause of reduced energy gap in MEH-PPV nanotubes/nanorods. The proposed mechanism is shown schematically in Figs. 3(a) & 3(b). In conjugated polymer, π electron delocalization increases if the overlapping region of different chain segments increases or different chains come very close to each other. As shown in Fig. 3(a), in the case of nanotubes/nanorods, parallel alignment of the polymer chain leads to the maximum overlapping region. In the case of ordinary thin films, crisscross alignment (Fig. 3(b)) reduces the overlapping region (cross position), which is the root cause of their higher energy bandgap.

The performance of a polymer solar cell device essentially depends on three factors- charge generation, charge dissociation and charge transport. In an organic solar cell, excitons are formed

due to photon absorption from the solar spectrum. Once an exciton is formed, it is very important to dissociate it to mobile charge carriers for their collection in solar cells. Usually, excitons migrate via the diffusion process and get dissociated at the heterointerface to form free charge carriers. In the absence of exciton dissociation, the photogenerated exciton can recombine through the radiative or non-radiative process via defect states, traps etc. For efficient photovoltaic performance, the excitons mustn't recombine before their dissociation occurs. Therefore, an increase in exciton lifetime is beneficial in achieving high photovoltaic performance.

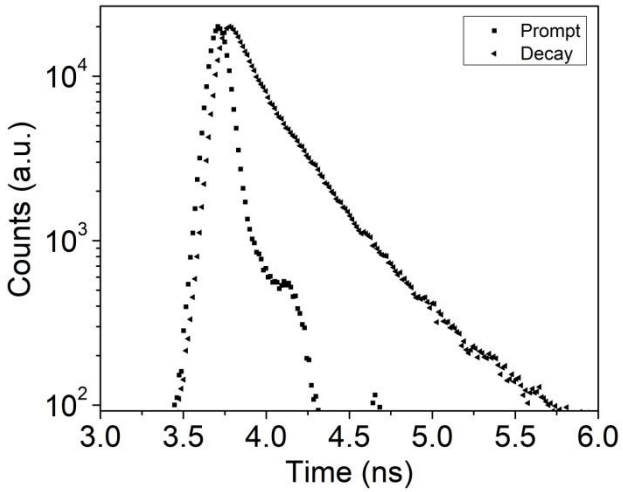

FIGURE 4. Typical Time Correlated Single Photon Counting (TCSPC) decay profile of Polymer nanotubes/nanorods.

To check the exciton lifetime is nanotubes/nanorods of MEH-PPV polymer, I carried out time-resolved PL spectroscopy for all the samples. Fig. 4 shows a typical result of time-resolved spectra for sample 2, from which two decay constants, one ~150 ps and the other ~500 ps, have been extracted. Early reports [21,22,23] show that time constants for intrachain and interchain exciton diffusion in the bulk film of pure MEH-PPV is about 20 ps and 100ps, respectively. Therefore, in the present series of samples, ~150 ps correspond to the intrachain contribution, and ~500 ps is the interchain contribution.

From electrical measurements, it is generally observed that polymer nanotubes/nanorods show improved electrical conductivity compared to films and particles. The better chain alignment and

interchain connection, less cross-linking and comparatively defect-free chains are the origins to achieve this improved electrical conductivity [24,25]. In the present work, it is seen that lifetimes for samples are higher compared to films. It means the exciton migrates over a longer distance along the aligned polymer chain, contrary to the film where this distance is very small as the exciton decays radiatively or non radiatively due to defects states and traps arising from cross-linking or entanglement of polymer chains. To study charge transport, an electron transport layer needs to be incorporated on the surface of MEH-PPV nanotubes to dissociate the exciton to form a charge carrier for transport. Such work is now in progress.

Conclusion:

In summary, MEH-PPV nanotubes/nanorods have been synthesized using the nanochannel of the Anodic Alumina template. UV-ViS absorption data shows that the absorption spectra redshift in developed nanotube/nanorods due to better p-electron delocalization and close packing of polymer chains. Exciton lifetime, an important parameter for photovoltaic application, also increases due to better alignment and defect-free polymer chains.

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PROTECTING THE PRECIOUS SUNDARBANS: A COMPREHENSIVE REVIEW OF BIODIVERSITY, THREATS AND CONSERVATION STRATEGIES IN THE MANGROVE ECOSYSTEM

Aloke Saha[1]

Chandan Sarkar[2]

ABSTRACT

The Sundarbans is a unique and highly productive ecosystem in the intertidal zone. This mangrove ecosystem is the aggregation of plants, animals, and microorganisms that are acclimatized to the unsteady, fluctuating environment of the tropical seashore zone. This mangrove ecosystem is a highly valued ecosystem in terms of ecology, environment, and economics. The mangrove ecosystem of the Sundarbans is a World Heritage Site and a unique wetland in terms of its biodiversity and ecology. As the largest coastal wetland in the world, Sundarbans covers an area of 1,000,000 hectares of land and water, of which 60% is situated in Bangladesh and the remaining 40% in India. This area experiences annual rainfall of 1600–1800 mm and severe cyclonic storms. The huge amount of sediment carried by the rivers helps in the improvement of soil quality. The biodiversity includes 350 species of vascular plants, 250 species of fish, 300 species of birds, 250 species of insects, 70 species of mammals, 7 species of amphibians, 49 species of reptiles, and numerous species of plankton and microbes. Sundarbans is the exclusive habitat of many rare and endangered animals (*Batagur baska, Pelochelys bibroni* and *Chelonia mydas*) and plants. It is the main habitat of the Royal Bengal tiger (*Panthera tigris*). The biodiversity is threatened for several reasons, like deforestation, erosion, pollution, overexploitation of fish, floral, and faunal components. Climate change is also a big problem. The paper discusses the necessity of conservation strategies, which are needed for the protection of biodiversity in the Sundarbans.

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Received: *1st October, 2022 / **Accepted:** 3rd November, 2022*

Keywords: *Conservation, Endangered Wildlife, Mangrove Ecosystem, Sundarbans, Wetland*

1. Introduction:

The term mangrove refers to woody halophytic trees of the seashore zone of the coastal-estuarine region. Mangroves are confined to tropical and subtropical regions (Tomlinson 2016). The total global area of the mangroves is only 18.1 million hectares (Spalding1997). The mangrove ecosystem is one of the most productive wetlands found in the coastal zone of the world (Chaudhuri and Choudhury 1994). The mangrove in the Ganga-Brahmaputra-Meghna delta is shared between India and Bangladesh, and it is the largest coastal wetland system in the world. The Sundarbans mangrove ecosystem is of immense ecological, economic, and cultural significance. It is the largest mangrove forest in the world, covering an area of approximately 10,000 Km^2. The Sundarbans play a crucial role in supporting the biodiversity of the region, providing habitats for a wide range of flora and fauna. It is home to several endangered species. The Sundarbans also supports a diverse range of aquatic life and provides livelihoods for millions of people who depend on fishing, honey collection, and other forest products. The Sundarbans also serves as a natural buffer against storms, floods, and other natural disasters. This ecosystem is 20 times more productive than oceanic production (Ghosh et al. 2015). Mangrove ecosystems are recently threatened by global climate changes and particularly sea level rise (Ward et al. 2016). In this review, we discuss the current state of our knowledge about the biodiversity of the Sundarbans, ecological interaction of mangrove flora and fauna, and different threats to and conservation strategies for this ecosystem.

2. The Sundarbans:

The Sundarbans (21º 30′ to 22º 40′ N, 88º 05′ to 89º 55′ E) include various islands that are formed by the sediments deposited by three major rivers (the Ganga, the Meghna, and the Brahmaputra) and a network of smaller rivers. The western limit of the Sundarbans is defined by the River Hooghly, and the eastern limit is defined by the River Baleshwar. The River Ichamati demarcates the border between India and Bangladesh. About 60 percent of the mangrove forest is in Bangladesh, and the rest is in West Bengal. The area of the Sundarbans in India is 426,300 ha and in Bangladesh it is 599,330 ha (Gopal and Chauhan 2006).

2.1. Climate:

Seasons are very well defined in the Sundarbans, each with a three-month duration. The premonsoon lasts from March to May with almost no rainfall and a high temperature of 42°C. The monsoon season lasts from June to August with moderate temperatures and high rainfall (2000 ml). The postmonsoon lasts from September to November with the lowest temperature of 10°C and occasional rainfall. The temperature and humidity (>80%) remain very high throughout the year, and well-distributed rainfall occurs during the monsoon season. The maximum air temperature in March is around 43 °C. The temperature of the Sundarbans is increasing gradually. The average annual rainfall in the Bangladesh region is only 2790 mm. In the Indian region, average annual rainfall is only 1661 mm. Most of the rainfall (about 74%) occurs during the monsoon period (Sahana et al. 2021).

2.2. Geology:

Several geological changes, including tectonic movements in the northwestern and southeastern flows of the Ganga, resulted in the deposition of sediments and the development of the Sundarbans (Stanley and Hait 2000). It's significant that the Ganga and Brahmaputra rivers along with them carry the world's largest sediment load to the oceans. Throughout the sixteenth century, the Ganga modified its course to shift eastward and become a part of the river Brahmaputra (Ganguly et al. 2006). Later, within the middle eighteenth century, the combined Ganga and Padma rivers once more inclined eastward to empty into the River Meghna. Most of the rivers, apart from the Hooghly, that contributed to the formation of the Ganga Delta have lost their connections with the Ganga due to siltation (Ganguly et al. 2006).

2.3. Soil:

A complex network of waterways runs in a generally north-south direction and intersects the whole area. Easily eroded sands are deposited at the river mouths, where they form banks and canyons. Loam is the main soil type in the Sundarbans, though sandy and silty loams also occur. Clays with sludge occur in swamps and alluvial lakes. The deposits in the mouth of the river are rich in calcium or magnesium and organic matter (Biswas et al. 2021). The coastal soils are classified as saline, non-saline, and alkali soils. The surface soil is soft and fertile in the eastern part of the coast,

and in the west part it is harder and less fertile (Choudhury, 1968). The average soil pH is 8.0 (Muhibbullah et al. 2005).

2.4. Hydrology and salinity:

The hydrology of the Indian Sundarbans is mainly governed by the rivers Ganga, Brahmaputra, and Meghna and their associated tributaries and tides. The freshwater flows from the rivers, and the recurrent events result in a gradient of salinity. Water is usually fresh on the inland side of the Sundarbans; salinity is higher near the coast. The construction of dams and barrages in the River Ganga has resulted in a decreased silt load and less deposition (Wahid et al. 2017; Islam and Gnauck 2011).

2.5. Tidal level, volume and duration:

The shoreline zone represents that part of the continental shelf that remains between high and low tidal levels. The intertidal zone is mainly classified into three different sub-zones, such as high tide level (HTL), mid-tide level (MTL), and low tide level (LTL). The high tide level is the uppermost part of the intertidal zone. The low tide level represents the lowermost part of the intertidal zone. The mid-tide level is the maximum area of any intertidal zone, ranging from the uppermost border of the low-tide level to the lowermost border of the high-tide level (Pitchaikani and Bhaskaran 2019).

3. Biodiversity of Sundarbans:

Due to a wide range of variation in different ecological conditions (temperature, rainfall, nutrients, salinity, pH, etc.) and ecological processes (duration of tidal exposure and inundation, erosion, accretion, volume of water, fresh water inflow and mixing with saline water, etc.) in different streams, feeders, marshes, sandflats, and mudflats, the Sundarbans mangrove supports a rich diversity of flora and fauna. The variability in hydrological regimes, topography, salinity, and their interactions ensure an equally diverse biodiversity. The gradients of salinity and freshwater occur across the Sundarbans from west to east, and they are clearly reflected in the floral distribution. The following information is largely based on the Indian Sundarbans, with frequent comparisons with the Bangladesh Sundarbans (Gopal and Chauhan 2006; Gopal and Chauhan 2016).

3.1. Floral diversity:

3.1.1. True mangrove and mangrove associated species:

Mangrove plants are broadly classified into true mangrove, mangrove associate, and back mangrove species. Globally, Duke (1992) recognized 69 species of true mangroves, which include members of 26 genera and 20 families. Of these, at least 30 true mangroves occur in the Indian Sundarbans (Gopal and Chauhan 2006). Debnath and Naskar (1999) identified 36 species of true mangroves in the Sundarbans. A summary of the studies of Maiti (1999), Ghosh et al. (2003), Mukherjee (2004), and Sharma and Naskar (2010) gave an estimate of about 180 species under 54 families and 118 genera. Usually, the Bangladesh part of the Sundarbans differs in the relative abundance of various mangrove species. The flora classified as mangrove taxa exhibits features like salt tolerance mechanisms, viviparous germination, and aerial roots (pneumatophores). The main families of mangroves are Rhizophoraceae, Combretaceae, Arecaceae, Avicenniaceae, Agialitidaceae, Poaceae, Sonneratiaceae, Sterculiaceae, Meliaceae, Euphorbiaceae, Rubiaceae, and Acanthaceae (Sharma and Naskar 2010). Mainly, two types of propagules are found in mangrove forests. The first type of propagule is transported to another location by the effects of tidal currents after falling from the mother plant (Avicennia, Sonneratia, and Aegialitis). The second type of propagules has hypocotyles, and they find substratum for establishment after falling from the mother plant (Rhizophora, Bruguiera, and Kandelia) (Ismail, 1990). *Heritiera fomes* (Sundari) is the most important timber species of the Sundarbans (Mukherjee et al., 2017).

Mangrove associates are plant species that are entangled with the mangrove community in riverine forests. The herbaceous non-mangroves generally grow as climbers. The most common climbers are *Cassythafili formis*, *Pentatropis capensis*, *Tylophora tenuis*, *Finlaysoni aobovata*, *Macrosolen cochinensis*, *Viscum monoicum* and *Viscum orientale*. Back mangroves grow near mangrove stands toward the landward side. They are able to grow in high salinity and low-nutrient soils. *Hibiscus tiliaceous*, *Thespesia populneioides*, *T. populnea*, *Dalbergia spinosa*, *Dalbergia monosperma*, *Dalbergia candenatansis*, *Instia bijuga* and *Cerbera odollam* are the most common back mangrove species. *Pluchia indica* is a coastal indicator species with a dense population on human-inhabited islands (Maiti 1999).

3.1.2. Sea Grasses: Sea grasses are submerged marine angiosperms. These belong to three monocotyledonous families, such as Hydrocharitaceae, Potamogetonaceae, and Ruppiacae. Only one species of sea grass, *Ruppia maritima*, is found in the Sundarbans, where it grows mainly in brackish water.

3.1.3. Algae: Algae are the most important primary producer group that sustains the total ecosystem. The Sundarbans have a highly diverse algal flora. Islam (1973) has reported 34 species of planktonic and benthic algae in the Bangladesh Sundarbans. Sen et al. (1999) listed 80 species of algae from the Indian Sundarbans. Banerjee and Santra (1999) recorded 48 species of diatoms. Recently, Naskar et al. (2004) have listed 150 species of algae. The Sundarbans have an algal diversity of 270 species (Sarkar, 2017). *Caloglossa*, *Botrychia* and *Catenella* species form a covering on mangrove tree trunks and pneumatophores (Mandal and Naskar, 1994). Observations have established that different habitats offer a variety of niches with sufficient diversity to allow several morphologically similar algal species to coexist. Blue-green algae prefer a soft, biologically active mud with organic matter, while green algae prefer soil rich in nutrients previously released by bacterial flora and blue-green algae. Finally, red and brown algae prefer hard, compacted soil (Sen et al. 2002).

3.1.4. Lichens: Lichens are symbiotic organisms composed of a fungal partner, the mycobiont, and one or more photosynthetic partners, the photobiont, that may be either a green alga or a cyanobacterium. They are referred to as 'bioindicators' for detecting air or water pollution (Sinha, 2017). More recently, the detailed study of lichens in the Sundarbans resulted in 167 species under 56 genera and 25 families. Most common lichens of Sundarbans are *Anthracothecium bengalense*, *Arthonia ravida*, *Arthothelium atro-olivaceum*, *Cryptothecia alboglauca*, *Arthothelium nigrodiscum*, *Buellia curatellae*, *Stirtonia alboverruca*, *Pyrenula subcylindrica*, *Anisomeridi umubianum*, *Arthothelium adveniens*, *Anisomeridium consobrinum*, *Arthonia radiate* and *Arthopyrenia analepta* (Sinha, 2017).

3.1.5. Fungi: Fungi are one of the ‘mega-diverse’ groups of organisms. They help in many ecological processes like bioremediation, nutrient recycling, litter decomposition, and soil

formation. In the Indian mangrove ecosystem, approximately 150 species of mangrove fungi have been reported (Manoharachary et al. 2005). The majority of research in the Indian Sundarbans has focused on macro-fungi rather than micro-fungi (Pal and Purkayastha 1992). Dutta et al. (2013) found a total of 62 species of macro-fungi distributed within 46 genera, 27 families, and 10 orders.

3.2. Plankton diversity:

The term plankton refers to any small biota (size range from a few microns to cm) living in the water. Plankton is classified into six types: megaplankton, macroplankton, mesoplankton, microplankton, nanoplankton, and picoplankton. Megaplanktonare larger than 20 cm and include large jellyfish, salps, etc. Macroplankton are generally 2–20 mm in size and include comb jellies and jellyfish. Mesoplankton are generally between 0.2 and 2 mm in size and include copepods, small salps, etc. Microplankton are generally 20–200 micron in size and include diatoms, dinoflagellates, nauplii, etc. Nanoplankton are generally between 2 and 20 microns, and they include single-celled diatoms, flagellates, small ciliates, etc. Protists, bacteria, and archaea are all examples of picoplankton, which ranges in size from 0.2 to 2.0 microns. Based on function and trophic level, plankton are classified into bacterioplankton, phytoplankton, and zooplankton. Bacterioplankton play an important role in the remineralization of organic matter. Whereas phytoplankton (autotrophic) are key to primary productivity and require light for photosynthesis. Zooplankton feed on phytoplankton, so energy is transferred from phytoplankton to zooplankton (Aziz et al., 2012).

3.3. Faunal diversity:

3.3.1. Protozoa: Recently, a total of 171 protozoan species belonging to 86 genera have been recorded from the Indian Sundarbans. These protozoan species belong to four phyla: Sarcomastigophora, Apicomplexa, Myxozoa, and Ciliophora. Sarcomastigophora includes 62 species in 29 genera. Apicomplexa includes 36 species under 15 genera. Myxozoa includes 25 species under 12 genera. Ciliophora includes 44 species under 19 genera. Among the free-living protozoan species, dinoflagellates and foraminifera are two important groups (Biswas and Bandyopadhyay 2016).

3.3.2. Molluscs: Molluscs are a highly diversified and heterogeneous group of animals that are popularly known as shells or snails. In the Sundarbans, the molluscs belong to 177 species in 80 families. Out of 177 species, 14 are terrestrial, 133 are estuarine and marine species, and 30 are freshwater species. Gastropoda are represented by 102 species, Bivalvia are represented by 67 species, Cephalopoda are represented by 7 species, and Scaphopoda are represented by only one species (Dey 2006).

3.3.3. Annelids: Annelids are a diverse group of segmented worms that play a crucial role in the ecological functioning of the Sundarbans mangrove ecosystem. They contribute to nutrient cycling, soil aeration, and decomposition of organic matter, which are essential for maintaining the health of the ecosystem. Annelids in the Sundarbans include the polychaetes, oligochaetes, and hirudineans, which inhabit a range of habitats such as mudflats, mangrove roots, and intertidal zones. They are an important food source for many aquatic and terrestrial animals, including fish, birds, and crabs. There are several important annelid species found in the Sundarbans mangrove ecosystem, including: Nereid worms, Bloodworms (*Glycera dibranchiata*), Lugworms (*Arenicola cristata*), Marine Leeches (*Hirudinaria granulosa*), and *Tubifex* worms. So far, 55 species of polychaetes have been recorded. Most of the species are restricted to the mouth region of the estuarine complex. Out of 55 species, 38 species belong to the Errantiate family, and 17 species belong to Sedentarian species (Sanitha K. Sivadas and Russell Carvalho 2020; Siddique et al. 2022).

3.3.4. Crustacea: Crustacea belong to the phylum Arthropoda, which includes barnacles, crabs, wood lice, shrimp, lobsters, crayfishes, and wood lice. Total of 329 species of 183 genera of crustaceans recorded so far from the Sundarbans. Crustacea are of great economic, ecological, and medical importance. They are the second-most important source of protein after fish. Some crustacean species are also pollution indicators (Mandal and Nandi 1989).

3.3.5. Insect: Mitra et al. (2016) recorded 591 species of insects, which includes 404 genera in 100 families belonging to 13 orders in the Indian parts of the Sundarbans. Diptera (133 species), Hyemnoptera (96 species), Coleoptera (81 species), Orthoptera (19 species), Dermaptera (8

species), Isoptera (7 species), Neuroptera (6 species), Thysanoptera (2 species), Blattodea (2 species), and Phthiraptera (2 species) have the most species richness.

3.3.6. Fish: The fish diversity of the Sundarbans reflected a high species richness. The fish fauna of the India Sundarbans includes 350 species belonging to 225 genera, 86 families, and 25 orders (Mishra and Gopi 2017). The Bangladesh Sundarbans support 322 species belonging to 217 genera, 96 families, and 22 orders. Mukherjee (1975) listed only brackish-water and marine species of fish in the Sundarbans. Recently, Dubey et al. (2015) reported 62 freshwater-inhabiting fishes. Elasmobranchs comprise only 36 species belonging to 21 genera, 10 families, and 6 orders. The rest, 314 species in 204 genera, 76 families, and 19 orders, are Osteichthyes. The primary freshwater fishes of the Sundarbans belong to the families Notopteridae, Cyprinidae, Pangasidae, Clariidae, Heteropneustidae, Adrianichthyidae, and Aplocheilidae. Synbranchidae, Cobitidae, Horabagridae, Bagridae, Schilbeidae, Siluridae, Sisoridae, Mastacembelidae, Datnioididae, Badidae, Nandidae, Anabantidae, Osphronemidae, and Channidae. However, only 20 species are freshwater forms, and the other 23 species are marine forms (Mishra and Gopi 2017). The dominant fishes in brackish water are *Hilsa ilisha*, *Pomadasys hasta,* and *Coilia sp*. *Hilsa*, *Pama, Polynemus*, etc. are mainly marine, but they travel through estuaries to upstream areas for breeding and again go back to the sea after breeding. *Scoliodon, Pristis, Sphyrna, Rhinobatus,* and *Aetobatis* also invade the estuary (Mishra and Gopi, 2017). The most common gobiids are *Boleophthalmus boddarti, B. histophorus, Periopthalmodon schlosseri, Brachygobius nanus* (Ham), *Gobiopterus chuno* and *Gobius elegans*. They are known as mudskippers (De and Nandi 1984).

3.3.7. Amphibia: The species richness of amphibians is mostly similar in the Sundarbans of India and Bangladesh: 8 and 7 amphibians in each country, respectively (Hussain and Acharya 1994). Mandal and Nandi (1989) have reported 7 species of amphibians. Among amphibians, frogs and toads are very common in this mangrove zone. The Common Indian Toad (*Bufo melanostictus*) and *Microhyla ornata* are terrestrial in habit. Only the tree frog (*Racophorus maculatus*) is arboreal in habit (Mandal and Nandi 1989).

3.3.8. Reptilia: The species richness of reptiles is mostly similar in the Sundarbans of India and Bangladesh: 53 and 59 reptiles in each country, respectively (Hussain et al. 1994). Mandal and Nandi (1989) have reported 56 species of reptiles from the Sundarbans. Agarwal and Ghose (1995) have reported 17 species of reptiles from the Sundarbans. In 2005, Chowdhury and Vyas reported 41 species of reptiles from the Sundarbans. Varanus and snakes like the Python, Cobra, Krait, and Viper are ground dwellers. The population of these reptiles has become reduced due to the commercial value of their skin. *Varanus salvator* and *Varanus flavescens* are carnivorous in habit, and they feed mainly on mollusks and crustaceans. A few species of snakes, like the Common Indian Bronzeback (*Dendrelaphis tristis*), *Ahaetulla nasuta* and *Lycodon aulicus* inhabit the mangrove trees (Mandal and Nandi 1989). Common reptiles in estuaries are sea snakes, turtles, and crocodiles. Common sea snakes are *Hydrophis obscurus*, *H. nigrocinctus*, *H. caerulescens* and *Microcephalophis gracilis*. Common turtles are represented by *Balagur baska*, *Lepidochelys olivacea, Trionyxgan geticus*, and *Lissemys punctata*. *Lepidochelys olivacea* is an endangered species. Captive rearing of the Olive Ridleys (*Lepidochelys olivcea*) has been initiated at Bhagabatpur Crocodile Rearing Centre by the Govt. of West Bengal (Mandal and Nandi 1989).

3.3.9. Aves: The avifauna of the Sundarbans is very rich. Total 234 species of birds under 46 families are found in the Sundarbans (Mookherjee 2017). Out of 234 species, 149 are resident and 85 are migrant. 92 species of the order Passeriformes are the most abundant in this area. Four bird species are found here that are mainly restricted to the mangrove forests of India: the Mangrove pitta, the Brown-winged and Collared Kingfisher, and the Mangrove Whistler (*Pachycephala grisola*). The red jungle fowl (*Gallus gallus*) is very common on the forest floor. The Eurasian Collared Dove (*Streptopelia decaocto*) and the Orange-breasted Green Pigeon (*Treron bicincta*) are also very common birds of the Sundarbans (Mookherjee, 2017). A very uncommon species is the Spoon-billed Sandpiper, *Eurynorhynchus pygmeus*. A total of 30 species of small waders, like sandpipers, stints, plovers, curlews, etc., and nine species of gulls are found here. The Mangrove Whistler, *Pachycephala grisola*, is definitely found (BirdLife International, 2023). Apart from the wetland birds, there is also a considerable variety of forest birds, such as shrikes, drongos, mynahs, minivets, woodpeckers, barbets, babblers, and many others (Mahmud et al. 2020).

3.3.10. Mammalia: Mammalian diversity exhibits huge differences between the Indian and Bangladeshi sides of the Sundarbans. The Indian Sundarbans have 31 species of mammals and the Bangladesh Sundarbans have 49 species of mammals (Hussain and Acharya 1994). Mandal and Nandi (1989) reported 47 mammals from the Indian Sundarbans. Six mega-herbivore species, namely the water buffalo (*Bubalus bubalis*), swamp deer (*Cervus duvauceli* Cuvier), Javan rhinoceros (*Rhinoceros sondaicus*), gaur (*Bos frontalis* Lambert), and hog deer (*Axis porcinus),* have disappeared locally. Another mammal belonging to the Artiodactyla that has disappeared from the Indian Sundarbans is the barking deer, *Muntiacus muntjak*. The one-horned rhinoceros (*Rhinoceros unicornis*), Indian bison (*Bos gaurus),* and Sambhar (*Cervus unicolor*) are also now locally extinct (Mukherjee 2017). The population of Rhesus macaques (*Macaca mulatta*) is declining gradually. The Sundarbans of Bangladesh and India support one of the largest populations of tigers, *Panthera tigris*. Spotted deer (*Cervus axis*) and wild boar (*Sus scrofa),* which occur in large numbers, are the principal prey of tigers (Mukherjee 2017). On average, 23 people are killed by tigers every year. Recent analysis suggests that the killing of humans is partly related to the frequency of tiger-human interaction (Mallick 2011). Wild cats such as *Felis bengalensis, F. chaus,* and *F. viverrina* are very common in the Sundarbans. Another very common animal is the Ganges River Dolphin (*Platanista gangetica*) (Gopal and Chauhan 2006).

3.4. Microbial diversity: The diversity of bacteria in the Sundarbans has not been thoroughly studied. Although some reports mention the effects of various microbes on decomposing litter and soil, bacteria play a significant role in mangrove environments. In the Sundarbans, salinity and total suspended solids play a unique role in determining the distributional pattern of microbes. Along with salinity, sewage from adjoining municipalities plays an important role in determining the distribution pattern of microbes (Pramanik et al. 2019).

4. Ecology of Sundarbans:

The ecology of the mangrove ecosystem includes the interactions among its different structural components, viz., plants, animals, microbes, soil, and water.

4.1. Trophic relationship: Three different types of green plants, i.e., mangrove plants, benthic algae, and phytoplankton, represent the first trophic level as primary producers. Primary producers are taken up as food by primary consumers. Primary consumers represent the secondary trophic level. The secondary trophic level includes insects, intertidal crabs, molluscs, deer, wild boars, birds, etc. The fauna of tertiary trophic levels is usually carnivorous and also omnivorous. The fauna of the tertiary level is also the secondary consumer. Omnivores and carnivores of the tertiary level are larger fish, dolphins, water monitors, leopard cats, turtles, and different birds. The ultimate end of the trophic level includes top carnivores like the Royal Bengal tiger (*Panthera tigris tigris), the* crocodile (*Crocodylus porous),* etc. (Neogi et al. 2017; Borrell et al. 2016).

4.2. Role of Physicochemical parameter: Several physicochemical parameters of soil and water determine the variation of biodiversity components and govern their succession and distribution. Different physicochemical parameters of soil also control biological productivity by maintaining energy flow. They also control the decomposition cycle. Fluctuations of temperature, precipitation, wind flow, etc., along with marine physical processes like tides and waves, make this mangrove environment very unstable (Basu et al. 2021).

4.3. Ecology of Flora: Change of plant species composition and distribution occurs from east to west in the Sundarbans. 24 true mangrove species, 21 mangrove-associated species, and 9 bio-invasive plants are found in the north-east region of the Sundarbans. 17 true mangrove species, 19 mangrove-associated species, and 10 bio-invasive plants are found in the south-west region of the Sundarbans. 16 true mangrove plant species and 8 mangrove-associated plant species are found in the central part of the Sundarbans (Rahman and Asaduzzaman 2013). Changes in distributional patterns are affected by salinity, water holding capacity, and the textural composition of soil. Various factors that affect forest structure and distribution pattern of mangroves include land building processes that lead to autogenic succession of mangrove forests, physiological adaptations of mangroves to stress gradients in shoreline zones, and dispersal patterns of mangrove plant species propagules in accordance with rooting time (Hutchings & Saenger, 1987).

4.4. Ecology of Fauna: The ecology of plankton and benthos in the Sundarbans has been studied extensively by different researchers. Sarkar et al. (1986) discovered that the copepod is the dominant zooplanktonic group with the highest population density during the monsoon. Crabs and molluscs in the Sundarbans mangrove ecosystem displayed seasonal fluctuations in population density. Crab's population density is highest during the premonsoon. Population density of polychaetes is maximum during the monsoon (Murugesan et al. 2018). Abele (1974) described that the substrates play an important role in determining the species composition in various habitats. A species can use one substrate as a feeding ground and a source of nutrition and another as a shelter. In this way, a greater number of species can inhabit a small zone. The nutrients of the mangrove ecosystem play a vital role in determining the community interactions of the fauna (Gokul and Seth 2017).

5. Threats to the Biodiversity of Sundarbans:

Many natural and anthropogenic threats that have an impact on biodiversity of Sundarbans. More than 50,000 people enter the Sundarbans forest areas daily to take resources for their livelihood. The collection of timber by cutting mangrove trees, fuel wood from trees, and golpata leaves for multipurpose uses such as roof thatching, partitioning, fishing in the rivers and catching crabs in mud, and the collection of honey from beehives are the main sources of income (Ghosh et al. 2015). The Sundarbans is facing a number of challenges that are leading to a loss of biodiversity. One of the primary causes is habitat destruction, which is largely driven by human activities such as deforestation, industrialization, and urbanization. Climate change is also having a significant impact, causing sea level rise, increased salinity, and changes in rainfall patterns that are affecting the forest's ecology. Pollution, both from land-based sources and marine debris, is another major cause of biodiversity loss in the Sundarbans. Overfishing and poaching, as well as human-wildlife conflicts, are also contributing to the decline of various species in the area (Aziz and Paul 2015). Development of fisheries, aquaculture, and agriculture promoted large-scale possession of land on deltaic islands, which is leading to deforestation. Large-scale destruction of juveniles of different fish species is occurring for the collection of shrimp juveniles (*Peneaus monodon*), which is used in semi-intensive aquaculture. Now a days, nylon nets with small mesh sizes have become a major threat to marine turtles, threatened fishes, and migratory birds (Ashton 2008). The changing flow

pattern of the Ganga river due to faulty neotectonic movements during the last few centuries has influenced the hydrology of the Sundarbans region (Stanley and Hait 2000). Improper use of fertilizers and pesticides in the catchment areas of the Ganga and Brahamaputra rivers pollutes both the water and the land mass, and it also affects the vegetation and fauna directly. Major pollution occurs through oil spills from fishing boats and passenger-carrying boats (Rahman et al. 2009). The construction of the embankment hampered the water circulation and changed the sedimentation pattern of the river. Ecotourism in different parts of the Sundarbans is causing the degradation of the coastal area (Abdul 2014).

A time series analysis of the change in the geomorphic features of the Sundarbans over the past 32 years shows some important changes like an increase in salinization, the development of saline banks within mangrove swamps, and the degradation of mangrove swamps (Mahmudur Rahman 2012). During the previous centuries, many disastrous cyclones had struck the Sundarbans, but due to the vast area of the Sundarbans forest, those storms could not cause much damage to the coastal area. About 28% of the Sundarbans have been damaged by Cyclone Amphan in 2020 (Mishra et al. 2021). Global warming accelerates erosion by increasing the intensity of currents. Changes in the abiotic parameters like sea level rise, salinity invasion, and low pH affect the biodiversity of this dynamic ecosystem (Neogi et al. 2017).

6. Conservation of Biodiversity of Sundarbans:

The Sundarbans, the world's largest mangrove forest, has been the focus of numerous conservation efforts by governments and NGOs in recent years. The Indian and Bangladeshi governments have implemented a range of measures to protect the forest, including the creation of protected areas, the introduction of stricter penalties for poaching and illegal fishing, and the promotion of sustainable livelihoods for local communities. NGOs such as WWF, IUCN, and Conservation International have also been involved in a variety of conservation initiatives, such as conducting research, community engagement, and awareness-raising campaigns (Aldashev and Vallino 2019). Conservation of the Sundarbans has started with its declaration as a reserve forest (Indian Forest Act of 1878). After enlisting the Bengal tiger (*Panthera tigris tigris*) as an endangered species, the hunting of tigers was banned completely in 1970. In 1973, under Project Tiger, the Government of India established a Tiger Reserve in the Sundarbans, which covers 2,585 Km^2. The core area,

which is 1,330 Km^2, was designated as a national park (Mallick 2012). In 1976, another sanctuary was established on Haliday Island to protect the wild boar (*Sus scrofa*), spotted deer (*Axis axis),* and rhesus macaque (*Macaca mullata*). The Sundarbans National Park of India was included in the World Heritage List in 1987. The Sundarbans of Bangladesh were also inscribed on the World Heritage List in 1997 by the IUCN. Collection of seeds of black tiger prawn (*Penaeus monodon*) is allowed in the manipulation zone. Efforts are being made to rehabilitate the degraded areas through afforestation. The estuarine crocodile and the Olive Ridley turtle are receiving some attention for conservation by way of captive breeding. The Sundarbans Tiger Reserve has started a conservation program for sea turtles (Gopal and Chauhan 2018). These efforts have resulted in some notable successes, including the increase in tiger populations and the introduction of sustainable fishing practices. The local people play a crucial role in creating mass awareness and conservation efforts in this fragile ecosystem. Local people can educate and create awareness among others about the importance of the Sundarbans ecosystem, its biodiversity, and the threats it faces. This can be done through organizing awareness camps, workshops, and seminars. Local people can initiate community-based conservation efforts by working with forest officials, NGOs and other stakeholders. Local people can be encouraged to engage in sustainable livelihoods such as eco-tourismand sustainable fishing. Local people can report any illegal activities to the authorities. Local people can participate in policy-making processes related to the Sundarbans ecosystem by providing inputs, feedback, and suggestions to the government and other stakeholders (Chandra and Biswas 2022; Ghosh 2015; Begum et al., 2022; (Mondal and Das 2022). In summary, their knowledgeand participation are critical in creating mass awareness and conservation efforts in this fragile ecosystem. However, challenges remain, particularly in addressing the root causes of biodiversity loss such as habitat destruction and climate change.

7. Conclusion:

The Sundarbans mangrove ecosystem, located in the delta region of the Ganges, Brahmaputra, and Meghna rivers in Bangladesh and India, is of paramount importance for both ecological and socio-economic reasons. The Sundarbans is the world's largest contiguous mangrove forest and serves as a natural barrier against cyclones and storms, protecting millions of people from their devastating impacts. It is also home to numerous endangered and endemic species, including the

Bengal tiger, Indian python, and saltwater crocodile. The Sundarbans also provides essential ecosystem services, such as carbon sequestration, fisheries, and timber, supporting the livelihoods of millions of people. However, the Sundarbans is under threat from climate change, sea-level rise, and anthropogenic activities such as deforestation, overfishing, and pollution. Therefore, the conservation of the Sundarbans is critical to maintaining ecological integrity, protecting biodiversity, and sustaining human well-being. Although many significant conservation measures have been taken for the biodiversity conservation of the Sundarbans, an integrated plan and immediate action are required on the basis of the recommendations and outcomes of multidimensional research. Based on the research, proper guidelines are needed to be drafted for future steps.

ACKNOWLEDGEMENT:

We would like to express our deep gratitude to the Officer-in-Charge, Krishnagar Government College, the H.O.D., P.G. Department of Zoology, Krishnagar Government College, and the H.O.D., Department of Zoology, University of Kalyani for their enthusiastic encouragement and useful critiques of this research work.

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Dynamics of modified Leslie-Gower predator-prey mathematical model with disease in prey

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ABSTRACT

A predator-prey model followed by Leslie-Gower model with disease in the prey population is considered. Assume that the disease can only spread over the prey population. The prey population is divided into two groups, namely susceptible prey, infected prey whereas the predator population remains free from infection. The existence of various equilibrium points and local stability analysis at those equilibrium points has been discussed. It has been observed that a Hopf-bifurcation may occur about the interior equilibrium point taking carrying capacity parameter and rate of infection parameter are bifurcation parameters. All the important analytical findings are numerically verified.

Keywords: Predator-prey, Eco-epidemiology, Infection, Stability, Oscillation, Hopf-bifurcation.

Introduction

The predator prey system carries a dynamical relationship. And for its existence this relationship is an important part in ecology. Mathematical modeling is considered to understand the dynamical activities of such a system. Researchers [1, 2] have studied eco-epidemic models in which predator populations are infected through eating prey. In the references [3, 4, 5, 6, 7] in which the authors had studied a predator-prey model, out of which the motivating dynamics of Holling Tanner model [7] shows an important part in the ecology. Leslie [8, 9] introduced predator-prey model in which the carrying capacity of predator was proportional to the number of prey. Incorporating the Holling type-II functional response the modified Leslie-Gower prey-predator model was obtained, for example [10].

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Received: *15th September, 2022* / ***Accepted:*** *1st November, 2022*

Recently, the effect of disease on ecological systems is an important issue from mathematical as well as experimental point of view as the effect of infectious disease on the ecological system controls the size of the populations. Venturino [11, 12], Haque and Venturino [13], Haqueet.all. [14,15,16], Xiao and Chen[17,18], Tewa [19], Hethcote[20], Rahman[21], Shaikh[22], Pal[23], Haque[24], Chattopadhyayet.all [25,26,27] discussed the dynamics of prey-predator system with disease in prey population.

In this paper, a modified Leslie-Gower and Holling type-III predator prey model is considered.

Some similar kinds of models have appeared in the recent literature, but the main new distinctive feature is the inclusion of an infectious disease in the prey population and also the inclusion of predator consuming susceptible prey and infected prey by Holling type-III and Holling type-II functional responses respectively. Under this additional effect the model becomes more realistic than the existing models in ecological as well as epidemiological point of view.

2. Mathematical Model

To construct the mathematical model, we make the following assumptions:

- The prey whose total population density is denoted by N and the predator whose total population density is denoted by z.
- In the presence of disease total prey population is divided into two classes viz.

susceptible class (x) and (ii) infected class (y). So, at time 't', total prey population is

$N = x + y$. Disease does not spread from prey to predator by feeding or any other ways

andassume that the disease only transmits from susceptible prey (x) to infected prey (y).

- We assume that the susceptible prey is capable of reproducing in logistic law with carrying capacity k and intrinsic birth rate r :

$$\frac{dx}{dt} = rx\left(1 - \frac{x+y}{k}\right).$$

- The susceptible prey (x) becomes infected following the mass action law at constant rate of infection α.

- Predators consume susceptible prey by Holling type-III functional response at constant rate c_1. Again, predators consume infected prey by Holling type-II functional response at constant rate c_2.

Considering the above basic assumptions we can now write down the following dynamical system:

$$\frac{dx}{dt} = rx\left(1 - \frac{x+y}{k}\right) - \alpha xy - c_1\frac{x^2 z}{k_1 + x^2} \equiv F_1(x, y, z),$$

$$\frac{dy}{dt} = \alpha xy - r_1 y(x+y) - c_2\frac{yz}{k_2 + y} - d_1 y \equiv F_2(x, y, z),$$

$$\frac{dz}{dt} = az - c_3\frac{z^2}{k_2 + y} \equiv F_3(x, y, z), \qquad (1)$$

Where a is the growth rate of predator, c_3 is the maximum value of per-capita reduction rate of predator population. k_1, k_2 are the half saturation constants for prey and predator population respectively. d_1 is the death rate of infected prey, r_1 is the intra and inter-specific competition of infected prey.

This system (1) has to be analyzed with the following initial conditions,

$$x(0) > 0, y(0) > 0, z(0) > 0, \qquad (2)$$

3.Qualitative analysis of the system

3.1Boundedness of the System

Theorem1: *All the solutions of the system (1) are bounded.*

Proof: Consider the function $u(t) = x(t) + y(t) + z(t)$.

Now using the equations (1), we have

$$\frac{du}{dt} = \frac{dx}{dt} + \frac{dy}{dt} + \frac{dz}{dt}$$

$$= rx\left(1 - \frac{x+y}{k}\right) - c_1\frac{x^2 z}{k_1 + x^2} - r_1 y(x+y) - c_2\frac{yz}{k_2 + y} - d_1 y + az$$

$$- c_3\frac{z^2}{k_2 + y} \leq rx - \frac{r}{k}x^2 - \frac{r}{k}xy - r_1 xy - d_1 y + az - c_3\frac{z^2}{k_2 + y}$$

Therefore, $\frac{du}{dt} + \mu u = x\left\{r + \mu - \left(\frac{r}{k} + r_1\right)x\right\} - (d_1 - \mu)y + \left(a + \mu - c_3\frac{z}{k_2+y}\right)z$

$$\leq x\left\{r + \mu - \left(\frac{r}{k} + r_1\right)x\right\} - (d_1 - \mu)y + \frac{(k_2 + \mu)(a+\mu)^2}{4c_3}$$

$$= x\left\{r + \mu - \left(\frac{r}{k} + r_1\right)x\right\} - \left\{d_1 - \mu - \frac{(a+\mu)^2}{4c_3}\right\}y + \frac{k_2(a+\mu)^2}{4c_3}$$

$$\leq \frac{(r+\mu)^2 k}{4(r + kr_1)} + \frac{k_2(a+\mu)^2}{4c_3}$$

Now we can choose μ in such way that $d_1 > \mu + \frac{(a+\mu)^2}{4c_3}$, then we can find a constant $P > 0$, such that $\frac{du}{dt} + \mu u < P$

Now by the theory of differential equation [28] we have,

$$0 \leq u(t) \leq \frac{P}{\mu}(1 - e^{-\mu t}).$$

As $t \to \infty$, then $0 \leq u(t) \leq \frac{P}{\mu}$. Hence $u(t)$ is bounded.

3.2 Equilibria Analysis

- The equilibria $E_0(0,0,0)$ and $E_1(k,0,0)$ exist for all parametric values.
- The prey free equilibrium point $E_2\left(0, 0, \frac{ak_2}{c_3}\right)$exists for all parametric values.

The predator free equilibrium point$E_3(\bar{x}, \bar{y}, 0)$, where $\bar{x} = \frac{krr_1+d_1(\alpha+r)}{\alpha(\alpha+r-r_1)}$, $\bar{y} = \frac{kr(\alpha-r_1)-rd_1}{\alpha(\alpha+r-r_1)}$, exists if $R_1 = \frac{k(\alpha-r_1)}{d_1} > 1$ and $R_2 = \frac{\alpha+r}{r_1} > 1$.

The infected prey free equilibrium point$E_4(\hat{x}, 0, \hat{\bar{z}})$ exists where $\hat{z} = \frac{ak_2}{c_3}$ $and \hat{x}$is the positive root of the equation

$$A_1x^3 + B_1x^2 + C_1x + D_1 = 0,$$

and the coefficients are given by

$$A_1 = rc_3, B_1 = -krc_3, C_1 = \alpha kk_2c_1 + rk_1c_3, D_1 = -rkk_1c_3.$$

The positive interior point $E^*(x^*, y^*, z^*)$, where $z^* = \frac{\alpha(k_2+y^*)}{c_3}$,

$y^* = \frac{(\alpha-r_1)x^*-L}{r_1}, L = d_1 + \frac{ac_2}{c_3}$and $x^*$is the positive root of the equation

$$Ax^3 + Bx^2 + Cx + D = 0,$$

and the coefficients are given by

$$A = \alpha kc_3(\alpha - r_1) + arc_3,$$

$$B = -\alpha kLc_3 + \alpha kc_1(\alpha - r_1) - rc_3(\alpha + kr_1),$$

$$C = \alpha kk_1c_3(\alpha - r_1) + \alpha kc_1(k_1r_1 - L) + \alpha rk_1c_3,$$

$$D = -rk_1c_3(kr_1 + L) - \alpha Lkk_1c_3$$

3. Stability analysis of equilibria

Let$J_i$denotes the jacobian matrix at the equilibrium$E_i, i = 0, 1, 2, 3, 4$.

4.1 E_0

The Jacobian matrix of the system (1) at E_0(0,0,0) is given by

$$J(E_0) = \begin{bmatrix} r & 0 & 0 \\ 0 & -d_1 & 0 \\ 0 & 0 & a \end{bmatrix}$$

So, the eigenvalues of $J(E_1)$are r, $-d_1$ and a.So the equilibrium point E_0 is unstable because one eigenvalue is positive.

4.2 E_1

The Jacobian matrix of the system (1) atE_1 is given by

$$J(E_1) = \begin{bmatrix} -r & -\left(\frac{r}{k}+\alpha\right) & c_1\frac{k^2}{k_1+k^2} \\ 0 & (\alpha - r_1)k - d_1 & 0 \\ 0 & 0 & a \end{bmatrix}$$

So, the eigenvalues of $J(E_0)$are r, $(\alpha - r_1)k - d_1$ and a.So the equilibrium point $E_1$is unstable because one eigenvalue is positive.

4.3 E_2

The Jacobian matrix of the system (1) atE_2 is given by

$$J(E_2) = \begin{bmatrix} r & 0 & 0 \\ 0 & -\left(\frac{ac_2}{c_3}+d_1\right) & 0 \\ 0 & \frac{a^2}{c_2} & -a \end{bmatrix}$$

The eigenvalues of $J(E_2)$are r, $-\left(\frac{ac_2}{c_3}+d_1\right)$ and $-a$.So the equilibrium point $E_2$is unstable because one eigenvalue is positive.

4.4 E_3

The Jacobian matrix of the system (1) atE_3 is given by

$$J(E_3) = \begin{bmatrix} \frac{-r}{k}\bar{x} & -\left(\frac{r}{k}+\alpha\right)\bar{x} & c_1\frac{\bar{x}^2}{k_1+\bar{x}^2} \\ (\alpha - r_1)\bar{y} & -r_1\bar{y} & -c_2\frac{\bar{y}}{k_2+\bar{y}} \\ 0 & 0 & a \end{bmatrix}$$

One eigenvalue of $J(E_3)$is positive i.e., a. Hence the equilibrium point $E_3$is unstable.

4.5 E_4

The Jacobian matrix of the system (1) atE_4 is given by

$$J(E_3)=\begin{bmatrix} r-\frac{r}{k}\hat{x}-2ac_1k_1k_2\frac{\hat{x}}{c_3(k_1+\hat{x}^2)^2} & -\left(\frac{r}{k}+\alpha\right)\hat{x} & c_1\frac{\hat{x}^2}{k_1+\hat{x}^2} \\ 0 & (\alpha-r_1)\hat{x}-\frac{c_2}{k_2}\hat{z}-d_1 & 0 \\ 0 & \frac{a^2k_2^2}{c_3} & -a \end{bmatrix}$$

Eigenvalues of $J(E_4)$are $-a,(\alpha-r_1)\hat{x}-\frac{c_2}{k_2}\hat{z}-d_1$and $-\frac{r}{k}\hat{x}-2ac_1k_1k_2\frac{\hat{x}}{c_3(k_1+\hat{x}^2)^2}$. Hence the equilibrium point $E_4$is stable if $r-\frac{r}{k}\hat{x}-2ac_1k_1k_2\frac{\hat{x}}{c_3(k_1+\hat{x}^2)^2}<0$ and $(\alpha-r_1)\hat{x}-\frac{c_2}{k_2}\hat{z}-d_1$.

4. Stability analysis of the positive anterior equilibrium

Theorem2: The positive interior Equilibrium point $E^*(x^*,y^*,z^*)$ is locally asymptotically stable if $p_1>0,p_3>0,p_1p_2-p_3>0$.

Proof: The jacobian matrix of the system (1) around the positive equilibrium point E^* is

$$J^*=\begin{bmatrix} m_{11} & -m_{12} & -m_{13} \\ m_{21} & m_{22} & -m_{23} \\ m_{31} & m_{32} & -m_{33} \end{bmatrix}$$

The characteristic equation of the jacobian matrix J^*at $E^*$is

$$\rho^3+p_1\rho^2+p_2\rho+p_3=0$$

where

$p_1=(m_{11}-m_{22}+m_{33})$

$p_2=m_{33}(m_{11}-m_{22})+m_{13}m_{31}+m_{12}m_{21}+m_{23}m_{32}-m_{22}m_{11}$

$p_3=m_{12}(m_{21}m_{33}-m_{31}m_{23})+m_{13}(m_{21}m_{32}-m_{31}m_{22})+m_{11}(m_{23}m_{32}-m_{22}m_{33})$

$p_1p_2-p_3=(m_{11}-m_{22})\{m_{12}m_{21}+m_{11}(m_{33}-m_{22})\}\quad(m_{33}-m_{22})\{m_{23}m_{32}+m_{33}(m_{11}-m_{22})\}+m_{13}(m_{11}m_{31}-m_{33}m_{32})+m_{32}(m_{12}m_{23}-m_{21}m_{13})$

By the Routh-Hurwitz criteria, all roots of the above characteristic equation have negative real parts if and only if $p_1>0$, $p_3>0$, $p_1p_2p_3>0$. Therefore, the positive interior equilibrium point $E^*(x^*, y^*, z^*)$ is locally asymptotically stable if$p_1>0$,$p_3>0$,$p_1p_2-p_3>0$.

5. Numerical simulations

In this portion, concentrated on the occurrence and termination of the disease is studied. For the set of parametric values in Table 1 and with initial value$Z_0=(x_0, y_0, z_0)$=(14.5,2.8,5), the existence conditions of the coexistence equilibrium point $E^*$is satisfied and the coexistence equilibrium point

E^*=(14.3314,2.0640,4.5720) is locally asymptotically stable with eigenvalues

$-0.1513\pm 1.93i$, -1.072 (see figure 1). Next to observe the effects of some parameters on system (1), firstly, consider $d_1 = 1.12$ and other set of parametric values in Table1, observe that the infected prey population goes to extinction (Figure2(a)). Again, if α is increased from 0.11 to 0.15 then it is observed that the solution of (1) changes from stable behavior to oscillatory behavior (see figure 3). Next, if k is increased from 22 to 29.5 then it is observed that the solution of (1) changes from stable Behavior to oscillatory behavior (see figure 4). Finally, for a clear understanding of the dynamical changes of system (1) due to change the value of the parameter α from 0.13 to 0.15, a bifurcation diagram is plotted as shown in the bifurcation diagram (seefigure5(a)). Also, for a clear understanding of the dynamical changes of system (1) due to change the value of the parameter k from 26 to 28.5, a bifurcation diagram is plotted as shown in the bifurcation diagram (see figure 5(b)).

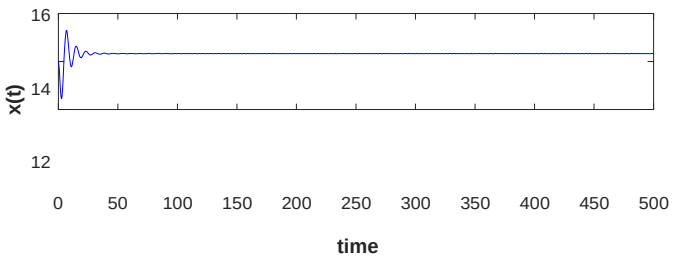
Parameter	**Definition**	**Value**	**Dimension**
r	Growth rate of susceptible prey	1.5	1/time
r_1	Intra and inter specific competition of infected prey	0.01	1/time
a	Growth rate of predator	0.9	1/time
k	Carrying capacity	22	mass/volume
α	The infectious rates in Prey populations	0.11	1/time
k_1	Half saturation constants in prey population	6	-
k_2	Half saturation constants in predator population	2	-

c_1	Consume rate of susceptible prey by predator	0.5	1/time
c_2	Consume rate of infected prey by predator	0.8	1/time
c_3	Maximum value of per-capita Reduction rate of predator population	0.8	1/time
d_1	Mortality rate of infected prey	0.4	1/time

Table1: A set of parameter values.

6. Conclusions:

An ecological predator-prey model and an epidemiological model have been partially applied in this work. Through the analysis an eco-epidemiological predator prey mathematical model has been established in which only prey population is affected by an infectious disease. Here we have a modified Leslie-Gower and Holling type-III predator-prey model also used to develop the same model. Prey population is divided into two categories, namely susceptible prey and infected prey. In this pa-per, there are six equilibrium points, namely one trivial equilibrium E_0, two axial equilibriaE_1, E_2, two planer equilibria $E_3, E_4$and an interior equilibriumE^*. Here E_0, E_1, E_2always exists but unstable. Next,E_3exists under some conditions and it is unstable. Also, E_4 exists and it is stable under some conditins. The interior equilibrium E^*exists and it is asymptotically stable under some condition. The stability switching and a Hopf-bifurcation may occur at the interior equilibrium taking rate of infection parameter (α) and carrying capacity parameter (k) are bi-fraction parameters. Without numerical verification of the analytical results cannot be completed. So all important analytical findings are numerically verified using Matlab here.



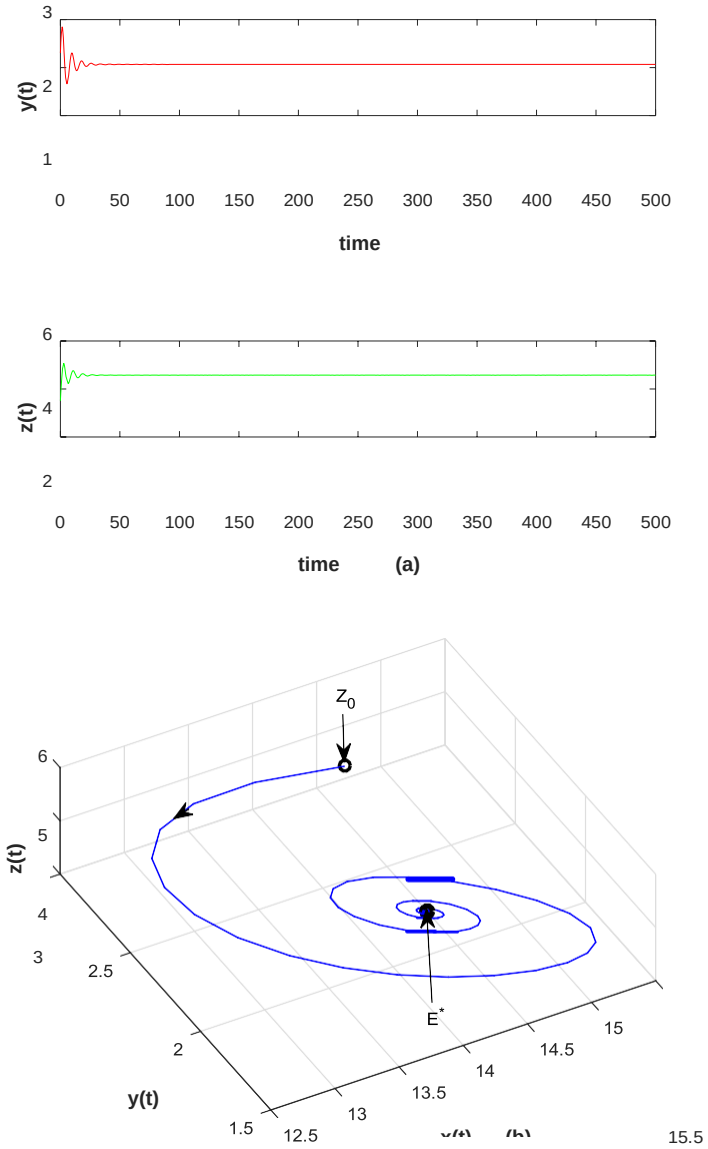
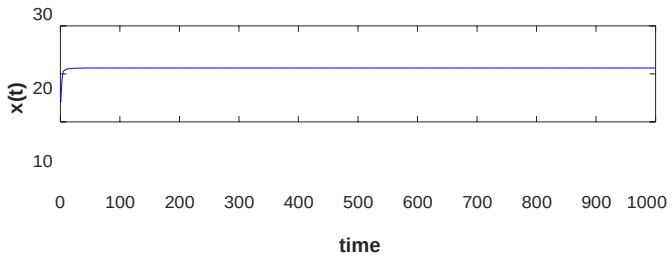


Figure 1: (a) Shows that all species coexist in stable position for the set of parameter in the Table1. (b) Phase diagram denotes the equilibrium point $E^*$is locally asymptotically stable for the set of parameter in the Table1.



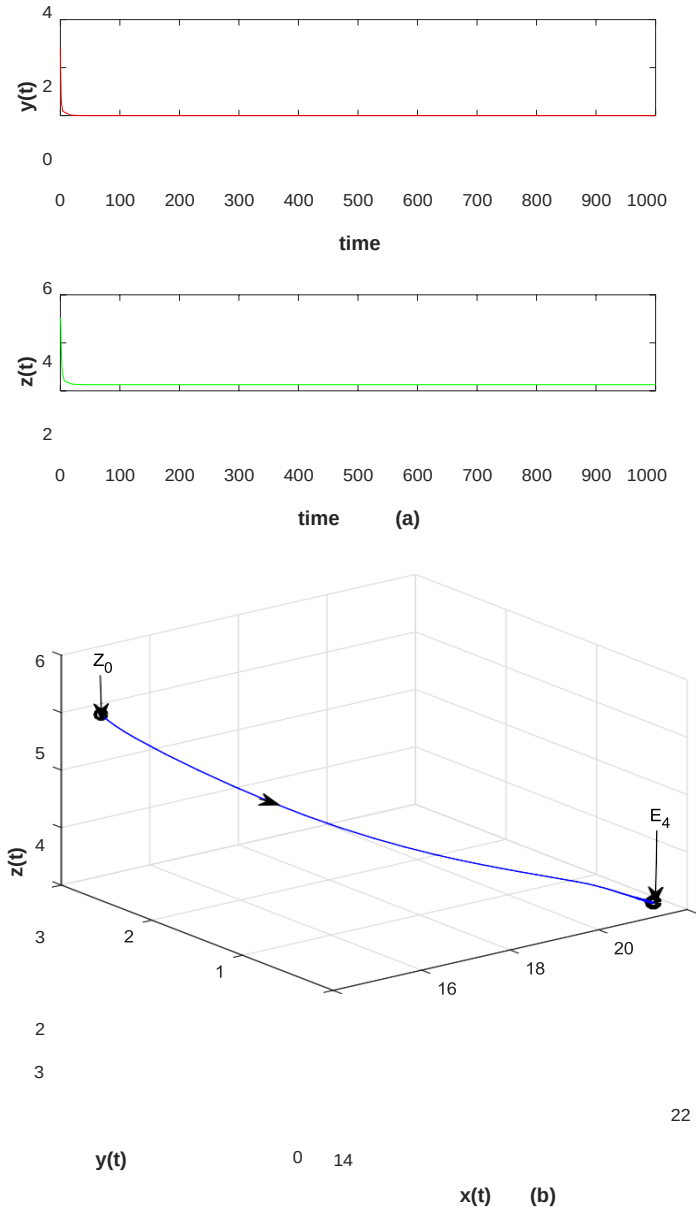


Figure 2: (a) Shows that the infected prey population goes to extinction for d_1= 1.12 and other parameters fixed as given in Table1. (b) Phase diagram denotes the equilibrium point E_4 is locally asymptotically stable for d_1= 1.12 and other parameters fixed as given in Table1.

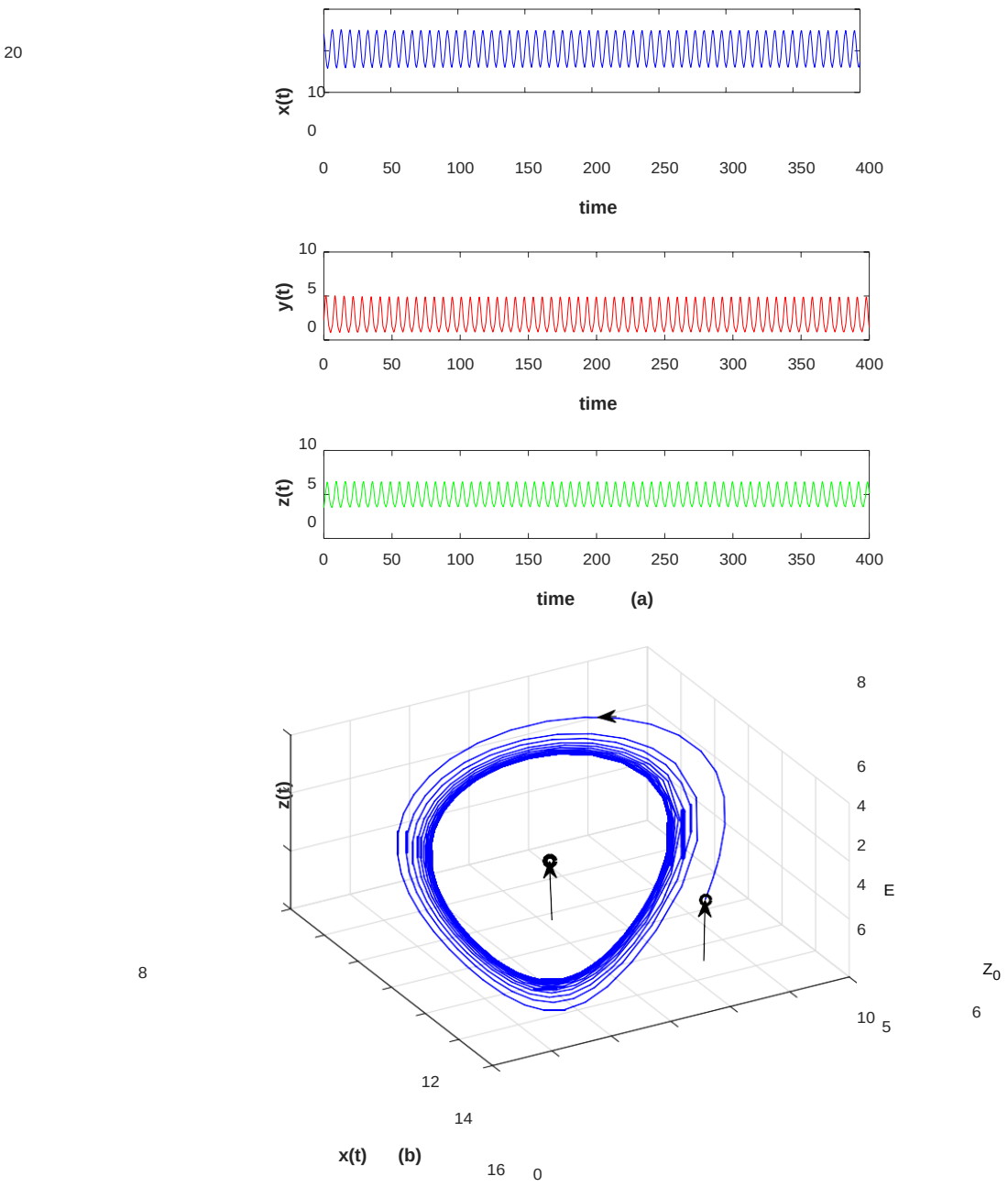


Figure 3: (a) The figure depicts oscillatory behavior of three species for α = .15, with other set of parameter fixed as given in Table1. (b) The phase diagram shows that limit cycle oscillation of all species for α = .15, with other set of parameter as given in Table1.

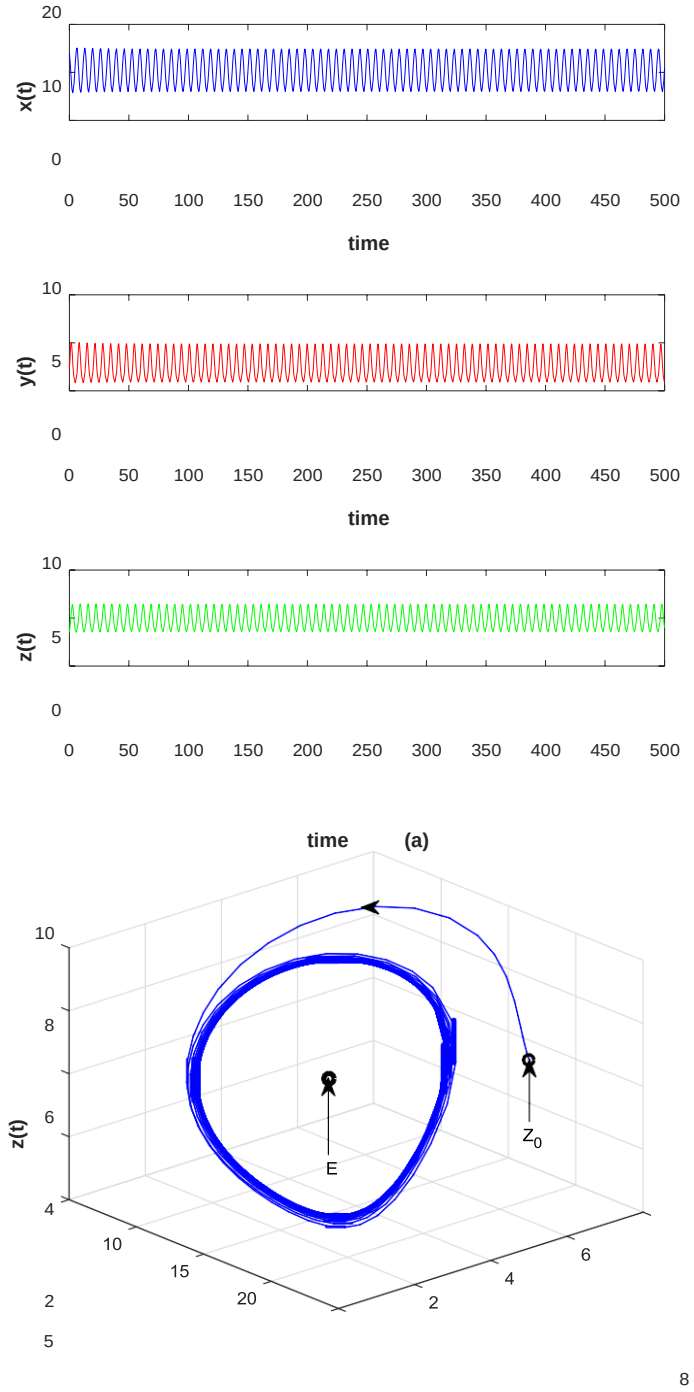


Figure 4: (a) The figures denote oscillatory behavior of three species for k = 29.5, with other set of parameter fixed as given in Table1. (b) The phase diagram shows that limit cycle oscillation of all species for k = 29.5, with other set of parameter as given in Table1.

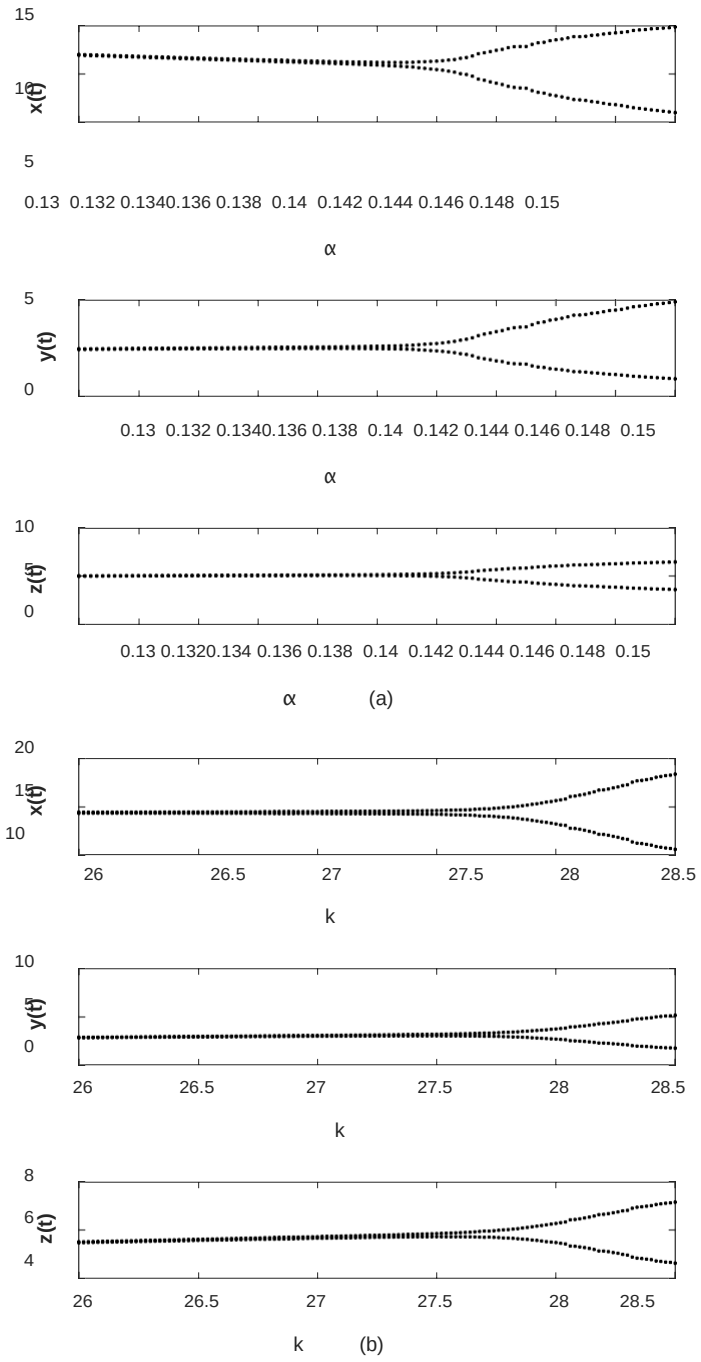


Figure 5: (a) The bifurcation diagram of three species for α. (b) The bifurcation diagram of three species for k.

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Ageism:Is It a Curse?

Edha chakrabarti*

ABSTRACT

Old age is often regarded as second childhood. Aged people are almost as dependent on others for basic requirements as infants or babies are. In many cases, they cannot function without constant attention or support. They regress to an earlier state of mind and being, and they become dependent on others for care, similar to a child. This is the time when the old seek the care and comfort of their children. Ones who are neglected by their children and the society are compelled to live a meaningless and painful life either in old age homes or in their own home. The second childhood stereotype has endured and finds expression in numerous works of literature. In the first two sections I shall undertake to discuss two such works of literature, one being a story named 'Boodhi Kaaki' by Munshi Premchand (originally written in Hindi and subsequently translated into other languages) and the other being 'Pather Panchali', originally written in Bengali, by the eminent writer Bibhutibhushan Bandyopadhyay. In the third section of this paper, a comparison has been made between the two characters. In the last section, I would also indicate what positive contributions can be provided in their lives and would show that ageism is not an illness or a curse, rather a grace.

Section I

Old Kaki behaved just like a child. She would rest for most part of the day. Her age had enfeebled her. She had not, however, lost her appetite and her yearning for food. She would start wailing like a child if she was not given her meal at the appointed time. Kaki had given Budhiram, her nephew, all her property, in lieu of which he had promised to look after her. She had nobody else to depend upon. But Budhiram was forbearing as long as he did not have to fork anything out of his pocket. He was aware of the fact that his respectable position in the society was backed only by the property bestowed upon him by Kaki. His good intentions were

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Received: *21st October, 2022 / **Accepted:** 23rd November, 2022*

drowned by the anxiety of having to bear any additional expense. His wife Roopa was rather brusque in her speech, but she was devout. The sons of Budhiram were rude to the old woman. Ladli, Budhiram's little daughter was the only one in the family who was compassionate towards Kaki and cared for her. When her brothers teased Kaki, Ladli always came to her rescue. She had to part with her share of food for Kaki's sake, but that never seemed to concern the little girl.

One day, on the occasion of their son Sukhram's engagement, Kaki was ill-treated both by Budhiram and his wife. They did not offer her any food. They eventually forgot about her and went to sleep. But Ladli found it intolerable. She had hidden her share of *puris* in a basket for Kaki and fed her. But the old woman was so starved that the little amount was not enough for her. Kaki asked Ladli to take her to the place where the guests had eaten. Ladli led Kaki to the dining area. Kaki began wolfing down the leftovers from the leaf-plates lying scattered all over. Roopa woke up and after seeing the pathetic scene, she was horrified. Struck by her conscience, she begged for mercy from the Almighty. Roopa piled a tray with food and carried it to Kaki. With tears in her eyes, Roopa asked Kaki to have the food and forgive her. Just as sinless children forget a rebuke after receiving a gift of sweets, Kaki ate, forgetting all the humiliation and negligence that she had to face.

Section II

With reference to the book 'Pather Panchali' by the renowned author Bibhutibhushan Bandyopadhyay, a similar character seeks our attention, who is Indir Thakuran, an old and helpless woman like Kaki. Being ill-treated by her sister-in-law Sharbojaya, was a part of her daily routine. But never did she complain about her ill-treatment. Whenever Sharbojaya rebuked her, she used to give a toothless grin and left the house. So sinless was she that she never realised that Sharbojaya actually thought her to be a burden to their family. Even after leaving their house, she would always return as there was no other place for her shelter. Just like Ladli, Sharbojaya's daughter Durga loved Indir Thakuran, so much that she proved to be a pillar of strength to the old woman in times of trouble. One day after a quarrel with Sharbojaya while she was ill, she left the house. Sharbojaya did not care about that and went back to her daily life. But in the afternoon, terrible news spread through the village like wildfire. Indir Thakuran, lay dead near the husk-house of the Palits. While reading this story, a pang of sadness lingers in readers' minds.

Comparing Kaki's character with Indir Thakurun, we find similarities as both are dependent on the charity of relatives who consider them an added burden. Both elderly women show immense maturity and they never wished to harm those who humiliate them. Both these characters leave a moral lesson for the other characters.

Section III

How is social welfare possible when we are often either too busy or when we simply dismiss our elders and their valuable contributions? As we look around, we see that there is pressure on all aspects of carehas never been a problem for India where a value-based, joint – family system has often prevailed. But with the changing structures and moral norms of the modern-day family, the coping capacity of the younger and older family members is now being challenged. There is a growing realisation among the older person that they are more often than not being perceived by their own children as burdens. The perceived 'burden' is both in the capacity of time and of money. The growing tendency to regard older people as debilitated, incapable of contributing anything to the family or to society and hence unworthy of attention is, very unfortunately, quite rampant now.

It is worth remembering that we have to be not only considerate but also polite to those people whose bodies and minds are ageing, simply by the hands of time. Being kind and showing compassion is at least one step in the right direction. Let us use the analogy of a tree. What is a tree? It is a structure having a root system, trunk, branches larger and smaller, leaves, buds, petal, flowers, thorns etc. Now, what can you call a tree apart from these various names and forms? It is all of them together that constitute a single tree. So a tree is essentially inter-connectedness of such names and forms deriving their nourishment from the source. Thus, it is the inter-connectedness that makes a tree a tree, not independent existence of its parts. So if we realize our oneness, inter-connectedness, in spite of our seeming separations of age, of culture and other barriers, we can realise the vision of '*Sarva bhuta hita ratah'*[1]. Here mentioning an incident of Mahabharata would not be an out of place. In the epic text, in the section CCCIX-CCCXIII named as 'Aranya Parva', Yaksha put out question after question rapidly to Yudhisthira, and Dharmaraja answered them equally fast, with confidence and precision as demonstrated by his great wisdom and learning. One of the questions was: what happiness is? He answered that 'happiness' is the result of good conduct or behaviour.

We all seek to become happy and fulfilled. Caring for others, particularly our elders, to whom we owe a great debt of respect for already having shown us the path, is one of the ways of becoming truly happy. The elders are our sources of wisdom and inspiration. We have to realize that ageing is a natural process that is likely to happen to all of us. The compassion and love that the older people are having towards their children and grandchildren is beyond any comparison. They provide emotional, physical, and even financial support. They show us the right paths. Therefore, growing old must not be treated as the curse of our life. It is just a new day of life, which can be made beautiful like all other days by honest endeavour, sympathy and unconditional love.

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Vidyasagar and Feminist Philosophy: A Short Discussion

Dilip Sarkar*

ABSTRACT

Feminism is a widely discussed doctrine in modern society. Its main objective is to create a gender-discriminatory society based on the equal rights of women and men. Feminists generally do not deny the 'sex difference' between men and women; they deny 'gender difference'. 'Gender' refers to the contextual idea of women and men in their individual roles in the masculine society. Although Pandit Iswar Chandra Vidyasagar was not generally a feminist philosopher, he fought for a long time for women. In the present paper, I shall explain how women are gradually falling behind in everything compared to men in a patriarchal society. I shall also explain here how Vidyasagar freed women from hellish torments and brought them back into the mainstream of society.

Keywords: Feminism, gender, discrimination, freedom, rights, *satidah*

1. Introduction:

Feminism is an important ideology of the present society. Based on this ideology, the women's liberation movement has developed at different times. The main aim of feminism is to create a gender-discriminatory society based on the equal rights of women and men, where women will live with their individual identities. "অথচ বেদ থেকে কোরান, অ্যারিস্টটল থেকে ওল্ড টেস্টামেন্ট বিভিন্নভাবে এই কথাগুলোই প্রমাণ করতে চেয়েছেন যে, নারীর শরীর দুর্বল, তার মস্তিষ্ক কোন গুরু-ভাবনার দায় বহন করতে পারে না, তার মন সবসময়ই প্রলোভনে সাড়া দিতে উদ্যত।" [1] According to the French philosopher Russo's social contract doctrine, society is governed by a 'universal will'. But there was no place for women in this 'ideal republic' of Russo. Because the family is a natural organization, there is a male family owner, the woman is under him. [2] Plato says in his 'Republic' the role of women in education should not be followed. [3] Aristotle said in his book 'Politics', "the slave is wholly lacking the deliberative element; the female has it but it

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Received: *1st December, 2022* / ***Accepted:*** *29th December, 2022*

lacks authority; the child has it but it is incomplete." [4] According to Kant, learning geometry is not the job of women. Descartes' theory will continue even if they do not understand it. [5]

2. Explanation:

Mary Astell strongly opposed the philosophers' statement that women had the right to education. Because education can be given equal rights to all. As a result of education, women are gradually aware of child custody, separation, property rights, and voting rights. Mary Wollstonecraft in her 'A Vindication of the Rights of Woman' discusses women's rights in detail. She is the first spoke about women's education, and political and economic rights. John Stuart Mill addresses the rights of women in his book 'The Subjection of Women'. He has shown the miserable reality and plight of women's lives under men. He sought the equality of men and women not only for the welfare of women but also for the welfare of the entire human civilization. Mill is the first man who has seen a woman as a human.

The term 'sex difference' and 'gender difference' is very important in feminist philosophy. Feminists always see these two words as separate. Feminists generally do not deny the 'sex difference' between men and women; they deny 'gender difference'. While the common meaning of the terms 'sex' and 'gender' is the same, in feminists, there are important differences between the words. 'Sex' means biological sex. This biological sex difference between women and men cannot be denied. The chromosome pair of the male sperm is X Y, while the female chromosome pair is X X. This biological difference between women and men is natural. 'Gender' refers to the contextual idea of women and men in their individual roles in the masculine society. That is the idea of gender discrimination created by society. [6] At the root of this gender difference are the discriminatory social norms and ideas of patriarchal and male-centric society. Growing women and men in the same society are different in the social environment, and from that time on, women and men became aware of their own doings. In this way, the masculine spirit is gradually aroused among men, and feminine feelings are aroused in women in the direction of society. The difference between these two ideas is not sex difference, it is the gender difference created by society. In this context, the commentary of the feminist philosopher Simone de Beauvoir is very interesting. She says that "One is not born, but rather becomes, a woman." [7] When gender discrimination is done between men and women, it is called gender discrimination.

Gender discrimination works on three levels, namely, the level of conduct, the institutional level, and the ideological level. Feminists call the first sexism, the second patriarchy, and the third phallocentrism. [8] At the first level, sexism is the way to use words or behaviors or to motivate women less than men. In the second level, men are at the center and the role of women is determined by the interests of men. Kamla Bhasin says, "… that in patriarchy the broad principles remain the same; men are in contral, the nature of this contral may differ." [9] And at the third level, discrimination between men and women further reduces women's position. This level gives rise to a thought in which women do not have their point of view. In a word, this is to see the world through the eyes of men. Shefali Moitra has given a beautiful explanation of phallocentrism in her book 'Feminist Thought'. In her words, "It means that the tertiary sex-linked male traits are treated as the regulative principles of phallocentrism, it is through these lenses that the entire conceptual space is perceived, evaluated, organized, and reorganized." [10]

It can be said with certainty that due to gender discrimination, women have been deprived of the right to education, economic rights, political rights, social rights, rights of law, rights to empowerment, etc. At present, Western countries are careful enough to protect women's rights. It is interesting to see what the image of women's rights in India was like. The feminist movement in India begins to protect women's rights in the eighteenth and nineteenth centuries. During this time, the status of women in India gradually improved under the leadership of some social reformers. Notable among these are Raja Rammohan Roy, Iswar Chandra Vidyasagar, Radhakanta Dev, Dwarkanath Tagore, and Debendranath Tagore.

During the period of the Renaissance Indian society was agrarian and feudal. During this time, women were considered male property. Apart from this, women were also victims of *satidah* rituals, child marriage, polygamy, and *devdasi* customs. The reasons for all this misconduct are economic deprivation, feudal prejudice, and social conservatism. Also at that time, Indian society was subjected to class discrimination and racial discrimination. Against all this misconduct, the social reform movement that Rammohan Roy initiated came to the fore in the hands of Vidyasagar. For the overall welfare of the people of the country, Vidyasagar wanted to introduce a model of education for all men and the betterment of the women's nation by playing a leading role in the women's development movement. Because he realized that society stood on two pillars- one male race and the other female race. If both do not improve, then society becomes lame. But the situation of women in India at that time was very bad, which excluded Vidyasagar. So he called the widow's marriage a virtuous act of his own life. In a letter to Shri Shambhu Chandra Vidyaratan, Vidyasagar said that, "বিধবাবিবাহ প্রবর্তন আমার

জীবনের সর্বপ্রধান সৎকর্ম। এজন্মে যে ইহা অপেক্ষা অধিকতর আর কোন সৎকর্ম করিতে পারিব, তার সম্ভাবনা নাই। এ বিষয়ের জন্য সর্বশান্ত হইয়াছি এবং আবশ্যক হইলে প্রাণান্ত স্বীকারেও পরাঙ্মুখ নহি।" [11]

There was some fundamental difference between the thinking of Rammohan and Vidyasagar. Rammohan told the *brahmacarya* life of Hindu women by stopping the *sahamaranpratha*. But Vidyasagarwas not satisfied with the widow's *brahmacarya* life. He spoke of their remarriage so that widows could live with dignity in society. In this regard, he said, "কত শত বিধবারা, ব্রহ্মচর্য-নির্বাহে অসমর্থ হইয়া, ব্যভিচারদোষে দূষিত ও ভ্রূণহত্যাপাপে লিপ্ত হইতেছে; এবং পতিকূল, পিতৃকুল ও মাতৃকুল কলঙ্কিত করিতেছে। বিধবাবিবাহের প্রথা প্রচলন হইলে, অসহ্য বৈধব্যযন্ত্রণা, ব্যভিচারদোষ ও ভ্রূণহত্যাপাপের নিবারণ ও তিন কুলের কলঙ্ক নিরাকরণ হইতে পারে। যাবৎ এই শুভকারী প্রথা প্রচলিত না হইবেক, তাবৎ ব্যভিচারদোষের ও ভ্রূণহত্যাপাপের স্রোত কলঙ্কের প্রবাহ ও বৈধব্যযন্ত্রণার অনল উত্তরোত্তর প্রবল হইতেই থাকিবেক।" [12] Vidyasagar provided that the widow's husband died, but all the hunger, thirst, lust, etc. remained. So the widows need to get remarried. Because the body of the widow is also a body of flesh and blood, it is not possible for them to restrain their senses and desires. Vidyasagar, in his book on widowhood, said that because widow marriages are not practiced, many widows fail to perform *brahmacarya* and engage in heinous acts like adultery and fornication. As a result, they are tarnishing the names of parents and husbands. Therefore, if the widow's marriage is practiced, the unbearable pains, adultery and fornication of the widow will be eliminated. At the same time, the shame and disgrace of the husband and parent's family will be removed. In Indian's patriachal society, the body of a woman is the property of a man. But in feminism, the rights of women have been recognized. There are also feminist interpretations of Vidyasagar's thoughts on women's bodies.

It is not just that Vidyasagar speaks of the right of women in their bodies. He had a special affection, love, and devotion to women. He felt the widow's grief; sorrow and suffering from his heart and as a result, resolved to relieve her suffering. Vidyasagar's desire to liberate oppressed women from the agony of hell had become strong. The reason is his heartache and sensitivity. Keshav Chandra Sen writes in Sulabha Samacara: "আমাদের দেশে এখন অনেকে ভালরূপে লেখাপড়া শিখিয়াছেন, সাহেবী ধরনেও অনেকে চলিতেছেন, অনেকেই মুখে লম্বা লম্বা কথাও বলিয়া থাকেন, কিন্তু স্ত্রীলোকদিগের দুঃখ দেখিয়া কয়জনের প্রাণ কাঁদিয়া ওঠে। একমাত্র বিদ্যাসাগর মহাশয়কেই

স্ত্রীলোকদিগের দুঃখের নিমিত্তে কাতর দেখিতে পাওয়া যায়। তিনিই তো অন্যথা চিরদুঃখিনী বিধবাদের দুঃখ নিবারণের নিমিত্তে কায়মনপ্রাণে চেষ্টা করিয়াছেন।" [13] An example of how aware Vidyasagar was about the suffering of women is that one day Vidyasagar had to write in a girl's school horse carriage: "কন্যাকেও যত্নের সঙ্গে শিক্ষা দিয়ে পালন করা উচিত।" [14] Vidyasagar's statement indicates that he had a 'co-feeling' towards women. And in the meantime, the analogy of feminist Carol Gilligan's ethics of care can be noticed.

Vidyasagar realized that the welfare of women is not possible if the ignorance and illiteracy of women cannot be eliminated. He said that women should be taught in such a way that they can fight against men equally, being aware of their rights. Rammohan wrote in support of women's education, "স্ত্রীলোকদিগের বুদ্ধির পরীক্ষা কোন কালে লইয়াছেন যে তাহাদিগকে অল্পবুদ্ধি কহেন?...আপনারা বিদ্যাশিক্ষা, জ্ঞানশিক্ষা স্ত্রীলোককে প্রায় দেন নাই, তবে তাহারা বুদ্ধিহীন হয় ইহা কিরূপে নিশ্চয় করেন?" [15] The issue of women's awakening is closely related to women's education. Education can help a woman develop her self-depended, and self-control. To him, education does not just mean literacy; education means the development of dignity, the full perception of one's position in society. Real literacy shows awareness of the right to work, the right to give, and the right to receive as a social person. The first aim of women's education is to develop the consciousness of women and the end goal is to establish equal rights in society between women and men.

According to feminist philosopher Simon de Beauvoir, because of the strict economic control over women, the place of women in society or the state is shrinking. Therefore, women cannot actively participate in any major development process or decision-making. As a result, women's economic rights are eroded. In India, women do not enjoy the equality of men in any respect for their ownership of property, control of their property, the amount earned, the amount of food received, and the right to medical care. In the past women have been dependent on men. That is why the place of women in society is very miserable. Vidyasagar thinks of financial security for women during misfortune. He arranged a family pension for women so that the women would not suffer any economic problems if their husbands died prematurely or in old age. Under his efforts, the Hindu Family Annuity Fund was established in 1872. In this way, he sought to empower women economically through self-depended. The legal rights of women are essential for the elimination of equality in society. Feminists demand legal reforms in the interest of women. Their important demands are the rights of women in the family, the

rights of their dignity, the rights of their own employment, and property rights. Vidyasagar has been saying that rights for women all his life.

3. Conclusion:

Based on the above discussion, we can say that feminists and various social reformers like Iswar Chandra Vidyasagar, and Raja Rammohan Roy have demanded the social, political, legal rights, and economic rights and empowerment of women. As a result, in some cases in the present world, the importance of women's rights is being emphasized. The United Nations declares 1975 as International Women's Year and the 8th March every year as International Women's Day. In 1981, the Convention on the Elimination of all Forms of Discrimination Against Women (CEDAW) was adopted by the United Nations. At the United Nations Human Rights Conference in Vienna in 1993, women's rights were recognized as human rights. Also at the 1994 international conference organized by the United Nations in Cairo, women have been given full freedom of birth and birth control. Now in the present world, more than half of the women, so without the liberation of women, total human liberation is never possible. Finally, we can say that Pandit Iswar Chandra Vidyasagar, one of the great human beings of the women's liberation movement in India, opened the door to women's liberation in society through various reforms movement. As a result, the present women have survived their unique identity with self-respect and the future has paved the way for the advancement of women.

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Witchcraft and its Effects in the Society of Dooars

Pinky Bhowmik*

ABSTRACT

We all know that our present society is suffering from various problems like caste discrimination, dowry, child marriage, poverty, witchcraft, etc. Among them, the practice of witchcraft is one of the important problems in our society. The primitive tribal communities of India were practicing witchcraft. The practice of witchcraft also exists in the Dooars plantation field of West Bengal. Women are the main victim of this practice. The main feature of this practice is at first identifying a woman as a witch, then torturing her in various ways. Witch hunts steal the self-independence and confidence of innocent tribal women. Sometimes simple innocent women lost their life through this practice. The tribal doctor or *Janguru* are mainly responsible for practicing witchcraft, they suspected women as a witch, and after that, for their own profit, they sometimes killed the tribal women. Tribal people blindly believed in *Janguru*, because they think that *Janguru* are next to God. In modern society, we are not found any scientific base for witchcraft. There are various ways to prevent this peculiar practice from our society. In the present paper, I shall discuss the negative effect of witchcraft. I shall also discuss here some necessary remedies to prevent this peculiar practice from our society.

Keywords: Witch, *Janguru*, *Bhagat, Sokha*, Tribal, Superstition, Custom.

Introduction:

The tribal population of India is larger than that of any other country in the world. North Bengal is one of the important parts of West Bengal. At present North Bengal is divided into eight Districts. Dooars are an important part of the Jalpaiguri District. Dooars are surrounded by Malbazar, Nagrakata, Madarihat, Metili, Chalsa, Moynaguri, Dhupguri, Rajganj, etc. In Dooars witch-hunting is a burring problem among various tribal communities. There are lived lots of tribal communities like *Santal, Oraon, Munda, Ho, Rava,* etc. Witch-hunting is their popular ritual but the practice of witchcraft creates a very negative impact on their life. It is undoubtedly an-age old evil practice and social problem. The tribal people especially tribal women are the

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Received: *1st November, 2022 / **Accepted:** 3rd December, 2022*

victims of certain economic and social conditions. At the same time, it is a contributing factor in instigating with-hunting. In India, the practice of witchcraft is widely prevalent among various tribal groups, other indigenous people, and ethnic groups, particularly among the *Santals* and *Oraon*, the belief in witches is quite strong. It is a reflection of their age-old belief system old occupies a significant place in their religious life. Geographically Dooars is the backward part of North Bengal because there is a lack of modern education and modern medical facilities. The tribal people of Dooars belong to a very poor community, and for this reason, they cannot effort education as a result their thinking is surrounded by superstition. So, as a result, of superstition they have strongly followed their thousand years old primitive practices witchcraft is one of the primitive social practices. The innocent tribal people strongly believe that through the practice of witchcraft, they can easily get relief from all of their problems and misery, surprisingly in witch-hunting the victims are mostly women as a part of male conspiracy they are often identified as a witch. In the case of witch killing not only do the local witch doctor neighbors and others in her villages join in this conspiracy. The main interest behind this entire killing is to curb the independent authority of certain women and keep them under male subjugation. Tribal women workers work harder than their man counterparts. But the occupational status of women workers is much lower than men. Women are treated as a commodity they are more conservative than men. Due to illiteracy, the tribal women are completely ignorant about the modern changes, which are taking place in the outer world. They have considerable faith in the traditional way of life and other archaic beliefs and customs. In such a state of condition, they become the victim of witch-hunting. So there is a need to inculcate among them new ideas and values to counter many old practices including witch killing. The overall setup of the tea garden is not conducive for plantation laborers. Locationally most of the tea gardens are somewhat isolated and where the laborers lead a secluded life. Outside influence is very rare in garden life. Garden administrations do very little for the tribal workers. Laborers pass their leisure by taking *ganja, bhang, haria,* etc. Laborers live in unhygienic conditions. As a result, they frequently suffer from malaria infections, dysentery leprosy, and T.B., and no encouragement and arrangement have been a mode for their recreation and entertainment. This precarious condition of health and hygiene has often led to make them being quite faithful to witchcraft and sorcery.

MAP OF THE AREA OF DOOARS

Effects of witchcraft:

Witchcraft creates a very negative impact on the tribal society of Dooars. When Indian adopted modern development initiatives its motive was to bring about reform in society both structurally and qualitatively simultaneously, it want to facilitate all-around economic growth which would reduce regional sectoral and social disparities. “Eradication of poverty, unemployment and inequality once again become the foremost slogan of most Indian states”.[1] Witch-hunting creates a very negative effect on tribal health. In most of the above-stated cases, a strong relationship between health and witchcraft had been noticed. In all these cases women were suspected of witch and murdered due to the illness of others medical facilities and water supplies are inadequate in the tribal area. As a result of the bad climate conditions, cholera, dysentery, leprosy, and many other diseases abounded in the tribal area. “Unhealthy condition was reflected in the rate of absenteeism, sickness is also an important cause of absenteeism.”[2] The people depend on *Ojha, Gunin*, and the spiritual leader for cure occasionally the *Janguru* exercises his supernatural power to detect the cause of illness. He brands a woman as a witch. “The tribal people think that the words of *Janguru* as the same of the wards of god. For this reason they absolutely ignore the modern medical facilities.”[3] The

health of the tribal women was also affected due to the practice of witchcraft. Health in tribal life was neglected in the pre-independence period. Tribal women are still unaware of good nutrition and health programs. Due to the practice of witchcraft, health condition has a certain bearing on the exploitation of tribal women. Such evil superstitions are so strong that it implies the villagers kill simple innocent tribal women in the name of witchcraft.

Witch-hunting also creates the worst effect on women's education. They believed that girls or women are not born for education. Few people are getting the benefit to literate themselves and among them, the literate women are very few. They are belonging to a very backward community as a result they think education is not for them. The tribal lives in forests and mountains somewhat isolated from the generally inhabited areas. The tribals are rural and the poorest social group for this reason the literacy rate of the tribal is low, and the literacy rate of the tribal women is lowest than men. They strongly believe in their primitive rituals. They think that through their rituals they can get relief from their misery and backwardness. At the same time, they believe that modern educational opportunities destroyed their tradition and society so; they don't want to take the facilities of modern education. "As a result of their old orthodox system, low standard of living, low level of literacy strong hold of tradition, ignorance of women education some of the effecting factors which may be accounted for witch-killing" [4].

The social life of the tribal people of Dooars is strongly affected due to the practice of witchcraft. In India, the tribals as a whole belong to a lower socioeconomic status group. In tribal communities, values and social ethos play important roles in shaping their society. Cultural life on social and economic considerations the tribal people are not homogeneous. They belong to different levels of socioeconomic formation. The life of tribal communities in our country is governed by distinct social systems and traditions. Before discussing the social effect of witchcraft it is necessary to discuss the socio-cultural formation of the tribal society of Dooars. Socio-cultural status is generally considered as a combination of education, income, occupation, and ethnic status. The tribal of Dooars are more careful of keeping their cultural values local beliefs customs and practices. In socio-cultural formation, language is the most important one. Most of them speak in their own dialects; Knowledge of tribal dialects makes intimate contact and easy communication with them. "If development workers have no knowledge of their dialects then it may be difficult for him to work among the tribals occasionally, it may be repulsive when certain words witch conveys different meanings in

different dialects of languages are spoken."[5] Tribals have many peculiar words of their own sometimes it is formed by mixing with regional languages concerning the social life of the Indian tribes. There are some communities, and almost all of them assert themselves to their own traditional names that are known to all tribal groups and are patriarchal in terms of social organization where descent, inheritance, authority, and residence are male-determined. At the same time practice of witchcraft is their primitive taboo. This peculiar taboo has destroyed the backbone of their society.

The practice of witchcraft creates a very negative effect on the cultural life of the tribal people. Culturally the tribal belongs to the backward section of Indian society. Due to a lack of education and requisite skills, they have failed to take full advantage of new economic opportunities. "Tribal people are often exploited by middleman and contractors and also by the money lenders".[6] They often suffer from some common diseases, and most of these diseases could be cured easily if they are properly attended to in time by a qualified doctor. Tribal people often attribute their illness to supernatural forces. "As they are unaware of the cause of illness, they believe chicken pox, titanus and diarrhea are super naturally controlled. They approach the *Bhagat*, their traditional village doctor for cure."[7] The tribal have a strong belief in him and his treatment skill. All the tribal groups have their traditional deities and spirits. So to fight out the disaster and unknown evil forces of supernaturalism many formalities in the shape of taboos, restrictions prayers chanting of hymns are in use to placate and pacify the deities to achieve a secure and undisturbed life and living. All these procedures, according to their tradition can avert the occurrence of misfortune and bring success and prosperity to their life. Thus we find warships sacrifices and other forms of prayer to appear the displeasure of all the angry spirits who are believed to bring about illness, drought, mischance, and calamities of various natures. In the case of crop failure in the attack with illness, several tribals believe that the witch is the cause of their misery. "Anything unusual or evil, which serves to raise suspicion that the witches may be practicing their mischievous."[8] Witchcraft is no doubt an evil practice, the torture done in this connection is in humans too. Primitivism and belief in old traditional rituals culturally affected the tribals and primitivism also forced the tribals for practicing witchcraft.

CASES OF WITCHCRAFT IN DIFFERENT AREAS OF DOOARS BETWEEN 1982- 2001

Sl. No.	Name of Victim	Village/ Police Station	District	Date/ Year
1	Maity Hansda	Tilar, Chalsa	Jalpaiguri	1982
2	Budhari Rai and Kanchan Rai	Naxalbari	Darjeeling	1985
3	Birsi Mahali	Mateli	Jalpaiguri	1987
4	Parvati Oraon	Mateli	Jalpaiguri	21.08.1988
5	Dukhani Oraon	Banarhat	Jalpaiguri	1990
6	Manguli Majhlyain and Somrai Manjhi	Nagrakata	Jalpaiguri	22.10.1990
7	Charki Murmu	Nagrakata	Jalpaiguri	1991
8	Sumitra Kisku	Banarhat	Jalpaiguri	1992
9	Dipali Tudu	Odlabari	Jalpaiguri	15.12.1992
10	Rupi Murmu	Malbazar	Jalpaiguri	07.07.1993
11	Reshmi Munda	Naxalbari	Darjeeling	03.04.1995
12	Somari Murda	Nagrakata	Jalpaiguri	25.11.2001

Necessary steps against witchcraft:

There are various remedies present against witch-hunting crimes when rural women are deprived of every right the Indian constitution grants to them irrespective of their caste, creed, or sex; when a social evil like witch-hunting is dealt with by the police in the same manner as they would any other crime when gender discrimination becomes an accepted reality when it is always the women who are branded a witch and not a man when witches are subjected to cruel violence like sexual assault, rape and murder on mere suspicion; when people become superstitious and blind when modern education fails to fight a social evil arising out of ancient traditions, and superstition-low and its strict implementation remain the only recourse to justice. Because justice is the only way that can rejuvenate home among simple ignorant and sub-massive women who have been exploited for generations as witches. “Witch-hunting is a clear cut manifestation of gender discrimination because in most of the cases women are found victimize.”[9] It is a burning problem in tribal society. Education is one of the agents of

socioeconomic change in society, education institutions serve to modify social and cultural conditions. But the plantation workers of Dooars are mostly of tribal origin, the majority of them are illiterate, and the rate of female literacy is absolutely low. So due to illiteracy and poor health condition, most of the tribal women retain good faith in their traditional beliefs and customs. "This strong adherence on blind faith creates misfortune in their life. Thus occasionally they became the victim of witch-hunting."[10] There are various suggestions to prevent witch-hunts and they are (i) the profession of the witch doctor, *Janguru, Sokha, Mati,* etc. must be banned. (ii) In school books and syllabus, anti-witch stories must be propagated, and anti-dyne and anti-*Janguru* campaigns should be organized by the government through files and documentaries in different tribal languages. In radio and Doordarshan there should be continuous publicity against witches and *Janguru*. In this way, we can remove this superstitious practice from our society.

Conclusion: In conclusion, it can be said in modern society witch hunting is nothing but only a superstitious practice, based on some primitive belief. There is no logical base for witchcraft. In the present society, anthropologists and social scientists all are concerned about women's empowerment. So before concerning women's empowerment we have to permanently stop this evil practice. Various social campaigns in the tea garden or tribal village to improve the health condition of tribal people can remove this crucial practice, if our government and local *panchayat* have been taking various development schemes for the upliftment of the tribal women, then the tribal people can understand the negative effects of witchcraft. It is only possible through education because education is a major instrument of social change and cultural progress by introducing new ideals, perspectives, motivations, and social values. Different NGOs should be encouraged with the help of local administration against witch and *Janguru* campaigns in tribal areas. Lastly, there should be strict specific laws in the country that will enforce the anti-witch and anti-*Janguru* activities very rigorously like the sati-dah of William Bentinck, so we can prevent this peculiar practice from our society.

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Digital Divide in School Education: Teachers' Perspective

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ABSTRACT

The present study is an exploratory qualitative research to find out the present scenario of digital divide in government sponsored schools from teachers perspective. The study included a teacher sample of 60 secondary school teachers from government sponsored schools of Kolkata. Data was collected through the Semi-structured interview. It was analyzed using deductive reasoning following coding into themes after transcription. The findings demonstrated that teachers perceive substantial digital divide in government sponsored schools despite the quick advancements in technology. The digital divide is present among school teachers at all the three levels - access, skill-usage, and effect. It can be concluded that the digital divide is now a concern for teachers. The gap between technology user and non-user must be bridged for the better future of education.

Keywords: Digital Divide, Education, Teachers, Perspective

Introduction

Face to face classroom teaching and interaction play the most vital role in the academic pursuits of students as well as the teachers. Following the outbreak of COVID-19 pandemic, the schools and colleges were forced to shift to online education. The technologies and online platforms used for accomplishing the task were new to the teachers and students. A 2020 study by the West Bengal and Campaign against Child Labour (CACL) and Right to Education Forum (RTE Forum) — covering 2,154 children and their families in West Bengal, found that Digital education is creating a large social divide within children and their families, depriving the majority of children from their right to free and compulsory education; the government should recognize this an important issue and make plans to include all children within the school education system on an equitable basis.

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Received: *16th August, 2022 / **Accepted:** 25th September, 2022*

Digital Divide in Education

Since the early days of the internet, the 'digital divide' has been of concern to social scientists. Digital inequalities, according to Ragnedda & Kreitem , 2020 correspond to the three levels exists in terms of *access* (first level of digital divide), digital skills and digital competences required *to use* the Internet competently (second level of digital divide), and inequalities in the capacities *to get the benefits* from the access and use of the Internet (third level of digital divide). The literature has proposed three levelsof the digital divide (Scheerder, 2017).

First Level is *Access Divide (the physical availability of the technology)*

Second Level is *Skills and Usage Divide (technical skills and technology use)*

Third Level is *Effects Divide (benefit and transformation)*

Access Divide **-** Although access to computer, digital gadgets and internet was initiallyasignificant source of difference, presently it is not accounting for a big difference between social groups, at least not in highly developed nations. However, even today access varies across socioeconomic groups in terms of material availability of devices, software, subscriptions, and secondary electronic and digital equipment. Pro-technology opinions in digital divide research highlight the disparity between those who have access to technology and those who do not have access to technology. This school of thought assumes that once people has access, everyone has the potential to use technology and enjoy benefits . Example is in e-governance.

Skills and Usage Divide **-** Skills and usage of technology concerns the second level of divide. Determinants of skills and usage are generally socioeconomic status, age, gender, location, and ethnicity. The literature distinguishes between various forms of internet usageand skills, where predominantly information seeking and engaging in commercial transactionsare stratified by educational attainment, and information seeking is strongly stratified by being a student and learning community.

Effects Divide- This is the third level of digital divide. It is concerned with the effects of technology access, skills and usage on various outcomes such as employment, education, social and health (Van Deursen and Helsper 2015). In educational context, studies showsthat digital skills enhance educational performance, particularly among students from less advantaged

backgrounds. Resources and appropriation theory of also predicts digital inequalities from the appropriation of technology use by elites. So it is observed that in the digital divide, society is divided in groups whetherthey have access, have the skills, use technology, and experience benefits of Education and other domains. In case of digital inequalities in education, it is also dependent on the context in which students are educated

Digital Divide and the Teachers

The COVID-19 pandemic has changed the face of the classroom. The teachers are made to integrate technology efficacy into classroom. ICT aids teachers not only in teaching only; it aids them for continuous enrichment and professional development. Now the question is why the teachers need to adapt to new technologies. In this digital age teachers are facilitators of learning, they are guide by the side. The importance of technologyfor teachers is that the teaching profession is evolving from an emphasis on teacher-centered, lecture based instruction to student–centered, interactive learningenvironment with the emerging new technologies UNESCO (2002). For designing and implementing successful technological change in education, it is essential that pre- service and in-service teachers have basic technological skills and competencies. Teacher education institutions must provide the leadership for pre-service and in-service teachers and must be model in the new pedagogies and tools for learning equipped with technologies. Only a section of the teachers are technologically sound. This has created a gapbetween and among the teachers. This may be refereed as Teacher'digital divide.

Research Questions

The researcher tries to address the following research questions in this study**:**

(1) What do the teachers' perceive about digital divide in education?

(2) To what extent teachers are prepared to adopt technology in education?

(3) How, do the teachers speak out, regarding access and usage of technology in education?

(4) Whatare the problem areas, teachers face in adopting technology in education?

(5) What teachers suggest for overcoming the problems of digital divide?

Research Methodology

This study is an exploratory qualitative study. The present study adopted a qualitative research methodology to explore the perspective of digital divide in selected school teachers in order to get answers to the research questions.

Sampling

Purposive sampling technique was used to select the total teacher sample of 60 secondary school teachers from government sponsored schools of Kolkata. A purposive sample is a sample selected in a deliberative and non-random fashion to achieve a certain goal. A purposive sample share the same weaknesses as a convenience sample and have difficulty making strong quantitative inferences from such a sample. But for qualitative study is quite a good option.

Data Collection

Data collection was done in this exploratory qualitative study using a Semi-structured interview over online video conferencing mode using Google meet application. The period of data gathering was during the month of December 2021. I a Semi-structured interview data is collected in a flexible way. The interview questioning order can be controlled while still allowing forspontaneity. The interviewer asks many questions, and the interviewee can be pressedfor complete answers or may respond to complex and deep issues (Cohen, Manion, and Morrison, 2007).

Data analysis and Interpretation

Data collected through the Semi-structured interview were first transcribed and then coded into themes. It was analysed using deductive reasoning, which is a way of finding, organizing, characterizing, and reporting the themes in the collected data (Braun and Clarke, 2008). Based on the conceptual framework, the transcribed data from interviews and surveys were divided into various themes. Based on the data Table 1 represents the procedural definitions of the categories.

Code	Description
Access Divide	Teachers view access varies due to material availability of devices, software, subscriptions, and digital equipment. Pro-

	technology opinions highlight the disparity between those who have access to technology and those who do not have access to technology. Contribution: Access Divide added apathy among teachers to use and harness the benefit of new technology. It also acted as demotivator.
Skills and Usage Divide	Teachers remind the lack of training and the procedures in their administration. Usage Access teachers describe the schools' infrastructure as unprepared and fragile due to their lack of resources and its adequacy. Contribution: Skills and Usage Divide further augmented gross digital devide.
Effects Divide	Teachers believe that technology gives students and teachers, access to the best pedagogy and learning resources, e- content. This changes the teacher's role and teaching potential. Teachers feel technology evolves to teach more topics adequately making teachers good facilitators of learning. Contribution: Effects Divide promoted disparity in teaching effectiveness across different subjects and discipline.

Discussion

School teachers in their interview, acknowledged that most of them enjoy using digital devices like laptop desktop and smartphone and feel at ease doing so, majority of them are not interested in using Smartphones for ease of use. A few of them view it as an impractical instrument that makes them feel burdened when they use it and feel stressed. Additionally, from their perspective, guardians, parents lack the motivation to use digital devices. Motivation is impacted by a variety of factors, including an unwillingness to purchase digital devices, dissatisfaction with online learning, student boredom, and cyber hazards, device malfunctions. Study also revealed that the high price of devices, weaker socio-economic situation, lack of material access, scarcity of computers in school, contributed to lower use of technology by teachers and students.

Teachers demonstrated that all teachers are not technology friendly neither they are technology ready. Some teachers have advanced knowledge and skills while others have no have that at all. The lack of digital competence of teachers in schools has also been noted. In addition the elderly teachers are not willing to acquire skills for new technologies. Many teachers excuse their resistance to adopting technology by saying that it takes a lot of time to prepare lessons. Rather it is easier to prepare lessons in traditional paper pencil mode. The purpose of the study was to investigate the teachers' experiences with the digital divide in schools. According to the results of the current study, not everyone has equal access to ICT resources. The findings showed that there were disparities in access that led to a widening of the digital divide in public schools. The three levels of the digital divide are contributed by: **Indifference** – A sizable sectioncorresponding to 30% of the teachers show no interest for the use of technology based tools in their teaching. They do not use these tools sometimes because of generation gap sometimes due to lack of familiarity of using computers, the Internet, and other digital media on a daily basis. They are of a kind of digital immigrants Marc Prensky, (2001).**Infrastructural Inadequacy**– Inadequacy of technological infrastructure like devices and internet is a disabler for teachersmotivation to integrate technology inteaching learning process. **Professional lagging** - Training facilities regarding the use of internet and other computer based software are not given properly and productively.

Institutional free internet- Most of the institutions lack the free internet facility which creates situation of digital divide among teachers and students. Non-availability of internet facilities is one of thereasons of digital divide.**Technophobia -** Teachers have a kind of anxiety and fear of technology. This technophobia is usually due to the poor knowledge and skills.**Language &E-Lingua Franca**- Most website pages are in English. Internet is English dominating.Lack of authentic and proper translation of such material into other languages, creates problem in understanding and making proper use of the vast knowledge available online.

Conclusion

Present study tried to explore digital divide in government sponsored schools, as these schools constitute the largestproportion of the public. The findings demonstrated that teachers perceive substantialdigital divide in government sponsored schools despite the quick advancements in technology. Thedigital divide is present among school teachers at all the three levels ofaccess,

skill-usage, andeffect. Based on the study's findings, we recommend that relevant institutions, to improve technology skills and implementation, teachers need to be more aware of how they personally use technology in their classrooms and personal use too. Teachers can use technology in their teaching to increase the instructional use of digital devices in their classrooms.Even if teachers do not have the power to change many of the circumstances in their school's learning environment, they can act as catalysts for change by modeling various methods ofintegrating technology into curriculum daily classroom practices. It can be concluded that the digital divide is now a concern for teachers too the gap between technology user and non-user must be bridged for the better future of education.

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পরিবর্তনের ধারায় দুর্গাপুর শিল্পাঞ্চল
নগরায়ন ও শিল্পায়নের ইতিহাস

রাজশ্রী দত্ত*

দ্বিতীয় পঞ্চবার্ষিকী পরিকল্পনার ভারি আর বুনিয়াদি শিল্পের যে সরকারী উদ্যোগ তার তৃতীয় ফসল হল দুর্গাপুর স্টীল প্ল্যান্ট- পশ্চিম বর্ধমান জেলায় অবস্থিত এই অঞ্চলটি বহু দিন যাবৎ বাংলার রুঢ় হিসেবে পরিচিত। হাজার হাজার মানুষের রুটি রুজির উৎস এই শিল্পশহর। জীবিকার সন্ধানে বহু মানুষ এখানে এলেও কালক্রমে তারা এখানকার স্থায়ী বাসিন্দায় পরিণত হন। আজ যেখানে যন্ত্র সভ্যতার দুর্নিবার অগ্রচারিতা, প্রায় ষাট বছর আগে তা ছিলো কিছু গ্রামবাসীর নিবিড় আশ্রয়। ছিল শাল,পলাশ,মহুয়া গাছের বিশাল জঙ্গল, ছিল বন্য পশুর ও ঠ্যাঙাড়দের রাজত্ব। আর এই অরণ্যে আচ্ছাদিত বিস্তীর্ণ ভূভাগে ছড়িয়ে ছিটিয়ে ছিল বেশ কয়েকটি গ্রাম- যা আজ শুধুই ইতিহাস। উনিশ'শ পঞ্চাশের দশকের মাঝামাঝি সময়ে দুর্গাপুরে শিল্পস্থাপনের পরিকল্পনাটিকে কার্যকর করার প্রয়াস শুরু হয় যার জন্য বেশ কয়েকটি গ্রামের মানুষদের হাতে পৌঁছে যায় পিতৃভূমি থেকে উচ্ছেদের উৎখাত পরোয়ানা। একদিকে উন্নয়ন আর অপরদিকে বাস্তু হারানোর যন্ত্রনা, গ্রামের তুচ্ছাতিতুচ্ছ বাস্তুহারা পরিবারগুলোকে ভীষনভাবে আলোড়িত করে।শিল্পায়ন ও নগরায়নের ইতিহাসে যাঁরা থেকে গেছেন অন্তরালে।শিল্পস্থাপনের সময় থেকেই এই অঞ্চল দ্রুত বদলে যেতে থাকে। গ্রাম কিভাবে শিল্পনগরীতে পরিণত হল? সবুজ প্রান্তর কীভাবে চিমনির ধোঁয়া সম্বন্বিত যন্ত্রাংশের ক্ষেত্রে পরিণত হল? কীভাবে গ্রাম দুর্গাপুর কৃষিভিত্তিক আর্থ-সামাজিক অবস্থার খোলস ছাড়িয়ে এগিয়ে যেতে থাকে শিল্পায়নের পথে- এইসব প্রশ্নের উত্তর খুঁজতেই এ লেখার আয়োজন- যা আমার আবাল্য বসবাস সূত্রে কিছুটা জানা, কিছুটা গ্রামে গিয়ে গ্রামবাসীদের কাছে স্বাক্ষাৎকার লব্ধ এবং কিছুটা সরকারি নথিপত্র ও পত্রিকা থেকে সংগৃহীত। শিল্পায়ন এবং নগরায়নের ধারাকে বোঝার জন্য এই নিবন্ধের Period হিসেবে নির্বাচন করেছি ১৯৫১-২০০১ পর্যন্ত সময়কালকে।

Primary Source হিসেবে আমি ব্যবহার করেছি Burdwan Census, Gazetteers, Administrative Report এবং মৌখিক সাক্ষাৎকার। Secondary Source হিসেবে ব্যবহার করেছি শিল্পাঞ্চলের উপর লেখা বেশ কিছু গ্রন্থ ও উপন্যাস।

সূত্রশব্দ: Census Report, ফায়ারব্রিক্স, শিল্পনগরী, Industrial Complex, ADDA, দামোদর ভ্যালি কর্পোরেশন

কলকাতা থেকে ১৫৮ কি.মি পশ্চিমে এবং রেলপথে ১৭১ কি.মি দূরত্বে দুর্গাপুরের অবস্থান।ভৌগোলিক মানচিত্রে ২৪°১৫' উত্তর ও ৮৭°৫৫ পূর্বদিক চিহ্নিত[১]।উনিশ'শ পঞ্চাশের দশকের আগে দুর্গাপুর ছিল

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Received: *16th September, 2022* / ***Accepted:*** *24th December, 2022*

শাল মহুয়ায় ঘেরা এক সবুজ বিস্তীর্ণ প্রান্তর। ১৯৫১ সালের Census Report অনুসারে দুর্গাপুর ছিল আসানসোল মহকুমার ফরিদপুর থানার অন্তর্গত একটি Union। এই রিপোর্টে ফরিদপুর থানা অঞ্চলকে একটি গ্রামাঞ্চল হিসাবে বর্ণনা করা হয়েছে। আরো জানা যাচ্ছে সেই সময় ফরিদপুর থানায় ছড়িয়ে ছিটিয়ে ছিল প্রায় ৪৫ টি গ্রাম।[২] যদিও এব্যাপারে মধু চট্টোপাধ্যায় লিখেছেন 'সেই সময় ফরিদপুর থানার অন্তর্গত ছিল ৮৭টি গ্রাম'।[৩]কিন্তু ১৯৫১ এবং ১৯৬১ সালের Census Reportএ উল্লিখিত হয়েছে ফরিদপুর থানার অন্তর্গত ৪৫টি গ্রামের নাম এবং তাদের জনসংখ্যা। জানা যাচ্ছে, ১৯৫১ সালে এই ৪৫টি গ্রামের জনসংখ্যা ছিল ২৭,৪৪৬ । এই প্রসঙ্গে জানিয়ে রাখা দরকার যে ১৯৫১ এবং ১৯৬১ সালের Census Report এর দিকে তাকালে এটা পরিষ্কার বোঝা যায় যে উনিশ'শ পঞ্চাশের দশকে দুর্গাপুরের কিছু গ্রাম ছিল ফরিদপুর এবং কিছু গ্রাম ছিল অন্ডাল থানার অধীন। সেদিক থেকে বিচার করলে অর্থাৎ ফরিদপুর এবং অন্ডাল থানা মিলিয়ে সেই সময় দুর্গাপুরে অবস্থিত মোট গ্রামের সংখ্যা ৫০টাও ছাড়িয়ে যাবে।[৪]

আজ যেখানে যন্ত্র সভ্যতার দুর্নিবার অগ্রচারিতা, প্রায় ষাট বছর আগে তা ছিলো কিছু গ্রামবাসীর নিবিড় আশ্রয়। ছিল শাল, পলাশ, মহুয়া ও কেন্দ গাছের বিশাল জঙ্গল, ছিল বন্য পশুর ও ঠ্যাঙাড়দের রাজত্ব।[৫] আর এই অরণ্যে আচ্ছাদিত বিস্তীর্ণ ভূভাগে ছড়িয়ে ছিটিয়ে ছিল বেশ কয়েকটি গ্রাম– যা আজ শুধুই ইতিহাস। ১৯০৫ খ্রীঃ বার্ণ অ্যান্ড কোম্পানী দুর্গাপুর রেলস্টেশনের কাছে টালি ও ফায়ার ব্রিক্স অর্থাৎ অগ্নি নিরোধক ইটের কারখানা খোলে। দুর্গাপুরে সে সময় ঐ জাতীয় উন্নতমানের টালি তৈরীর উপযোগী Yellow Clay নামে বিশেষ ধরনের মাটি সহজলভ্য ছিল। বার্ণ কোম্পানী নামে এই সংস্থার টালি (রিফ্র্যাকটারি টাইলস) দিয়ে গোপীনাথপুর প্রাথমিক স্কুলের চাল তৈরী করা হয়েছিল, সেটা এখনো টিকে আছে। বর্তমানে দুর্গাপুর রেলস্টেশনের কাছে প্রায় একশত ফুট উঁচু বিশালাকার চতুস্কোন মনুমেন্টের মতো ইঁটের চিমনি যার গায়ে ১৯০৫

অঙ্ক লেখা, সেটি আজও দাঁড়িয়ে আছে। যা দুর্গাপুরের শিল্পের শতাব্দী–প্রাচীনত্ব ঘোষণা করছে। তবে দুর্গাপুরে ফায়ার বিক্সের বাজার ছিল না বলে রাণীগঞ্জ থেকে ঐ সমস্ত দ্রব্য বিক্রি করা হতো। ফলে বাংলার বাইরে দুর্গাপুরের টালি রাণীগঞ্জের টালি নামে বিখ্যাত হয়ে ওঠে।[৬]

এই অঞ্চল ছিল বনজ সম্পদে সমৃদ্ধ। ছিল শাল, পলাশ, মহুয়া ও কেন্দ গাছের বিশাল জঙ্গল। দ্বিতীয় বিশ্বযুদ্ধের বহু আগে থেকেই এই জঙ্গল কাঠ ব্যবসায়ীদের একটা বড় কর্মকেন্দ্র হিসেবে গড়ে উঠেছিল। দুর্গাপুর অঞ্চলে কাঠ সরবরাহের অন্যতম বড় ব্যবসায়ী ছিল বেঙ্গল কোল কোম্পানী। স্থানীয় কয়েকটি উচ্চবিত্ত পরিবারও এই অঞ্চলের কাঠ ব্যবসায় লিপ্ত ছিল। এদের মধ্যে পলাশডিহার সামন্ত পরিবার, বীরভানপুরের আচার্য পরিবার, সরপীর রায় চৌধুরী পরিবার বিশেষভাবে অগ্রণী ছিল।[৭] ১৮৪৩ সালে সৃষ্ট 'বেঙ্গল কোল কোম্পানী' এই বনাঞ্চল থেকে কাঠ সংগ্রহ করতো। এই সময় হাওড়া হুগলী অঞ্চলে শিল্পের প্রসার ঘটায় কাঠের চাহিদা ছিল খুব। ১৮৫৫ সালে 'ইস্ট ইন্ডিয়া রেলওয়ে কোম্পানী' হাওড়া হুগলী রেলপথকে রাণীগঞ্জ পর্যন্ত সম্প্রসারিত করে। ফলে এই রেলপথের মাধ্যমে একদিকে যেমন রাণীগঞ্জের কয়লা সরবরাহ করা হতো তেমনই অন্যদিকে দুর্গাপুরের ঘন বনাঞ্চল থেকে কাঠও সরবরাহ করা হতো। এই রেলপথের মাধ্যমে কাঠের যোগানকে নিশ্চিত করার জন্যই দুর্গাপুরে অবস্থিত গোপীনাথপুর মৌজায় একটি ছোট রেলস্টেশন স্থাপনের প্রয়োজন অনুভব করেছিল ইংরেজ বণিক কোম্পানী। এই স্টেশনটির নাম রাখা হয়েছিল 'দুর্গাপুর।' এই স্টেশনটির নাম থেকে বিরাট একটি অঞ্চল দুর্গাপুর নামে পরিচিত হয়েছে।[৮] বলা বাহুল্য বর্তমানে কিন্তু শাল, পলাশ, কেন্দ গাছের জঙ্গল আর চোখে পড়ে না। শিল্পনগরী বর্ধিষ্ণুতার কারণে তা হ্রাস পেতে পেতে আজ একেবারেই অবলুপ্ত হয়ে গেছে। শুধু ব্যবসা বাণিজ্য নয়, এই অঞ্চলে কিছু কৃষিজ উৎপাদনও হতো। ধান, আখ, ডাল জাতীয় শস্য, সরষে ও বিভিন্ন সব্জির চাষ হতো প্রায় সারা বছর ধরেই এবং উনিশ শ'পঞ্চাশের দশকের মাঝামাঝি সময় পর্যন্ত এই অঞ্চলের প্রায় ৯০ শতাংশ মানুষ নিবিড়ভাবে যুক্ত ছিল কৃষিকাজের সঙ্গে।

দুর্গাপুর নামকরনের পেছেনে আছে এক বর্ণময় ইতিহাস। ইতিহাস আনুসন্ধানে জানা যাচ্ছে ১৭৬০ খ্রীষ্টাব্দের ডিসেম্বর মাসে ইষ্টইন্ডিয়া কোম্পানী বর্ধমানের জমিদারি দখল করলেও বর্ধমানের মহারাজাকে গদিচ্যুত না করে রাজস্ব বৃদ্ধি ও আদায়ের সুব্যাবস্থার অজুহাতে ১৭৬১ খ্রীষ্টাব্দে বর্ধমানে একজন ইংরেজ রেসিডেন্ট নিয়োগ করে, যিনি একরকম বর্ধমানের মহারাজের অমতে জমিদারির অংশবিশেষ প্রকাশ্যে নিলামে সর্ব্বোচ্চ ডাকে লাটে বন্দোবস্তো শুরু করেন। ১৭৬৫ খ্রীষ্টাব্দ পর্যন্ত এই নীতি অনুসৃত হয়। লর্ড কনওয়ালিস ১৭৯৩ খ্রীষ্টাব্দে চিরস্থায়ী বন্দোবস্তো চালু করেন। এই সময় জঙ্গল মহলের একাংশ (যা বর্ধমানের মাহারাজার জমিদারির অংশ ছিল) নিলামে কিনে নেন গোপীনাথ চট্টোপাধ্যায় নামে এক জনৈক ব্রাহ্মন।এইভাবে জঙ্গলমহলের একাংশের যে বন্দোবস্তো

নেওয়া হল গোপীনাথ বাবুর নাম অনুযায়ী 'লাট গোপীনাথপুর মৌজা' নামে খ্যাত হয় (জে এল নং ৮৫–সরকারি রিপোর্টে পরিচিত)।

গোপীনাথবাবুর পূর্ব নিবাস ছিল বর্তমান বাঁকুড়া জেলার জগন্নাথপুর গ্রামে। সেখানে সদ্‌গোপ বংশীয় জমিদারের সঙ্গে বনিবনা না হওয়ায় তিনি তার পুত্র দুর্গাচরণ এবং কন্যা অনন্দময়ীকে নিয়ে নর্ডিহা গ্রামে (জঙ্গল মহলের পাশে অবস্থিত) কিছু জমি জমা সংগ্রহ করে বসবাস করছিলেন। গোপীনাথপুর মৌজার জমিদারী যখন তিনি পান, এই অঞ্চল ছিল ভয়াবহ জঙ্গল, ডাকাতদের উৎপাত। তিনি উদ্যোগী হয়ে এই অঞ্চলে প্রজাবিলি বন্দোবস্ত করেন, জঙ্গল কেটে বসতি স্থাপনের উদ্যোগ নেন। তাঁর মৃত্যুর পর পুত্র দুর্গাচরণ জলা সংস্কার করে চাষের সুবন্দোবস্ত করেন। নডিহা থেকে বসতবাড়ি, জমিদারী সেরেস্তা, গৃহদেবতার ভৈরব মন্দির স্থানান্তর করেন এই জঙ্গলমহলে এবং নিজ নামে এই অঞ্চলের নামকরণ করেন 'দুর্গাপুর'। অবশ্য সরকারী কাগজপত্রে সমস্ত মৌজা 'লাট গোপীনাথপুর মৌজা' (জে এল নং ৮৫) নামেই দুর্গাপুরে শিল্পস্থাপনের আগে থেকে চিহ্নিত হতো। তবে সরকারি সেটেলম্যান সার্ভের কাগজপত্রে জোত দুর্গাচরণ চট্টোপাধ্যায়ের উল্লেখ পাওয়া গেছে।[৯]

কৃষিপ্রধান দেশের উন্নয়নের জন্য স্বাধীনতা উত্তর ভারতবর্ষের রাষ্ট্রনায়করা শিল্পায়নের উপর জোর দেন। ফলে একের পর এক লৌহ ইস্পাতশিল্প গড়ে উঠতে থাকে ভারতে। প্রথমটি উড়িষ্যার রাউরকেল্লায়, দ্বিতীয়টি মধ্যপ্রদেশের ভিলাইয়ে এবং তৃতীয়টি দুর্গাপুরে। শিল্পস্থাপনের পরিকাঠামোগত সকল সুযোগ সুবিধা থাকায় দুর্গাপুর হয়ে উঠল "Ruhr of India"। দুর্গাপুরের কাছাকাছি রাণীগঞ্জ, আসানসোল, ধানবাদ, ঝরিয়ার সহজলভ্য উন্নতমানের কয়লা, সিংভূমের লোহা,বীরমিত্রপুরের চুনাপাথর আর গাংপুরের ডলোমাইট, দামোদর প্রকল্পের বিদ্যুৎ এবং জল সরবরাহ, পূর্ব রেলপথ এবং জাতীয় সড়কের পরিবহনের সুবিধা, শ্রমিকের সহজলভ্যতা, প্রয়োজনীয় জমির সংস্থান প্রভৃতি আবশ্যক উপাদানগুলি থাকার ফলে পশ্চিমবঙ্গ সরকার এই স্থানকে শিল্পকেন্দ্র হিসাবে গড়ে তোলার গড়ে তোলার সিদ্ধান্ত নেন।[১০] তৎকালীন পশ্চিমবঙ্গের মুখ্যমন্ত্রী ডাঃ বিধান চন্দ্র রায় নিজের হাতে ১৫ কোটি টাকা ব্যয় বরাদ্দে একটি বৃহৎ শিল্প সংস্থা গড়ে তোলার স্থির সংকল্পে তা অনুমোদন এর জন্য পাঠান দিল্লীতে। কিন্তু অনুমোদন প্রাপ্তির অহেতুক বিলম্বে ২৫ কোটি টাকা ব্যয়ের শেষ পর্যন্ত গড়ে উঠে দুর্গাপুর প্রজেক্ট লিমিটেড। একই সময়ে ১৯৫৬ সালের ৩১শে অক্টোবর ব্রিটিশ স্টীল কনসোর্টিয়াম প্রজেক্টের সাথে দুর্গাপুর স্টীল প্ল্যান্ট কারখানা স্থাপনের সিদ্ধান্ত চূড়ান্ত হয়। বস্তুত ১৯৫৫ সালেই শিল্প সংগঠনের Industrial Complex–এর রূপরেখা স্পষ্ট হয়ে দেখা দেয় দুর্গাপুরে[১১]।

লৌহ ও ইস্পাত শিল্পে বর্ধমান জেলায় একটি ঐতিহ্য আছে। ১৮৮৭ সালে কুলটি এবং ১৯৫৩ সালে বার্নপুরে লৌহ কারখানা স্থাপিত হয়েছিল ব্যক্তিগত উদ্যোগে। ১৯০৫ খ্রীষ্টাব্দে বার্ন এ্যান্ড কোম্পানী দুর্গাপুর রেলস্টেশনের উত্তরে টালি তৈরির কারখানা স্থাপন করে। ১৮৫৫ খ্রীষ্টাব্দ পূর্ব রেলের প্রধান শাখাটি অন্ডাল পর্যন্ত সম্প্রসারিত হলে দুর্গাপুরে একটি রেলস্টেশন স্থাপনের প্রয়োজনীয়তা অনুভব করে ইংরেজ ইস্ট ইন্ডিয়া কোম্পানী। স্টেশনটির নাম হয় 'দুর্গাপুর'। জি টি রোডের সানিধ্য অঞ্চলটিকে যোগাযোগ ও পরিবহনের উপযুক্ত অতিরিক্ত সুবিধা দান করেছিল। তৎকালীন মুখ্যমন্ত্রী ডঃ বিধান চন্দ্র রায় এই ঐতিহ্যের দিকে তাকিয়েই দুর্গাপুরকে শিল্পনগরী হিসেবে গড়ে তোলার স্বপ্ন দেখেছিলেন। (১২)

দুর্গাপুর রূপান্তরের সূচনা ১৯৫০-এর দশকের গোড়ার দিকে, দামোদর ভ্যালি করপোরেশন গঠনের সময় থেকেই। ১৯৫২ সালে দামোদর বাঁধ নির্মাণের কাজ শুরু হয়। শুরু হয় নগরায়নের যাত্রা, দ্রুত বদলাতে থাকে এই অঞ্চলের আভ্যন্তরীন মানচিত্র। ১৯৫৫ সালের ৯ই আগষ্ট এই বাঁধের আনুষ্ঠানিক উদ্বোধন করেন তৎকালীন উপরাষ্ট্রপতি ডঃ সর্বপল্লী রাধাকৃষ্ণান। এই ব্যারেজের মাধ্যমে একদিকে যেমন বর্ধমান ও বাঁকুড়া জেলাকে একসূত্রে গেঁথে দেওয়া হয় তেমনই সঠিক পরিসংখ্যান অনুযায়ী নয় লক্ষ তিয়াত্তর একর পরিমাণ খারিফশস্য, আর পঞ্চান্ন হাজার একর পরিমাণ রবিশস্যের জমিতে জলসেচের সম্ভাবনা দেখা দিল। দুর্গাপুরে আধুনিক সভ্যতার গোড়াপত্তন বলতে এই সময় থেকে। ব্যারেজ নির্মাণকে ঘিরে দুর্গাপুরে প্রথম উপনিবেশ গড়ে উঠল। দুর্গাপুরের অনতিদূরে লাচ্ছিপুরে আগে থেকেই একটি বিদ্যুৎ উপকেন্দ্র ছিল। ১৯৫৮ সালে ওয়ারিয়া রেল স্টেশনের কাছে দামোদর ভ্যালি করপোরেশন আর একটি তাপবিদ্যুৎ কেন্দ্র স্থাপন করে। নাম দুর্গাপুর থার্মাল পাওয়ার স্টেশন।(১৩)

১৯৫০-এর দশকের শেষ থেকে শুরু করে ১৯৬০ এবং ৭০-এর দশকে দুর্গাপুরে গড়ে ওঠে আরো অনেক কারখানা । অতি সংক্ষেপে সেই বিবরণ লিপিবদ্ধ করা হল। রাষ্ট্রায়ত্ত শিল্পগুলির মধ্যে উল্লেখযোগ্য এ্যালয় স্টীল প্ল্যান্ট (১৯৬৩), মাইনিং এ্যান্ড অ্যালায়েড মেশিনারী কর্পোরেশন (১৯৫৯), দুর্গাপুর কেমিক্যালস (১৯৬৩), ভারত অপথ্যালমিক গ্লাস লিমিটেড (বিওজিএল)১৯৬৫, হিন্দুস্থান ফার্টিলাইজার কর্পোরেশন (১৯৬৬)। প্রাইভেট শিল্প হিসাবে উল্লেখযোগ্য ফিলিপস্ কার্বন (১৯৫৮), এসিসি ব্যাবকক্ লিমিটেড (১৯৬০),শ্যাঙ্কি হুইলস (১৯৬৩), গ্রাফাইট ইন্ডিয়া লিমিটেড (১৯৬৪), এশিয়াটিক অক্সিজেন লিমিটেড (১৯৬২),

দুর্গাপুর সিমেন্ট ওয়ার্কস (১৯৭২), মর্ডান সেরামিক প্রাঃ লিঃ (১৯৭৮)। পশ্চিমবঙ্গ সরকারের অধীনে গড়ে ওঠে যেসব শিল্পসংস্থা সেগুলি হল উড় ইন্ডাস্ট্রি ওয়ার্কশপ, দুর্গাপুর কেমিক্যালস্ লিমিটেড (১৯৬৩),গ্রাফাইট ইন্ডিয়া লিমিটেড (১৯৬৪), হিন্দুস্থান ফার্টিলাইজার করপোরেশন (১৯৬৬), দুর্গাপুর স্টেটস্ ডেয়ারী (১৯৬৬), ইন্ডিয়ান অয়েল কর্পোরেশন (১৯৬৬), বাস্তবধর্মী শিক্ষার প্রয়োজনীয়তাকে স্বীকার করে নিয়ে দুর্গাপুরে কারিগরি শিক্ষার প্রথম পদক্ষেপ হিসাবে ১৯৬০ সালে রাজ্য সরকারের পরিচালনাধীন ইন্ডাস্ট্রিয়াল ট্রেনিং ইনস্টিটিউট প্রতিষ্ঠিত হয়। দ্বিতীয় পদক্ষেপ হিসাবে গড়ে ওঠে দুর্গাপুর রিজিওনাল ইঞ্জিনিয়ারিং কলেজ, তৃতীয় পদক্ষেপ হিসাবে গড়ে ওঠে সেন্ট্রাল মেকানিক্যাল ইঞ্জিনিয়ারিং রিসার্চ ইনস্টিটিউশন। রাষ্ট্রায়ত্ত উদ্যোগে গড়ে ওঠে পরিবহন সংস্থা দুর্গাপুর স্ট্রেট ট্রান্সপোর্ট করপোরেশন।[১৪]

এই শিল্পগুলি গত শতকের আটের দশকের প্রথম দিক পর্যন্ত চলে বৈদেশিক বাণিজ্যে আমদানি প্রতিস্থাপনমূলক নীতির জমানায় – যেখানে সামগ্রিকভাবে ভারতীয় অর্থনীতির স্বনির্ভরতা অর্জন করা ছিল জাতীয় লক্ষ্য। আটের দশকের মাঝামাঝি থেকেই অর্ন্তনিহিত নীতিগুলো বদলে যেতে থাকে এবং আমদানির উপর আগেকার বিধি নিষেধ তুলে নেওয়া হয়। রাষ্ট্রায়ত শিল্পেও প্রতিটি কারখানা নিজস্ব মুনাফা বাড়ানোর নীতিতে চলবে এটা ঠিক করার পরই বেশ কিছু কারখানা,এককভাবে যারা মুনাফা অর্জন করতে পারছিল না তাদের অস্তিত্ব অনিশ্চিত হয়ে পড়ে। নয়ের দশক থেকেই বেশ কিছু কারখানা বন্ধ হয়ে যায়। যেমন এম এ এম. সি, এইচ এফ সি আই, বি ও জি এল, জেশপ ব্র্যান্ড কোং, শ্যাঙ্কি হুইলস । তবে নতুন কারখানা প্রতিষ্ঠার ধারা বর্তমানেও অব্যাহত আছে, বিশেষত ইস্পাত শিল্পে – এই কারখানাগুলো সাধারণভাবে মিনিস্টীল প্ল্যান্ট নামে পরিচিত। মূলত স্পঞ্জ আয়রন ও ফেরো এ্যালয় প্রস্তুতকারী কারখানা এবং কিছু রোলিং ও ঢালাই কারখানা।[১৫]

১৯৬৮ সালের আগে দুর্গাপুর ছিল প্রথমে রাণীগঞ্জ ও পরে আসানসোল মহকুমার অধীন। ১৯৬৮ সালের ১৪ই এপ্রিল দুর্গাপুর স্বতন্ত্র মহকুমার স্বীকৃতি পায়। এই মহকুমার বর্তমান থানার সংখ্যা ৫টি। (১) দুর্গাপুর (২) ফরিদপুর (৩) অন্ডাল (৪) কাঁকসা (৫)বুদবুদ[১৬]

১৯৫৫ খ্রীঃ দুর্গাপুর ইন্ডাস্ট্রিয়াল বোর্ডের পরিচালনায় দুর্গাপুরে শিল্পস্থাপনের প্রাথমিক পরিকল্পনাগুলি গৃহীত হয়। অল্পদিনের মধ্যেই এই অঞ্চলে ব্যাপকতার পরিকল্পনার সম্ভাবনা সৃষ্টি হওয়ায় পশ্চিমবঙ্গ রাজ্য সরকারের এক আইনে ১৯৫৮ সালে 'দুর্গাপুর ডেভেলপমেন্ট অথরিটি' (D.D.A.) নামে এক

নতুন সংস্থা গঠিত হয়।এই সংস্থাটির সঙ্গে ১৯৮০ সালে 'আসানসোল প্ল্যানিং অরগানাইজেশন' সংস্থাটি যুক্ত করে আসানসোল দুর্গাপুর উন্নয়ন সংস্থা সংক্ষেপে A.D.D.A (Asansol Durgapur Development Authority) নামকরণ করা হয়েছে। এই সংস্থাটি আসানসোল দুর্গাপুর শিল্পাঞ্চলের বড়, মাঝারি এবং ক্ষুদ্র শিল্পসংস্থাগুলিকে ভূমিবন্টন ও পরিকল্পনা বিষয়ে সাহায্য করে থাকে। জানা যাচ্ছে পূর্ব-পশ্চিম পানাগড় থেকে বরাকর নদী এবং উত্তর দক্ষিণে অজয় নদ থেকে দামোদর নদ পর্যন্ত সুবিশাল ১৬১৫.৯ বর্গকিমি এলাকা এই কর্তৃপক্ষের উন্নয়ন নিয়ন্ত্রণাধীন।[১৭]

এই প্রসঙ্গে উল্লেখ করা দরকার, দুর্গাপুরে একের পর এক শিল্প কারখানা গড়ে উঠল। আর পেটের ভাত জোগাড়ের জন্য ভিন্ন প্রদেশ থেকে আগত বহু ভাষাভাষী মানুষ ভিড় জমালো এখানে। ফলে জনসংখ্যার ক্ষেত্রে একটা বিশেষ পরিবর্তন সংগঠিত হয়। ১৯৫১ সালের Census রিপোর্ট অনুযায়ী দুর্গাপুরের জনসংখ্যা ছিল২৭৪৪৬[১৮] এবং ১৯৬১ সালের Census অনুযায়ী জনসংখ্যা ৯১,৫১৬।[১৯]১৯৭১ সালে২,০৬,৬৩[২০] এবং ১৯৮১ সালে ৩,০৫,৮৩৮।[২১]১৯৯১ সালে দুর্গাপুরের জনসংখ্যা ছিল ৪,২৫,৮৩৬ এবং ২০০১ সালে ৪,৯৩,৪০৫ বর্তমানে দুর্গাপুরের জনসংখ্যা প্রায় ৫ লক্ষ অতিক্রম করেছে বলে অনুমান করা হচ্ছে।[২২] উপরের পরিসংখ্যান থেকে এটা পরিষ্কার বোঝা যাচ্ছে ১৯৬১ থেকে ১৯৮১ সালের Census এর মধ্যবর্তী সময়ে জনবিস্ফোরণ ঘটে। তার কারণ হিসেবে আমরা বলতে পারি শিল্পস্থাপনের সূচনা থেকে বিভিন্ন জেলা থেকে মানুষ জীবিকার তাগিদে দুর্গাপুরে এলেও পরে তারা বেশিরভাগই স্থায়ীভাবে বসবাস করে এবং দুর্গাপুরের স্থায়ী বাসিন্দায় পরিণত হয়। এই পর্যন্ত বর্ণিত ইতিহাস হল উন্নয়নের ইতিহাস- যা খানেকটা শিল্পায়ন ও নগরায়নেরও ইতিহাস। এই ইতিহাস অনেকেরই জানা।এই শিল্পায়নের স্বপ্নকে বাস্তবায়িত করার জন্য ১৯৫০ এর দশকে বেশ কয়েকটি গ্রামের মানুষদের হাতে পৌঁছে যায় পিতৃভূমি থেকে উচ্ছেদের উৎখাত পরোয়ানা। শিল্পায়নের চাপে মাটি ও শিকড় হারিয়ে এঁরা পরিণত হন ছিন্নমূল উদ্বাস্তুতে। দুর্গাপুর স্টীল প্ল্যান্ট যত মানুষকে রুজিরুটির আশ্রয় দিয়েছে তারও বেশি মানুষকে প্রাণের শিকড় উপড়ে ছিন্নমূল পরগাছায় পরিণত করেছে। এঁরা হারিয়েছেন অনেককিছুই।শিল্পায়নের অমৃত এঁদের জীবনে অধরাই থেকে গেছে। উন্নয়নের স্বার্থে উচ্ছেদ বাস্তব সত্য হলেও উন্নয়নের উদ্বাস্তুরা অন্ধকারেই থেকে যায়। উন্নয়নের সুফল সমাজের সর্বস্তরের মানুষের কাছে (বিশেষত যারা উন্নয়নের উদ্বাস্তু তাদের কাছে) অনেকসময় অধরাই থেকে যায়।

প্রান্ত টীকা:

১. কেমব্রিজ ওয়ার্ল্ড গেজেটিয়ার, এ টু জেড অফ জিওগ্রাফিক্যাল ইনফরমেশন, এডিটেড ডঃ ডেভিড মুনরো, পৃ- ১৮২।

২. Census 1951, West Bengal, District Handbook, Burdwan

৩. মধু চট্টোপাধ্যায়, দুর্গাপুরের ইতিহাস প্রসঙ্গে, সাহিত্য শ্রী, কলকাতা ১৯৯১, পৃঃ ১৭২

৪. যজ্ঞেশ্বর চৌধুরী,বর্ধমান: ইতিহাস ও সংস্কৃতি, ৩য় খন্ড, পুস্তক বিপনী, কলকাতা ৭০০০০৯, অক্টোবর ১৯৯৪। পৃ- ১৯৭।

৫.এককড়ি চট্টোপাধ্যায়,বর্ধমান জেলার ইতিহাস ও লোকসংস্কৃতি, ১ খন্ড, র‍্যাডিক্যাল ইম্প্রেশন, কলকাতা ৭০০০০৯, অক্টোবর ২০০১, পৃ. ১৪।

৬.মধু চট্টোপাধ্যায়, শিল্পাঞ্চলের শিল্পসাহিত্য সংস্কৃতি - যোগমায়া প্রকাশনী, আষাঢ় ১৯৯৮ (পৃঃ ৩৪),

৭. প্রবোধ চট্টোপাধ্যায়, দুর্গাপুরের ইতিহাস, রূপকল্প প্রকাশন, বেনাচিতি, দুর্গাপুর - ১৩, ১৯৮৪ (পৃঃ ১৮২)

৮. প্রবোধ চট্টোপাধ্যায়, দুর্গাপুরের ইতিহাস, রূপকল্প প্রকাশন, প্রাগুক্ত পৃঃ ১৯২

৯. প্রবোধ চট্টোপাধ্যায়, দুর্গাপুরের ইতিহাস, রূপকল্প প্রকাশন, প্রাগুক্ত পৃঃ ৯।

১০. বর্ধমান সমগ্র (দ্বিতীয় খণ্ড), সম্পাদনা ডঃ গোপীকান্ত কোঙর ,পরিবেশক দে বুক ষ্টোর, কলিকাতা, প্রথম প্রকাশ: বর্ধমান বইমেলা, ১০ই নভেম্বর ২০০০ (পৃঃ ১৬৯)।

১১.বর্ধমান সমগ্র (দ্বিতীয় খণ্ড), সম্পাদনা ডঃ গোপীকান্ত কোঙর, প্রাগুক্ত পৃঃ ১৭২

১২. মধু চট্টোপাধ্যায়, দুর্গাপুরের ইতিহাস প্রসঙ্গে, সাহিত্য শ্রী, প্রাগুক্ত পৃঃ ১৬৭

১৩. প্রবোধ চট্টোপাধ্যায়, দুর্গাপুরের ইতিহাস, প্রাগুক্ত পৃঃ ১৮৫

১৪. প্রবোধ চট্টোপাধ্যায়, দুর্গাপুরের ইতিহাস, রূপকল্প প্রকাশন, প্রাগুক্ত পৃঃ ১৯০

১৫. এস.কে.এন চৌধুরী, 'দুর্গাপুরের শতাব্দী প্রাচীন শিল্পকারখানা' শীর্ষক প্রবন্ধ, দুর্গাপুর জনজীবন পত্রিকা, ১৪ই সেপ্টেম্বর ২০০৫

১৬.বিশ্বকোষ, ত্রয়োদশ খণ্ড, "তারাগুচ্ছ", ধ্রুবতারা প্রকাশন, পৃ.২০১- ২০২

১৭. Administrative Report, Asansol Durgapur Development Authority 2000-2001.

১৮. 1961 Census, West Bengal, Burdwan, Vol-II (P-589).

১৯. Census 1971, West Bengal, Burdwan District Series 22.

২০. Census of India 1981. Directorate of Census Operations, West Bengal Series-23

২১. Census of India 2001. Directorate of Census Operations, West Bengal, Vol-2.

২২. Administrative Report, Durgapur Municipal Corporation 2004-2005.

Manuscript style-guide for authors and editors

Below are the main elements of the formatting style that the authors are requested to follow while preparing their research paper. That will help faster and error-free processing for publication.

1. General guidelines

- The entire text should in *Arial* font with font size *11* and line spacing 1.5.
- The length of the original articles and review articles should not exceed 4000 words and 6000 words, respectively.
- The writers should provide full details for correspondence together with their current affiliation.
- All submissions should be accompanied by an abstract of a maximum of 200 words.
- Authors will also provide four to six keywords for their papers.

2. Headings and Labels

- Title of the paper should use title-case, with 14 font size, bold and centred.
- The name of the author should be in 11 font size bold, in italics, and right-aligned.
- The official designation of the author(s) should be mentioned as a footnote at the bottom of the first page
- Other sections of the paper should use sentence-case.
- In order to maintain the hierarchy of headings, please keep it to a maximum of three levels. For example,

> **4 Economic Development** (Level 1)
>
> **4.1 Family Income** (Level 2)
>
> **4.1.1 Education** (Level 3)

- Kindly restrict yourself to two levels of headings; it is advisable to avoid the third level if not absolutely necessary.

3. Tables and Figures

- Please cite each table or figure in the main text. Below are examples to be followed.
- Column labels should be centred.
- Graphs and charts should be prepared in MS Office and not in jpeg or other formats.
- All sources of information in the table and/or figure should be mentioned below the respective table/figure.

> The production of paddy was 52 million tonnes in 2001 compared to 41 tonnes in 1993 (Table 3).
>
> Production rose from 6800 light and medium vehicles in 1978-88 to more than 10,000 a year by 1998-99 (Figure 1).

4. In-text citations

(a) Author-date

- All author-date citations will go in the text, with full references in the bibliography.
- Please do not use ibid. or op.cit. In case of repeated citations, all such citations must follow the author-date citation approach.

> The studies revealed that advanced medicinal knowledge rarely reached the community. (Barua, 1993).
>
> Barua (1993) revealed that advanced medicinal knowledge rarely reached the community.

(b) Page numbers

The author and date should be provided, followed by a colon and the specific page number.

> According to Basu's analysis, self-development is related to education. (1986: 74).
>
> Theories on sustainability should consider environmental aspects. (Banerjee 1998: 19–27).

4. Citations and References

(a) Article in a scholarly journal

Author(s) (Year): "Title of article," Title of journal, Volume, Issue, pages - this sequence and style should be followed.

> Chatterjee, A. (1993): "From Hegemony to Counter Hegemony: A Journey in a Non-imaginary Unreal space", *Economic & Political Weekly*, Vol 23, No 5, pp 41–50.

(b) Government publications

- The ministry, committee, agency or any subdivision that served as the author needs to be cited first.
- Next should be the date, title, place, and publisher.

> Committee on Irrigation and Water Resources (1981): "Debate on the Water Policy," Monsoon session, 1981, Lok Sabha, New Delhi: Government Press.

(c) Books

For a book citation, the style should be - Last name, First name (Year of publication): Title of book, Place of publication: Publisher.

(i) Book with one author

> Beck, George (1974): *Society: A New Perspective*, New York: Penguin.

(ii) Book with more than one author

- First author name will be written with last name/ surname first;
- Subsequent author names will be written with the first name first and then the last name/surname.

> Fisher, Henry and Adams Joe (1995): *Sustainable Development*, Boston: Academic Corp.

(iii) Two or more books by the same author

A long dash should be used for the author's name after the first entry. The books should be listed according to the year of publication.

> Bhowmick, Bikash K. (1941): *Struggle for Independence: A Social Narration*, Good Earth: Southern London University Press.
>
> — (1947) *New Independent India*, Denver: Academic Press

(d) Online citations

- Providing only the URL is usually not sufficient.
- The author, title of the text, date, title of the website, the electronic address, and the page numbers should be mentioned.
- Also the date when the source was accessed must be mentioned.