ENVIRONMENTAL DEGRADATION

CAUSES AND REMEDIATION STRATEGIES
VOLUME 1

EDITOR

VINOD KUMAR

CO-EDITOR(S)

JOGENDRA SINGH | PANKAJ KUMAR

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AGRO ENVIRON MEDIA

IMPRINTS

COVER IMAGE(s) CREDIT

https://unsplash.com/

PUBLISHED BY

Agro Environ Media,
Publication Cell
Agriculture and Environmental Science Academy (AESA),
86, Gurubaksh Vihar (East),
Kankhal, Haridwar-249408, (Uttarakhand), INDIA
Email: agroenvironmedia.aesa@gmail.com
Website: https://www.aesacademy.org

ISBN: 978-81-942017-1-7 (Print)
ISBN: 978-81-942017-2-4 (Online)
DOI: 10.26832/aesa-2020-edcrs

Environmental Degradation

Causes and Remediation Strategies

Volume 1

Editors

Dr. Vinod Kumar
Assistant Professor (Senior Grade)
Department of Zoology and Environmental Science,
Gurukula Kangri University, Haridwar, India

Co-editor(s)

Mr. Jogendra Singh
Research Scholar,
Department of Zoology and Environmental Science,
Gurukula Kangri University, Haridwar, India

Mr. Pankaj Kumar
Research Scholar,
Department of Zoology and Environmental Science,
Gurukula Kangri University, Haridwar, India

Dr. Vinod Kumar (M.Sc., Ph.D., F.A.N.S.F.) is working as Assistant Professor of Environmental Science in the Department of Zoology and Environmental Science, Gurukula Kangri University, Haridwar (Uttarakhand), India. He has an academic experience of about 10 years and research experience of about 14 years. His interests of research area are Agro-ecology, Environmental Pollution and Bioremediation Research and Wastewater Management. He has published more than 100 research papers in national and international journals of repute. He is the founder President of Agriculture and Environmental Science Academy and Editor-in-Chief of the Journal of Archives of Agriculture and Environmental Science. He is serving as Editorial Board member and reviewer of about 10 reputed international journals. The Google citation: 900; h-index: 19; Scopus Citation: 220; h-index: 10 is in his credit.

Mr. Jogendra Singh works in the fields of water pollution, wastewater management, phytoremediation, agro-ecology, and bioenergy production. He received his master degree in the subject of Environmental Science from Gurukula Kangri Vishwavidyalaya, Haridwar, India. He has qualified Indian Council of Agricultural Research (ICAR-NET) National Eligibility Test in the year of 2014. He has also awarded Rajiv Gandhi National Fellowship (RGNF) funded by the University Grants Commission (UGC), New Delhi, India. He has been working as Editorial secretary of the international journal Archives of Agricultural and Environmental Science and Journal Applied and Natural Science, Haridwar India. He has published 27 research articles (cumulative impact factor 28.47 in the national and international peer-reviewed journals.

Mr. Pankaj Kumar is a young researcher working in the field of environmental pollution, bioremediation and bioenergy. He received his master degree in Environmental Science from Gurukula Kangri Vishwavidyalaya, Haridwar with gold medal. He has qualified NTA-UGC NET (June 2019). He has published 14 research papers in national and international peer reviewed journals with a cumulative impact factor of 21.71. He has 1 edited book, 11 conferences abstracts, and 2 book chapters in his credit. He has been working as Editorial secretary of the international journal Archives of Agricultural and Environmental Science.

CONTRIBUTORS

Contributor	Affiliation
Aditi Bisht	Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
Akanksha Bisht	Department of Medicinal and Aromatic Plants, Uttarakhand Altitude Plant Physiology Research Centre, Hemvati Nandan Bahuguna Garhwal University, Birla Campus , Srinagar-249161 (Uttarakhand), India
Alok Kumar Sahoo	Subject Matter Specialist (Agricultural Extension), KVK, Bargarh, OUAT, Gambharipali-768102, India
Aman Verma	Insect Biodiversity Laboratory, Department of Zoology, D.S.B. Campus, Kumaun University, Nainital – 263002, Uttarakhand, India
Amit Kumar Sharma	Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
Ardeep Kumar	Department of Agronomy, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar - 263153 (Uttarakhand), India
Ateeque Ahmad	Department of Geography, Faculty of Science, Aligarh Muslim University, Aligarh (Uttar Pradesh), India
Bashir Adelodun	Department of Agricultural Civil Engineering, Kyungpook National University, Daegu, Korea; Department of Agricultural and Biosystems Engineering, University of Ilorin, PMB 1515, Ilorin, Nigeria
Elango K.	Department of Entomology, Tamil Nadu Agricultural University, Coimbatore-641003, India
Ettammal Sreenivasan	Technical Manager & Head, R&D, The Western India Plywoods Ltd, Mill Road, Baliapatam P.O, Kannur, Kerala – 670010, India
Ezzat Khan	Department of Chemistry, University of Malakand, Chakdara 18800, Dir Lower, Khyber Pakhtunkhwa, Pakistan
Fidelis Odedishemi Ajibade	Department of Civil and Environmental Engineering, Federal University of Technology, Akure, Nigeria; Research Centre for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China
Hashim Olalekan Bakare	Department of Chemical Engineering, University of Ilorin, PMB 1515, Ilorin, Nigeria
Hazrat Ali	Department of Chemistry, University of Malakand, Chakdara 18800, Dir Lower, Khyber Pakhtunkhwa, Pakistan
Jogendra Singh	Agro-ecology and Pollution Research Laboratory, Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India

CONTRIBUTORS CONTINUED ...

Contributor	Affiliation
Jonatas da Silva Castro	Nilton Lins University Manaus, Amazonas Brazil
K. Sankara Rao	Department of Entomology, CCS Haryana Agricultural University (CCSHAU), Hisar-125004, India
Kyung Sook Choi	Department of Agricultural Civil Engineering, Kyungpook National University, Daegu, Korea; 7 Institute of Agricultural Science & Technology, Kyungpook, National University, Daegu, Korea
Madhumita Goala	Nehru College, Assam University, Labocpar Part II, Cachar 788098 (Assam), India
Manoj Kumar Arya	Insect Biodiversity Laboratory, Department of Zoology, D.S.B. Campus, Kumaun University, Nainital – 263002, Uttarakhand, India
Neeraj Pandey	Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
Nitin Kamboj	Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
Pankaj Kumar	Agro-ecology and Pollution Research Laboratory, Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
Piyush Kumar	Agro-ecology and Pollution Research Laboratory, Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
Pradip Kumar Maurya	Department of Zoology and Environmental Science Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
Qiaoqiao Zhou	College of Resources and Environment, Hunan Agricultural University, Changsha 410128, China
Rajesh Kumar	Rhizosphere Biology Laboratory, Department of Microbiology, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar Raebareli Road, Lucknow, India
Satinder Pal Kaur Malhotra	ICFAI Tech School, ICFAI University Dehradun, Rajawala Road, Selaqui, 248197, Uttarakhand, India
Shweta Sahni	Department of Microbiology, School of Basic and Applied Sciences, Shri Guru Ram Rai University, Dehradun-248001, Uttarakhand, India
Sk Ajim Ali	Department of Geography, Faculty of Science, Aligarh Muslim University, Aligarh (Uttar Pradesh), India
Sonika Kumari	Agro-ecology and Pollution Research Laboratory, Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
Sudhanshu Bala Nayak	Department of Entomology, CCS Haryana Agricultural University (CCSHAU), Hisar-125004, India
Swati Rastogi	Rhizosphere Biology Laboratory, Department of Microbiology, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar Raebareli Road, Lucknow, India

CONTRIBUTORS CONTINUED ...

Contributor	Affiliation
Taofeeq Sholagberu Abdulkadir	Department of Water Resources and Environmental Engineering, University of Ilorin, PMB 1515, Ilorin, Nigeria
Vinod Kumar	Agro-ecology and Pollution Research Laboratory, Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
Vishal Kamboj	Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India

PREFACE

Today, environmental degradation is the utmost problem leading to the extinction of several living organisms on the earth. Environmental degradation can be seen in the form of lost living forms due to disturbances in the earth's ecosystem. The recent developments in human civilization are the major reason for the degradation of the environment and its quality. This edited book is the compliance of selected reports destined to provide information regarding causes, effects and mitigation strategies of environmental degradation.

The compliance of this book is helpful for academicians, researchers, students, as well as other people seeking the relevant material in current trends of studies on the topic of environmental degradation. The book starts with an introductory chapter providing background information on the topic covering the necessity of the mitigation measures to be taken in order to ensure the conservation of our mother earth. The second chapter discussed the role of disasters leading to the degradation of environmental composition. The role of pesticides in the degradation of agricultural quality is discussed in the third chapter. Special attention is given to the degradation of river systems with reference to exhausting its resources. The book compliance includes many chapters focusing on environmental degradation by wastewater disposal practices. Certain mitigative measures are provided focusing on sustainable utilization of wastewater for agricultural and horticultural applications. The second half of the book includes sustainable utilization of various solid wastes such as spent mushroom compost, flower wastes, wood wastes, non-conventional plant residues, etc. which may cause deterioration of our environment. The last section of the book provides information regarding the impacts of environmental degradation on biodiversity as well as human economics including agriculture.

Lastly, the editors are thankful to the contributors who submitted their precious findings and views related to the book theme and to make it succeeded. We hope that this book will help the readers in its best to provide them the relevant information.

Editors

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DOI: 10.26832/aesa-2020-edcrs-01

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An introduction to environmental degradation: Causes, consequence and mitigation

Pradip Kumar Maurya[1,*], Sk Ajim Ali[2], Ateeque Ahmad[2], Qiaoqiao Zhou[3], Jonatas da Silva Castro[4], Ezzat Khan[5] and Hazrat Ali[5]

[1]Department of Zoology and Environmental Science Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
[2]Department of Geography, Faculty of Science, Aligarh Muslim University, Aligarh (Uttar Pradesh), India
[3]College of Resources and Environment, Hunan Agricultural University, Changsha 410128, China
[4]Nilton Lins University Manaus, Amazonas Brazil
[5]Department of Chemistry, University of Malakand, Chakdara 18800, Dir Lower, Khyber Pakhtunkhwa, Pakistan

ABSTRACT

The environmental degradation is the deterioration of the environment through depletion of resources which includes all the biotic and abiotic element that form our surrounding that is air, water, soil, pant animals, and all other living and non-living element of the planet of earth. The major factor of environmental degradation is human (modern urbanization, industrialization, overpopulation growth, deforestation, etc.) and natural (flood, typhoons, droughts, rising temperatures, fires, etc.) cause. Today, different kinds of human activities are the main reasons for environmental degradation. The automobile and industries increase the number of poisonous gases like SO_x, NO_x, CO, and smoke in the atmosphere. Therefore, the government must enhance filling the gap in the legal system to avoid illegal activities. This chapter discusses the impact of environmental degradation with its future impacts, city planners, industry, and resource managers plans to be considered to mitigate the long term effects of developmental environmental degradation.

KEYWORDS Environmental degradation, Manmade impacts, Mitigation, Pollution

Pradip Kumar Maurya, Email: pk.maurya86@gmail.com, pmaurya_rs@gkv.ac.in

Introduction

The environment is something we are very familiar with. It's everything that makes up our surroundings and affects our ability to live on the earth. Environmental degradation is a very serious problem worldwide which covers a variety of issues including pollution, biodiversity loss, and animal extinction, deforestation and desertification, global warming, and a lot more (Brown *et al*., 1987; Tian *et al*., 2004). The environmental degradation is deterioration of the environmental through depletion of resources which includes all the biotic and abiotic element that form our surrounding that is air, water, soil, plant, animals, and all other living and non-living element of the planet of earth (Bourque *et al*., 2005; Malcolm and Pitelka, 2000). Environmental degradation is also having a useful aspect, more new genes have been created, and some species have grown as someones have declined. For natural selection, species are constantly regenerating as the environment changes, and human activity is the main driver's power. Human is also a product of nature; this shift is to natural replacement.

Most of the people about three-fourths of its population depends directly for their livelihood on activities based on natural resource and the remainder of the population relies on these resources directly for food, fuel, industrial output, and recreation (Raven *et al*., 1998). Most of the natural resources including the environment in India are in a serious state of degradation. The use of agriculture fertilizer is a major factor for the degradation of soil quality, soil erosion, salinity and general loss of fertility of agricultural land as well as the loss of the production of the quality crop. Similarly, groundwater aquifers are overexploited in many arid and semi-arid areas, surface water sources are highly polluted and consequently, water for drinking and irrigation is increasingly getting scarce and polluted. Fishery yields are declining, and air quality is deteriorating. Increasing levels of air, water, and land pollution pose a serious threat to human health and longevity (Malik *et al*., 2014; Malik *et al*., 2018; Yadav *et al*., 2019). Good environmental management is essential for economic growth and development. It is not a sometime mistakenly asserted just a luxury for wealthy countries concerned with aesthetics. Climate change and environmental degradation affect all types of development projects in all countries. If the development agencies are seriously contributing to the reduction of poverty in the communities in which they work, they must give consideration to the climatic and environmental hazards which impact their projects. Climate change and environmental degradation are proceeding rapidly and are already affecting many communities in developing countries. O'Neill *et al*. (2010) reported that slowing population growth could provide 16-29% of the emissions reductions, and suggested to be necessary by 2050 to avoid dangerous climate change. His study in 35 countries suggested that, slowed population growth could save 1.4 to 2.5 billion tons of carbon emissions per year by 2050, certainly help to solve the climatic problem.

Causes of environmental degradation

The major factor of environmental degradation is human (modern urbanization, industrialization, overpopulation growth, deforestation, etc.) and natural (flood, typhoons, droughts, rising temperatures, fires, etc.) cause. Environmental pollution refers to the degradation of the quality and quantity of natural resources. Different kinds of human activities are the main reasons for environmental degradation. The automobile and industries increase the number of poisonous gases like SO_x, NO_x, CO, and smoke in the atmosphere. Unplanned urbanization and industrialization have caused water, air, soil, and sound pollution. Industrialization, urbanization, and sewage waste help to increase pollution of the sources of water (Olorode *et al.*, 2015). Similarly, the smoke emitted by vehicles and industries like Chlorofluorocarbon, nitrogen oxide, carbon monoxide, and other dust particles pollutes the air. Since man began to use tools and gradually formed a society, he began to play an important role in the evolution of the natural environment shown in Figure 1.

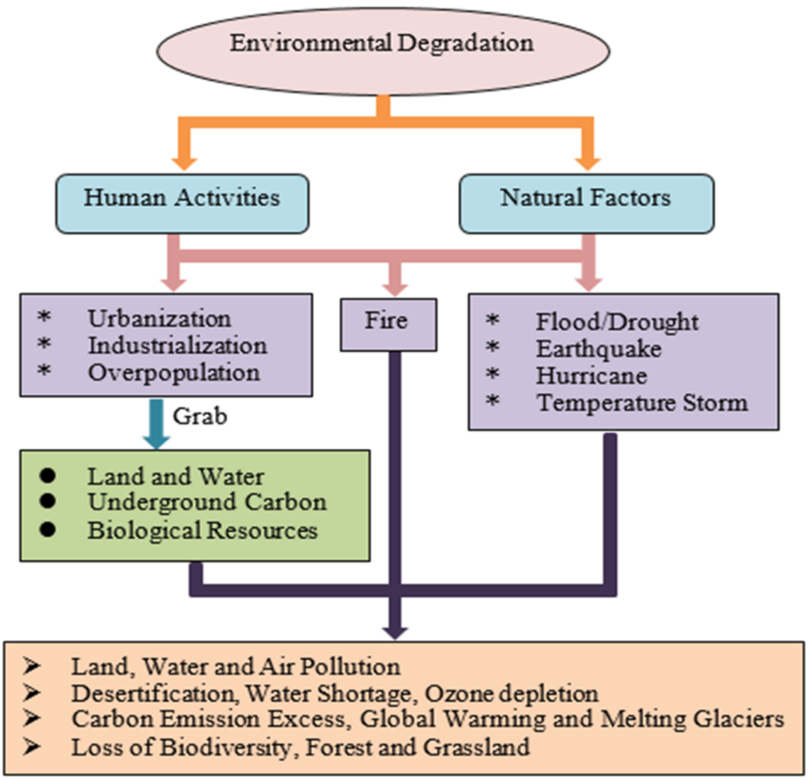

Figure 1. Different causes of environmental degradation.

Land degradation

Land degradation is a worldwide problem: land degradation may occur naturally as well as manmade activities. The climate change majorly combined with human activities for continuous soil degradation. Wilcox *et al*. (2003), Vanacker *et al*. (2014), Maurya and Malik (2016a), noted that surface soil disturbances can modify surface topographical features and the vegetation patch structure (Mohr *et al*., 2013; Malik and Maurya, 2015). The deforestation, desalination, waterlogging desertification, wasteland and soil erosion. FAO estimated that about 2 billion people (or ¾ of the population of developing countries at that time) depended on biomass for their daily energy consumption (Kumar *et al*., 2020).

Pollution

Air pollution refers to the release of harmful contaminants (chemicals, toxic gases, particulates, biological molecules, etc.) into the earth's atmosphere. These contaminants are quite detrimental, and in some cases, pose serious health issues. Water pollution is said to occur when toxic pollutants and particulate matter are introduced into water bodies such as lakes, rivers, and seas. These contaminants are generally introduced by human activities like improper sewage treatment and oil spills. Pollution is a very serious worldwide problem, pollution resulted in the deterioration of the quality of natural biotic and abiotic factors (Rahman *et al*., 2017; Cheng *et al*., 2016). Water pollution is a very big problem especially in developing countries in the world. The water covered about 71% of the total earth's surface and groundwater. The groundwater scarcity is especially in the developing countries of the worldwide (Karikari and Ansa, 2006). Water is one of the more demandable of all urban and rural amenities and indispensable for human activities including water for drinking and irrigation, recreational opportunities and habitat for economically important fisheries. Pollution poses a serious risk to life, especially when the water is a source of drinking and for domestic purposes for humans, polluted waters are potent agents of diseases such as cholera, typhoid, and tuberculosis. Olaniran (1995) defined water pollution to be the presence of excessive amounts of a hazard (pollutants) in water in such a way that it is no longer suitable for drinking, bathing, cooking or other uses. Pollution is the introduction of contamination into the environment**.** Water pollution is generally induced by humans. It results from the actions of humans carried on to a better self. These could be treated under the various activities that man engages in, which leads to pollution. The growth of the human population, industrial and agricultural practices is the major cause of pollution (Maurya and Malik, 2016a). As they respire, the decomposers use up dissolved oxygen (O_2) and the Biological Oxygen Demand (BOD) reduces. The flora and fauna of the rivers experience change and reduction in number due to death by suffocation (Maurya and Malik, 2016b; Maurya *et al*., 2019). The growing problem of pollution of the river ecosystem has necessitated the monitoring of water quality. Freshwater is a finite resource, essential for agriculture, industry and even human existence, without freshwater of adequate quantity and quality, sustainable development will not be possible. Industry and automobiles are the primary and secondary contributors to air pollution worldwide (Kay, 1999); the automobiles are used every gallon of gasoline manufactured, distributed and then burned in a vehicle, produced along with carbon dioxide, carbon monoxides, sulfur dioxide, nitrogen dioxide, and particulate matter; these emissions contribute to increased global warming (Alexander and Kanner, 1995; Mark, 1997).

The environmental protection agency (EPA) estimates that industrial workers suffer up to 300,000 pesticide-related acute illnesses and injuries per year, mostly cholinergic symptoms from anticholinesterases and lung disease from airborne exposure (Hansen and Donohoe, 2002; Mellon *et al*., 1995). These are toxic, remain in the environment long-term, resist degradation, and can travel long distances.

Global warming

Global warming which is also referred to as climate change is the observed rise in the average temperature of the Earth's climate system the global surface temperature is likely to rise a further 0.3 to 1.7 °C in the lowest emissions scenario, and 2.6 to 4.8 °C in the highest emissions scenario. These readings have been recorded by the "national science academies of the major industrialized nations". Future climate change and impacts will differ from region to region. Expected effects include an increase in global temperatures, rising sea levels, deforestation, imbalance climatic condition, changing precipitation, and expansion of deserts (Cunningham *et al*., 1999). Global warming has several adverse effects on human health, and agricultural production. It leads to an increase in heat-related diseases, civil conflict, decreases economic sources shown in Figure 2. Besides, it also indirectly affects human health due to the higher incidence of malaria, dengue, yellow fever and viral encephalitis caused by the expansion of mosquitoes and other disease carriers to warm areas. The adverse effect on agricultural production is due to the increased frequency of droughts, floods and hurricanes and increased incidence of pests, causing a shortage of food.

Overpopulation

It is very likely that population growth as a missing scientific agenda accounts in part for the reduced public knowledge and interest in this issue. The extent of environmental degradation varies across countries and regions of the world. Rapid population growth puts a strain on natural resources which results in degradation of our environment. The mortality rate has gone down due to better medical facilities which have resulted in increased lifespan. More population simply means more demand for food, clothes, and shelter. You need more space to grow food and provide homes to millions of people. This results in deforestation loss of biodiversity, destruction of the ecosystem which is another factor of environmental degradation shown in Figure 3.

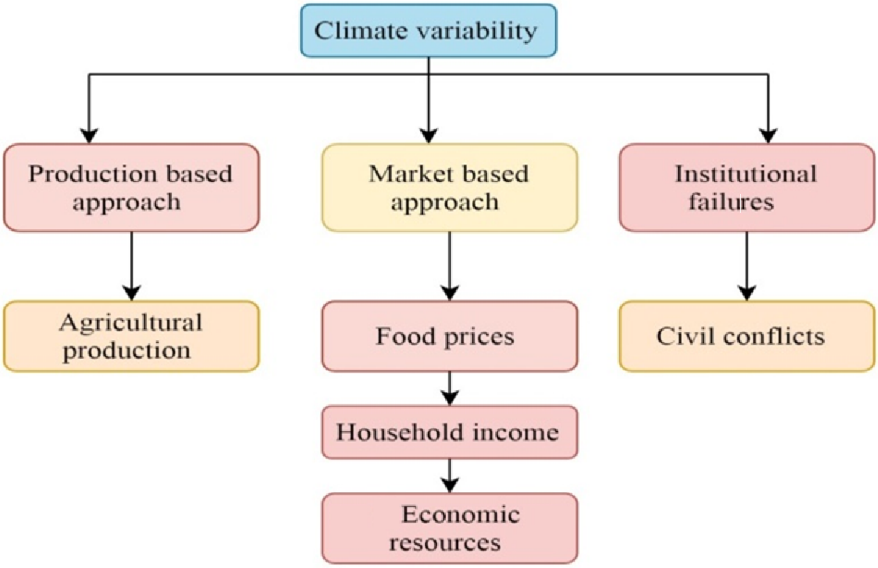

Figure 2. Climate variability matters for food insecurity- diagrammatic presentation.

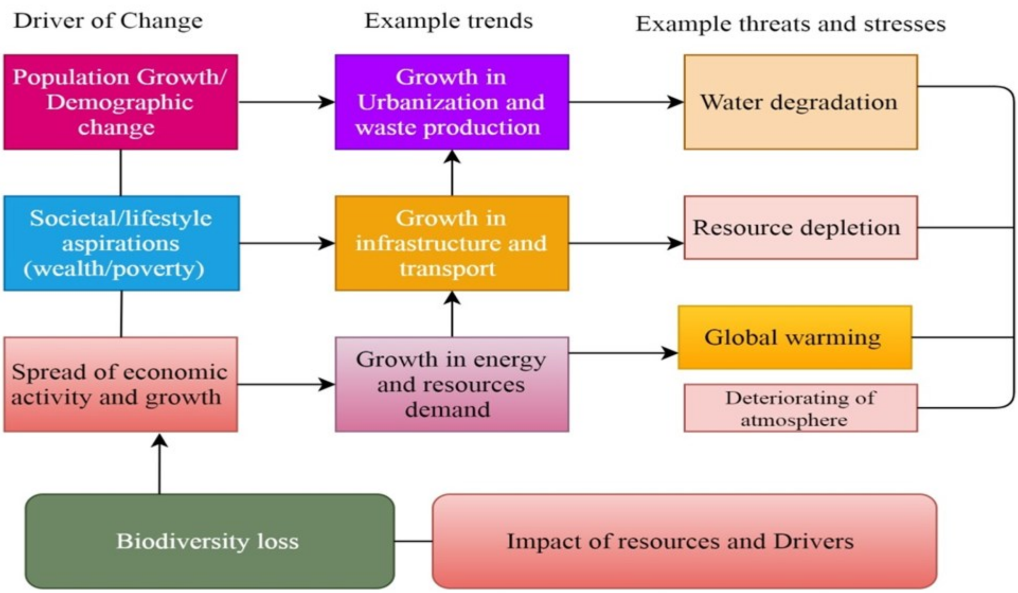

Figure 3. Flow chart indicated the loss of biodiversity through the developmental aspect (Source: Foresight, 2000).

Landfills

Landfills pollute the environment and destroy the beauty of the city. Landfills come within the city due to the large amount of waste that gets generated by households, industries, factories, and hospitals. Landfills pose a great risk to the health of the environment and the people who live there. Landfills produce a foul smell when burned and cause huge environmental degradation.

Deforestation

Forests are invaluable property of a nation because they provide raw materials to modern industries, timber for building purposes, habitats for numerous types of animals and micro-organisms. Good fertile and nutrient-rich soils having a high content of organic matter offer protection to soils by binding the soils through the network of their roots and by protecting the soils from the direct impact of falling raindrops. They encourage and increase the infiltration of rainwater and thus allow maximum recharge of groundwater resources, minimize surface run-off and hence reduce the frequency, intensity, and dimension of floods. Deforestation is the cutting down of trees to make way for more homes and industries. Rapid growth in population and urban sprawl are two of the major causes of deforestation. Apart from that, the use of forest land for agriculture, animal grazing, harvests for fuelwood and logging are some of the other causes of deforestation. Deforestation contributes to global warming as decreased forest size puts carbon back into the environment.

Deforestation gives birth to several problems encompassing environmental degradation through accelerated rate of soil erosion, increase in the sediment load of the rivers, siltation or reservoirs and river beds, increase in the frequency and dimension of Hoods and droughts, changes in the pattern of distribution of precipitation, intensification of greenhouse effects increase in the destructive force of the atmospheric storms, etc.

Natural causes

Things like avalanches, quakes, tidal waves, storms, and fires can totally crush nearby animal and plant groups to the point where they can no longer survive in those areas. This can either come to fruition through physical demolition as the result of a specific disaster or by the long-term degradation of assets by the presentation of an obtrusive foreign species to the environment. The latter frequently happens after tidal waves, when reptiles and bugs are washed ashore, of course, humans aren't totally to blame for this whole thing. Earth itself causes ecological issues, as well. While environmental degradation is most normally connected with the things that people do, the truth of the matter is that the environment is always changing. With or without the effect of human exercises, a few biological systems degrade to the point where they can't help the life that is supposed to live there.

The economic logic

Environmental change is one of the myriads of pressures or demands made upon state resources and attention. Many of the responses to environmental stress that occur involve uncoordinated human responses greatly affected by markets. Accordingly, producers and consumers respond to changes in prices, relative incomes, and external constraints. But frequently market 'signals' do not reflect social values, as in the case of intergenerational equity, for example, or the deleterious effects of environmental degradation are not internalized in market prices and remain as 'externalities'. As a result, states often choose to intervene with collective actions aimed at managing environmental change and reducing the associated adverse social and economic effects.

Effects of environmental degradation

Impact on human health

Human health might be at the receiving end as a result of environmental degradation. Areas exposed to toxic air pollutants can cause respiratory problems like pneumonia and asthma. Millions of people are known to have died off due to the indirect effects of air pollution (Adakole and Oladimeji, 2006).

Loss of biodiversity

Biodiversity is important for maintaining the balance of the ecosystem in the form of combating pollution, restoring nutrients, protecting water sources and stabilizing climate. Deforestation, global warming, overpopulation, and pollution are a few of the major causes of loss of biodiversity.

Ozone layer depletion

The ozone layer is responsible for protecting the earth from harmful ultraviolet rays. The presence of chlorofluorocarbons, hydrochlorofluorocarbons in the atmosphere is causing the ozone layer to deplete. As it will deplete, it will emit harmful radiation back to the earth (Buhaug *et al*., 2010).

loss for the tourism industry

The deterioration of the environment can be a huge setback for the tourism industry that relies on tourists for their daily livelihood. Environmental damage in the form of loss of green cover, loss of biodiversity, huge landfills, increased air, and water pollution can be a big turn off for most of the tourists.

Economic impact

The huge cost that a country may have to borne due to environmental degradation can have a big economic impact in terms of restoration of green cover, cleaning up of landfills and protection of endangered species. The economic impact can also be in terms of the loss of the tourism industry. As you can see, there are a lot of things that can have an effect on the environment. If we are not careful, we can contribute to the environmental degradation that is occurring all around the world. We can, however, take action to stop it and take care of the world that we live in by providing environmental education to the people which will help them pick familiarity with their surroundings that will enable to take care of environmental concerns thus making it more useful and protected for our children and other future generations.

Extents of environmental degradation

Land degradation

Trash and garbage are a common sight in urban and rural areas of India. It is a major source of pollution. Indian cities alone generate more than 100 million tons of solid waste a year. Street corners are piled with trash. Public places and sidewalks are despoiled with filth and litter, rivers and canals act as garbage dumps. Soils are a key element in the climate change equation and perhaps the least well understood. Although models of soil organic matter decomposition predict increasing rates with increasing temperature, field measurements seem to contradict model results (Sax *et al.*, 2002). In addition to increases in CO_2 emissions, industrialization has increased the amount of nitrogen deposition. Nitrogen deposition from human activities may help forests that are nitrogen-limited, but excess nitrogen deposition can lead to soil acidification and reduced nutrient availability to plants (Aber *et al.*, 2001; Magnani *et al.*, 2007).

Degradation of water resources

Microbe contamination of groundwater due to sewage outfalls and high concentration of nutrients in marine and coastal waters due to agricultural runoff are among the most serious threats (Kumar *et al.*, 2019a). Contact with unsafe drinking or bathing water can impose serious risks (both acute and delayed) on human health. While tap water is subject to treatment and is required to meet detailed testing and purity standards, it is not always disinfected of diarrhea inducing microorganisms, as illustrated by waterborne disease outbreaks such as that caused by Cryptosporidium in Milwaukie in 1993, which affected over 400,000people. Furthermore, faecal coliforms are not prohibited in bottled water (Nation Staff, 1996), and water bottled and sold within the same state is not subject to Food and Drug Administration standards (Hammitt *et al.*, 2006).

Today 40% of waters are unfit for fishing or swimming, and levels of mercury in fish in 40 states. Clean Water Act of 1972 states to publish a list of all bodies of water that fail to meet water quality standards, and for the states to set pollution limits and scale back pollution in watersheds until standards are met, compliance is negligible and enforcement weak. Discharge of untreated sewage is the single most important cause for pollution of surface and groundwater in India (Kumar *et al*., 2019b). There is a large gap between the generation and treatment of domestic wastewater in India. The problem is not only that India lacks sufficient treatment capacity but also that the sewage treatment plants that exist do not operate and are not maintained.

In a National Resources Defence Council study of the quality of bottled water (Nation Staff, 1996), approximately one-fifth of samples exceeded bacterial purity guidelines and/or safe levels of arsenic or other synthetic organic chemicals (AJS, 1999). Between 25% and 40% of bottled water was merely repackaged municipal tap water. The cost of illness approach and Shuval calculates the disability-adjusted life years (DALY), to quantify the health burden from illnesses associated with exposure to polluted recreational coastal waters. India is recognized as has to have major issues with water pollution, predominately due to untreated sewerage. Rivers such as the Ganges, the Yamuna, and Mithi Rivers, all flowing through highly populated areas, thus polluted.

Effluents are another by-product of industries which poses threat to the environment, leather and tanning industries, petroleum industries and chemical manufacturing industries create major waste products that are released directly into nearby streams without treatment, creating river pollution and causing harm to aquatic life. The majority of the government-owned sewage treatment plants remain closed most of the time due to improper design or poor maintenance or lack of reliable electricity supply to operate the plants, together with absentee employees and poor management. According to a World Health Organization study, out of India's 3,119 towns and cities, just 209 have partial sewage treatment facilities, and only 8 have full wastewater treatment facilities. Over 100 Indian cities dump untreated sewage directly into the Ganges River. Investment is needed to bridge the gap between 29000 million liters per day of sewage India generates, and a treatment capacity of a mere 6000 million liter per day.

Drought, desertification, and Water Scarcity

Drought and water scarcity are the third main climate change impact that may significantly contribute to climate-related migration. Droughts, desertification, and water scarcity are likely to increase because of global warming. These phenomena are projected to affect about one-third of the world's current population. Droughts are likely to displace millions of people all over the world, affecting food insecurity and human livelihoods. Sea level rise will extend areas of salinization of groundwater and estuaries, resulting in a decrease in freshwater availability for humans and ecosystems in coastal areas. Moreover, changing precipitation patterns create pressures on the availability of clean water supplies.

Degradation of fisheries

In many parts of the world, fish is one of the important components of the human diet. Due to this reason, fish caught from natural water bodies increased highly. This fact can tell us the need of studying the fish stocks in the natural water bodies especially the commercial fishes to manage them in an optimum way. Losses in fisheries include natural and fishing material losses of fish due to spoilage, breakage, size, discarding bycatch and operational losses. Although the extent of the problem varies from place to place, the country as a whole loses huge quantities of fish after capture before it reaches consumers. The need for assessment is a first step towards overcoming losses and defining solutions to the existing problem, Figure 4 indicated that trade work and GDP production economic scale structure technique and conservation of environmental policies structure.

The main reasons for losses were the fishing method, inadequate handling facilities, and delay between catch, collection and distribution, absence of regulations governing quality and standards of fish to be sold for human consumption, lack of regular supervision from the government side and poor extension service and fragmentation of duties and responsibilities in different institutions. Nevertheless, the protection of marine and coastal areas and habitat restoration should not be seen as solutions replacing conventional management approaches, but need to be components of an integrated program of the coastal zone and fisheries management.

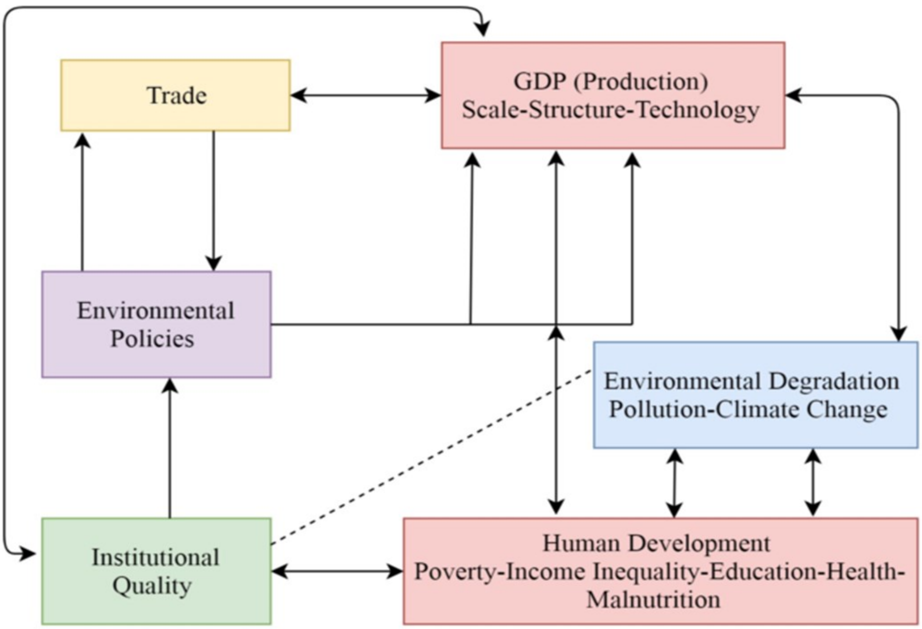

Figure 4. Relationship between environmental degradation and economic development.

Loss of biodiversity

India is a treasure chest of biodiversity which hosts a large variety of plants and has been identified as one of the eight important "Vavilorian" centers of origin and crop diversity. India accounts for 8% of the total global biodiversity with an estimated 49,000 species of plants of which 4900 are endemic (Groom *et al.*, 2010). The ecosystems of the Himalayas, the Khasi and Mizo hills of northeastern India, the Vindhya and Satpura ranges of northern peninsular India, and the Western Ghats contain nearly 90 percent of the country's higher plant species and are therefore of special importance to traditional medicine.

Biodiversity is declining on two scales- β diversity (the difference in biodiversity between regions species identities in more and more locations are becoming similar) and γ diversity (global biodiversity is declining), but at particular locations, α diversity may be increasing due to the addition of invaders (Sax *et al.*, 2002; Sax and Gaines, 2003). Sax and Gaines (2003) make clear that this phenomenon is not restricted to islands – rather, local biodiversity is increasing in many continental locations as well. Few authors documented declines in a number of components of biodiversity (Pimm *et al.*, 1995; Vitousek *et al.*, 1997; Sala *et al.*, 2000). The pertinent fact is that levels of extinction over the last 300 years are at least several hundred times greater than expected based on the geological record (Diamond, 1989; Dirzo and Raven, 2003). The destruction of wildlife is a different factor that is the reduction of forest and human interfere, hunting it is believed to have been amongst the most significant factors driving the extinction of large wildlife species Table 1 and Table 2 indicated that some endangered flora and fauna respectively. In India hunting has been recognized as a major factor in historical declines of wildlife.

Education and environmental preferences

Education is an essential tool for environmental protection. Education enhances one's ability to receive, decode and understand information, and that information processing and interpretation have an impact on learning and change behaviors. In recent years, education has been considered a vehicle for sustainable development and thus for the fight against pollution. Education is "a permanent learning process that contributes to the training of citizens whose goal is the acquisition of knowledge, soft skills, and know-how and good manners. The positive effect of education on environmental quality can be channeled in three ways. Firstly, educated people tend to be more conscious of environmental problems and therefore would have behaviors and lifestyles in favor of environmental improvement and demand for environmentally friendly products and decreases the population growth Figure 5.

Mitigation of environmental degradation

There are ways which can help to decrease degradation in our environment. Some of these include:

Table 1. Endangered flora, causes for loss of biodiversity and places last found (Sources: Anil *et al.*, 2014).

Species endangered	Place of interest	Causes
Rauvolfia serpentine, Terminalia chebula, Sapindus lauri-folius and Jatropha curcas	Western Ghats	Destructive harvesting followed by unscientific handling
Catuneregam spinnosa, Garcinia cambogea, Acacia pin-nata, Ficus benghalensis, Zanthoxzyllum rhesta, Hemi-des-mus indicus, Terminalia chebula, Wrightia zeylan-ica, Cin-namomum verum, Bombax ceiba, Sapindus laurifolius, Alangium salvifolium and Calophyllum inophyllum	Maradavally, Shimoga district	Medicinal use and deforestation
Abrus precatorius, Adenanthera paronina, Aegle mar-melos, Caesalpinia bonducella, Cardiospermum halica-cabum, Corallocarpus epigaeus, Gloriosa superba, An-drographis paniculata	Devrayanadurga forests, Tumkur, Deccan Plateau	Destructive harvesting and medicinal use
Lichen genera Parmotrema, Everniastrum, and Rimelia	Ramnagar and other places in India	Commercial use
Arunchal Hopea Tree (*Hopea shingkeng*)	Arunachal Pradesh	Construction of house posts
Hubbardia heptaneuron	Karnataka	Construction of the Linganamakki reservoir
Sapria himalayana	Himalayas	Human Influx

Table 2. Endangered birds, causes for loss of biodiversity and places last found (Sources: Anil *et al.*, 2014).

Species endangered	Place of interest	Causes
Seychelles Parakeet (*Psittacula wardi*)	Indian Ocean islands	Intense persecution by farmers and coconut plant owners.
Pink-headed Duck (*Rhodonessa caryophy llacea*) and the Himalayan Quail (*Ophrysia superciliosa*) (Adams *et al*., 2003)	Not reported	Annihilated, unrecorded
Great Indian Bustard (*Ardeotis nigriceps*), Bengal Florican (*Houbaropsis bengalensis*), Jerdon's Courser (*Rhinoptilus bitorquatus*), Forest Owlet (*Heteroglaux blewitti*), White bellied (*Heron Ardea insignis*) (IUCN endangered red list)	Not reported	Not reported
Narcondam Hornbill (*Aceros narcondami*) (IUCN vulnerable species list)	Not reported	Not reported
Sarus crane	Himalayas	Hunting
Great Indian hornbill *(Buceros bicornis*)	Arunachal Pradesh	Human traditions
Long-billed vulture (LBV: *Gyps indicus*), Slender-billed vulture (*Gyps tenuirostris*), and Oriental white-backed vulture, (OWBV: *Gyps bengalensis*)	Northern and Central India	Pesticides

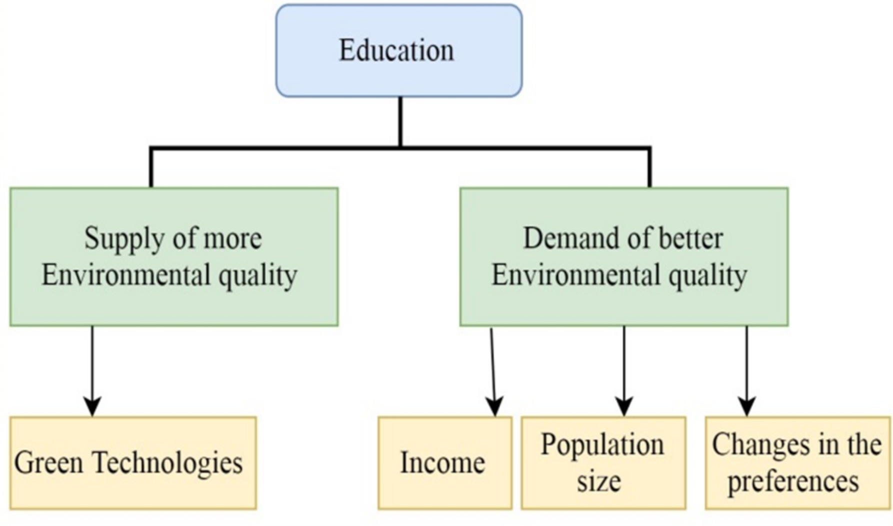

Figure 5. Impact of education on environmental quality.

- Purchase recycled products
- Conserve water
- Do not litter or throw waste into inappropriate places
- Conserve energy
- Join an awareness group
- Talk with others about the impacts of environmental degradation

The damage that we cause to the environment is currently not counted as a cost in economic and social terms. This lack of "environmental value" has allowed us to over-exploit "free" natural resources - which are, of course, not free. It has also led to over-production of cheap goods with very short life spans which are liberally discarded into the environment after use, and then new cheap goods are purchased and discarded again, this cycle goes on and on - affecting the planet's capacity to restore its environmental services in good time. We have to change this paradigm of our interaction with the environment. Certainly, don't have the right to exploit and destroy it without thinking about the future generations of humans and animals who will be hereafter us. We are drawing the flow diagram for the mitigation strategies and remediation of soil for the improvement of quality of soil shown in Figure 6, and different environmental component in Figure 7. All countries people have flowed the sustainable development goals their practice of conservation of environmental degradation shown in Figure 8.

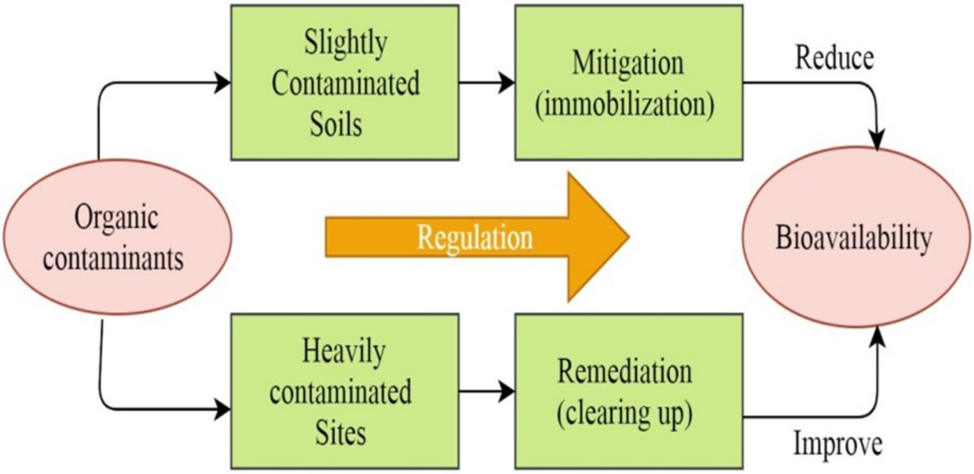

Figure 6. Strategies of mitigation and remediation for slightly and heavily contaminated soil.

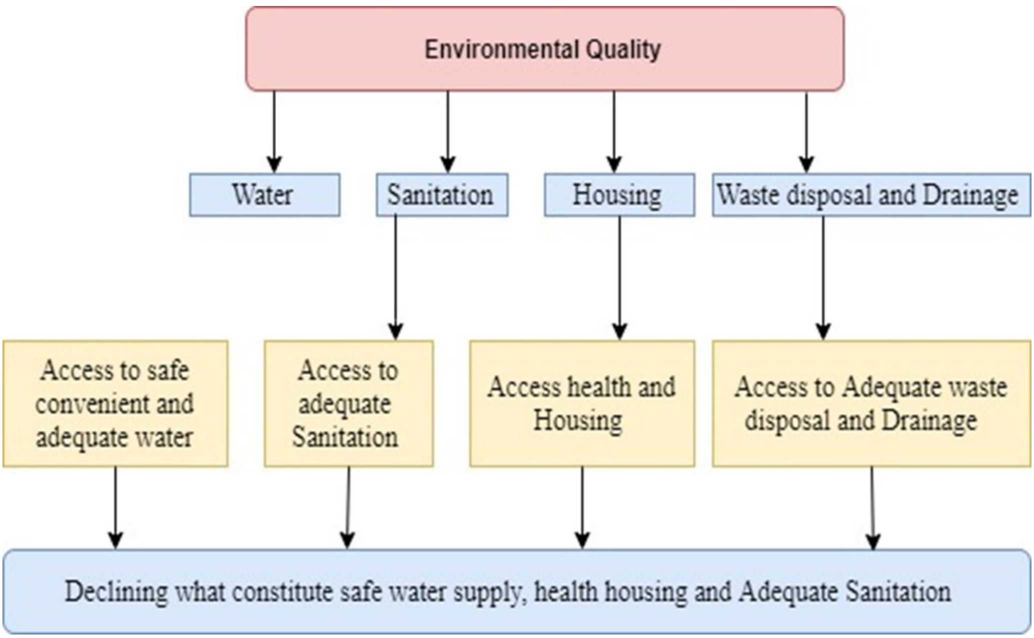

Figure 7. Different components of environmental quality.

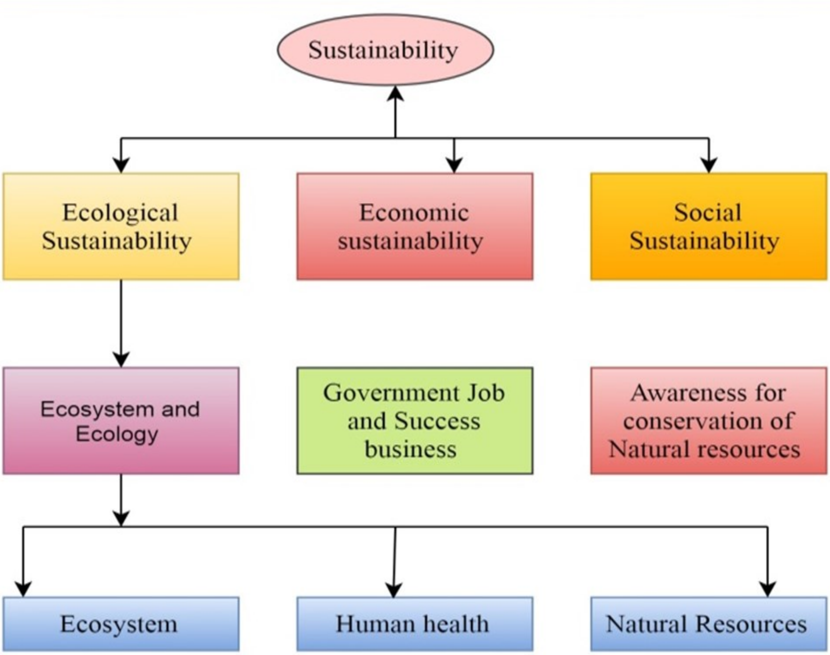

Figure 8. Sustainability components of human environment.

- Institutional instruction
- Direct control and regulation
- Economic instruction
- Technological measures
- Educational

In 2000, India's Supreme Court directed all Indian cities to implement a comprehensive waste-management program that would include a household collection of segregated waste, recycling and composting. These directions have simply been ignored. No major city runs a comprehensive program of the kind envisioned by the Supreme Court (Gov. of India).

Conclusion and recommendations

Environmental degradation is one of the most urgent environmental issues. Depending upon the damage, some environments may never recover. The plants and animals that inhabited these places will be lost forever. The primary causes of environmental degradation in India are attributed to the rapid growth of the population in combination with economic development and the overuse of natural resources. In order to reduce any future impacts, city planners, industry, and resource managers must consider the long-term effects of development on the environment. Major environmental calamities in India include land degradation, deforestation, soil erosion, habitat destruction and loss of biodiversity. Economic growth and changing consumption patterns have led to rising demand for energy and increasing transport activities. Air, water and noise pollution together with water scarcity dominate the environmental issues in India. According to the World Bank estimate, between 1995 through 2010, India has made one of the fastest progress in the world, in addressing its environmental issues and improving its environmental quality. Still, India has a long way to go to reach environmental quality similar to those enjoyed in developed economies.

There are ways which can help to decrease the degradation of our environment. The most effective method to control pollution and depletion is through completing the legal framework. There are some drawbacks existing in contemporary law, which encourages malfeasances implicitly. Therefore, the government must enhance filling the gap in the legal system to avoid illegal activities. Amendment to provisions relating to the exploitation of natural resources is urgent since over-exploitation is the main reason for the loss of biodiversity. The government has long shaped its perception of economic, as well as social methods to solve the problem of pollution, but the implementation remains limited. Eliminating environmental pollution and recovering our ecology requires more than a single effort to be successful. Authority of all levels must involve not only in policy-making but also in the implementation and supervision of progress, so that the national long-term environmental target can be attained, resulting in sustainable development.

- The government can utilize economic reward and punishment system to encourage forestation.
- Purchase recycled products
- Conserve water
- Do not litter or toss waste into inappropriate places
- Conserve energy
- Join an awareness group
- Talk with others about the impacts of environmental degradation
- Be an advocate to save our planet!
- improve the quality of drinking water
- Prevent casual use of other unapproved sources
- Increase the quality of water used
- Improve accessibility and of domestic supply

- Improve hygiene
- Strict laws should be passed to control water pollution by individuals and different bodies
- Safety measures to be implemented to prevent oil spillage.
- Chemical waste should be converted to harmless biodegradable substances before being dumped into the rivers and streams
- Refuse should be burnt in an incinerator with built-inn devices to prevent water pollution.
- By making people be aware of the causes and dangers of air pollution
- By improving machinery so that more efficient fuel combustion occurs.
- Control by ventilation- suitable ventilation system should be provided in the kitchen of every house so that the gases produced by burning of wood, coal, oil, etc. can be exhausted very quickly
- Control by vehicle rules- the design of vehicle should be such that complete combustion of fuel takes place in the engine
- Control by forestation- the planting of trees should be planted at parks and public place

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Cite this chapter as: Maurya, P.K., Ali, S.A., Ahmad, A., Zhou, Q., da Silva Castro, J., Khane, E. and Ali, H. (2020). An introduction to environmental degradation: Causes, consequence and mitigation. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 1-20, https://doi.org/10.26832/aesa-2020-edcrs-01

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-02

CHAPTER
[2]

Role of natural disasters in environmental degradation: An overview

Nitin Kamboj[1], Aditi Bisht[1,*], Vishal Kamboj[1], Neeraj Pandey[1] and Akanksha Bisht[2]

[1]Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
[2]Department of Medicinal and Aromatic Plants, Uttarakhand Altitude Plant Physiology Research Centre, Hemvati Nandan Bahuguna Garhwal University, Birla Campus , Srinagar-249161 (Uttarakhand), India

ABSTRACT

This chapter investigates the role of natural disasters in the degradation of the environment. In recent times, environmental degradation has become a matter of public concern. We studied the natural disasters occurring in the earth on the three types i.e. land, air and water. Globally, it is estimated that more than 100 types of disasters affect living beings and their environment. Therefore, this chapter, we have discussed the natural disasters, their causative phenomenon, types, causes and impacts on living beings including the form of deaths occurred worldwide. The sternness of a disaster is measured in lives lost, economic loss, and the skill of the inhabitants to rebuild. The life-threatening potential of any natural threat is assessed basically by its spatial degree and sternness. It has resulted in the degradation of the environment at an alarming rate. Mitigation plans are generally followed to protect the environment and reduce the adverse effect of disaster. Besides this, we also discussed the precaution, mitigation measures with do's and don'ts when natural disasters have happened.

KEYWORDS Environmental degradation, Natural disasters, Precaution and mitigation

Aditi Bisht, Email: minnib18@gmail.com

Introduction

Nature is the physical and material world, including plants, animals, the landscape and other features and products of the Earth. In other words, it can be defined as the combination of flora and fauna including climatic conditions, geological and physical processes (Harper, 2006). Nature provides the raw materials such as forests, water, air, food, *etc.* for the survival of living beings. It maintains the environment through a cyclic process including hydrological cycle (maintain water) and geochemical cycles (NPK). There are numerous reasons for natural degradation, nearly all of them instilled in human technology. While some are the result of the unintentional consequences of technological advancement, others are examples of humans becoming too successful and efficient at resource abstraction. By minimalizing our involvement with problematic activities and supporting sustainable ones whenever possible, we can do our part to conserve the environment for upcoming generations. Natural disasters are any calamitous event that is caused by nature or the natural processes of the earth. The sternness of a disaster is measured in lives lost, economic loss, and the skill of the inhabitants to rebuild. The life-threatening potential of any natural threat is assessed basically by its spatial degree and sternness. Rising industrialization and unfair manipulation of natural resources have brought our ecosystem to a limit of non-reversibility and disproportion. This has directed to danger from a set of natural threats like contamination, global warming and ozone depletion on a big or global scale.

Types of natural disasters

In this chapter, we categorized natural disasters in three types on the basis of their occurrence, i.e. land-based, air-based, and water-based disasters (Figure 1).

Land based disaster

The land-based disasters are those which cause disturbances on the earth's surface. Some of them are earthquakes, landslides, volcanic eruption and avalanches.

Earthquakes: Earthquake is a phenomenon that occurs when the two tectonic plates of earth slide on one another (Ohnaka, 2013). The point from where earthquake start is the focus and the point directly above the focus on ground is epicenter seen in Figure 2. Earthquake is common of four types *i.e.* tectonic earthquake caused by tectonic plates; the induced earthquake caused by anthropogenic activities; the volcanic earthquake caused due to an active volcano and collapse earthquake caused due to cave-ins. An earthquake occurs every other day but the magnitude is so low that it is not experienced on the surface (Sibson, 1982; Vassiliou and Hiroo, 1982; Ohnaka,

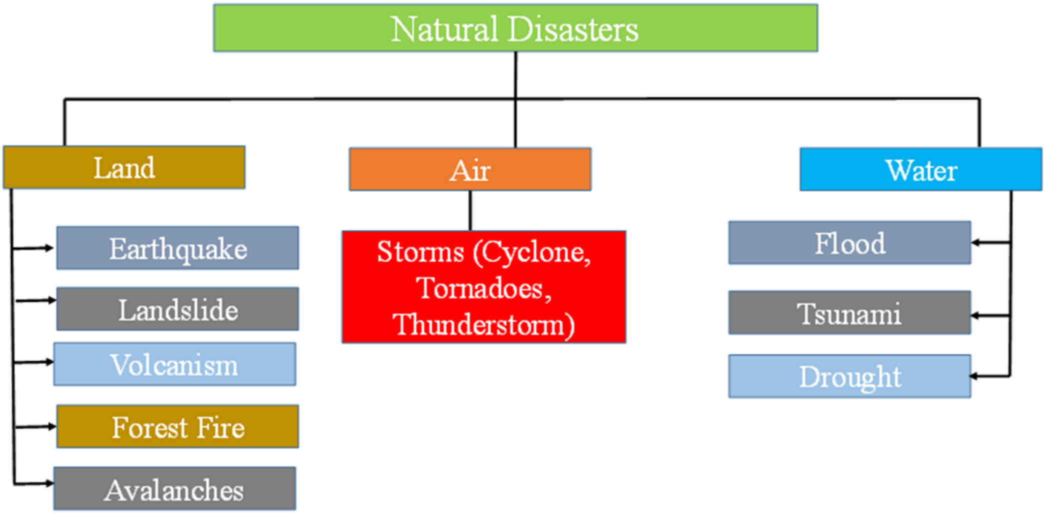

Figure 1. Types of natural disasters.

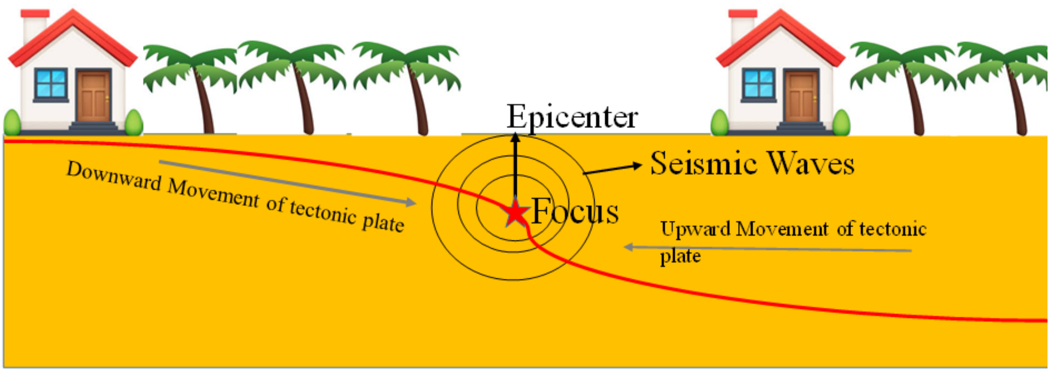

Figure 2. Pictorial diagram of earthquake.

2013). According to Alden (2019), the major earthquake zones in the world are 20 (Table 1). The scientist divided these regions on the basis of their previous research, seismic activities and past earthquake records. Earthquake of magnitude 6.3 hit North India in September 2019 whose epicenter was said to be in Pakistan causing no loss of life in India but 50 people were injured and 1 was killed there (Times of India, 2019). Recently, the earthquake has been reported in the south Philippines of 6.9 magnitudes causing the death of 15 people. The epicenter of the earthquake was in Magsaysay town. The movement of tectonic plates on the Pacific Ring of Fire makes the Philippines is more prone to earthquakes.

Landslide: It is the sliding or flowing of the earth material formed of rock soils and earth fills. Landslide is a downward movement of soil or rock downhill (Hu *et al.*, 2018). It occurs due to two reasons i.e. increase in shear tension and decrease in particle bond. The cause of landslides can be geographical, physical, morphological or human causes such as increasing population, deforestation, and change in the climate. In a hilly region, landslides are generally triggered by excessive rain, earthquakes and anthropogenic activities such as bomb blasting for construction of roads and for mining. There are three types of landslides that are divided into three principal groups *i.e.* slide, fall and topple. The slide-type landslide can be rotational or translational. In a rotational landslide, the movement of soil is in a rotational manner whereas in translational landslide the soil gets displaced downhill to the plane surface. Fall type landslide occurs because of the gravitational force (Mineral Resource Department, Fiji). The strong force leads to separation of huge rocks from parent rock and topple includes the frontward rotation and motion of rock, or regolith, of a slope at an axis lower than the center of gravity. Such a phenomenon occurs in steep cliffs only after large displacement of rock occur (USGS, 2004).

Table 1: Major Earthquakes zones around world.

Continent	Area/country
North America	Alaska central coast to Anchorage and Fairbanks; British Columbia to Baja California Peninsula; California's Central Valley and Southern California, San Francisco Bay Area; Mexico; Western coast of Central America
South America	Caribbean coast of Colombia and Venezuela; Central Chile; Chilean capital of Santiago; Peru
Asia	Japan; Indonesia; Fiji; Tonga; Sumatra; Russia; Norway; Central Asia; Black sea; Iran; Caspian sea southern shores
Europe	Iceland; Turkey; Mediterranean coast; Lisbon (Portuguese); Central Italy
Africa	Lebanon, Western Tanzania
Australia and New Zealand	Smaller neighbouring islands

In China, a landslide hit in the village of Xinmono and submerged 64 houses under the soil and killed about 10 people (Fan *et al.*, 2017). In August 2019 landslide occurred in Wayanad, in the Western Ghats in which more than 50 people were killed (The Hindu, 2019).

Volcanism: When the lava, ashes, and gases come out of the opening, cracks or weak spots known as a vent from earth it is called volcanic eruptions. The movement of tectonic plates causes the eruption. The movement of plates creates pressure and forces molten rocks from the earth to explode in the air causing the outbreak. The molten lava when cools when forming a new earth crust. Some researcher also says that volcanic eruption may influence climate and is one of the climate changes (Forsyth, 1988; Foulger, 2010; Young, 2016). The volcano is categorized on the basis of explosiveness it is called Volcano Explosivity Index as given in Table 2 (Newhall and Self, 1982). The categories of VEI are as follows:

- ***Hawaiian type:*** In this type of volcano the lava is in a molten form that flows from the peak and cracks on the slopes. It has ejection volume < 104 m^3 and Plume is < 100 m.
- ***Strombolian type:*** Here the gases burst out with clots of molten lava with unceasing or cyclic eruptions. It has ejection volume < 104 m^3 and the Plume is 100 m – 1 km. The Stromboli volcano is called the "lighthouse of the Mediterranean" because of its small and recurrent outbursts.
- ***Vulcanian type:*** The eruption forms dark-colored clouds It involves judicious bursts of gas and ashes. This mixture forms dark, turbulent clouds that rise and increase in different shapes.
- ***Pelean type:*** This type of eruption is explosive eruptions that produce a destructive mass of very hot and dense mixtures and gas. The ejection volume > 107 m^3 and Plume is 3-5 km.
- ***Plinian type:*** This is a violent volcanic eruption demonstrated by the eruption of Mount Vesuvius in Italy in AD 79. In this type of eruption, gases, hot magma generate nonstop blasts. The clouds formed by the ashes cause lightning strikes which pose one more fear to the outburst.

Forest Fire: A forest fire or wildfire is any uncontrolled fire generally in forest areas. The fire naturally occurs due to lightening through rain extinguishes such fires with no damage (Bruce and Kelli, 2009). High atmospheric temperatures and dry conditions make the perfect condition for a fire (Bowman *et al.,* 2009). The fire may burn for days to weeks. It can burn the entire forest and even destroy organic matter. They are also known as grass fires, peat fires, forest fire and bush fires depending on undergrowth which are being burnt. Fire is generally experienced in summer when there is no rain for months and there is a lot of fuel in the form of leaves and twigs on the floor. There are generally 2 types of fire i.e. surface fire and crown fire. Surface fire is one

Table 2. Volcanic Explosivity Index with examples of Volcanic eruption.

Volcanic Explosivity Index	Ejection volume (bulk)	Classification	Plume	Descrip-tion	Frequency	Examples of volcanic eruption
0	< 104 m^3	Hawaiian	< 100 m	Effusive	Continuous	Piton de la Fournaise (2017); Dallol (2011); Mawson Peak (2006)
1	> 104 m^3	Strombolian	100 m–1 km	Gentle	Daily	Raoul Island (2006); Nyiragongo (2002)
2	> 106 m^3	Vulcanian	1–5 km	Explosive	Every two weeks	Sinabung (2010); Galeras (1993); Cumbre Vieja (1949); Unzen (1792)
3	> 107 m^3	Pelean	3–15 km	Cata-strophic	3 months	Ontake (2014); Soufrière Hills (1995); Nevado del Ruiz (1985)
4	> 0.1 km^3	Pelean / Plinian /Sub-Plinian	> 10 km	Cataclys-mic	18 months	Calbuco (2015); Nabro (2011); Galunggung (1982); Katla (1918)
5	> 1 km^3	Pelean/Plinian	> 10 km	Parao-xymic	12 years	Puyehue (2011); Hudson (1991); El Chichón (1982); St. Helens (1980)
6	> 10 km^3	Plinian/ Ultra Plinian	> 20 km	Colossal	50–100 years	Pinatubo (1991); Novarupta (1912); Novarupta (1912); Krakatoa (1883); Huaynaputina (1600)
7	> 100 km^3	Ultra-Plinian	> 20 km	Super-colossal	500–1,000 years	Tambora (1815); Samalas (1257); Baekdu (946)
8	> 1000 km^3	Ultra-Plinian	> 20 km	Mega - colossal	>50,000 years	Taupo (25,360 BC); Yellowstone (630,000 BC); Toba (74,000 BC); Whakamaru (254,000 BC)

which is observed in the lower surface, it may be caused by leaf litter on the floor of the forest. The intensity of this type of fire is low to high. It affect the lower portion of the tree. The crown fire burns the crown of the tree. It may burn the tree and ultimately damaging forest canopy. The Garhwal and Kumaun Himalaya face the problem of forest fire regularly from the last few summers causing huge loss of biodiversity in 2016. Bargali *et al.* (2017) studied the fire frequency in Nainital, Uttarakhand. The area of Nainital district consisting of 55% of no fire areas, 25% of Low fire zone, 18% of the medium fire area and 2% of high fire area out of the total geographical area.

Avalanche: Avalanche is the movement of snow due to the steep slope. It is generally spontaneous, and sometimes it is caused by an external agency (e.g. by humans or animals). It is controlled by the variability of snow, weather conditions and their interactions with topography (Schweizer *et al.*, 2003). They cause serious danger to the people living in the Alpine areas. This phenomenon occurs throughout the year but is prominent in the winter months i.e. December to April especially in Northern Hemisphere. Avalanches are generally resulting from superimposing snow block and a weak base of the snow surface. They are generally of two types of release of avalanche i.e. loose and slab avalanche (Jamieson and Stethem, 2002; Schweizer *et al*., 2003). The snowstorm generates the highest risk of avalanches and it can be triggered by earthquakes and human activities. An avalanche in February 2019 in Italy killed 8 people including British and French skiers. Also, a recent avalanche collided at Siachen glacier at an altitude of 19,000 ft. at 3 pm in the month of November. This killed 4 army men and 2 civilians.

Air based disasters

Air is a mixture of gases and dust particles. It is the surrounding earth's atmosphere. The disasters which are due to the air or wind are an air-based disaster. The air-based disaster is generally in the form of storms.

Storms: Storms are the heavy winds with damaging effects. These winds are due to irregular heating of the Earth. The winds are important for maintaining the water cycle. In Monsoon seasons, wind holds moisture which causes rain. Rains are very important for groundwater recharge, drinking purposes, and agriculture. But strong winds have a negative impact also, thunderstorms and cyclones cause devastation of property and life.

Thunderstorm: A combination of light and thunder forms a thunderstorm. It generally needs moisture to form clouds and ultimately rain, front like sea breeze or mountains which aids in lifting the warm air upwards and when the temperature rises it warms up the air. The warm air rises up and creates strong wind (Money, 2007). Thunderstorms are a typical event in Alabama, Mississippi, and Florida at any time of day. There are around 2,000 thunderstorms in progress every day but only 1% is considered as severe. The severe storms are characterized as 1 inch or bigger hail accompanied by strong winds. In the starting of May 2019, northern part of India specially the U.P. was hit by thunderstorm taking 134 lives injuring over 400 people. In Agra U.P. most deaths were reported. Dust storms and thunderstorms caused chaos in four states i.e. Uttar Pradesh, West Bengal, Andhra Pradesh and Delhi. This event leads to many deaths and causing huge destruction (The Economic Times, 2018).

Cyclones: Cyclones are ferocious storms moving in the spiral and combined by strong breezes and devastating rains. It is formed when the strong wind blows around the central area having low atmospheric pressure. As the water vaporizes, it consumes heat from the environment and later cools down. Cooled water changes into liquid and releases heat. This heat warms the air around it. The air then moves from high pressure to low pressure. This cycle goes on and forms a cyclone with low pressure in the center and high pressure around. The recent cyclone hit India in 2018, North Indian Ocean cyclone which was most active after 1992.

Tornadoes: Tornado is formed after thunderstorms which reach the ground as funnel-shaped cloud. It may have speed more than 400 km per hour. A tornado is very damaging to property. Tornadoes generally convert from one type to another. The types of tornadoes are rope tornadoes, cone tornadoes, wedge tornadoes, multi-vortex and satellite tornadoes, water and land spouts. The United States is more susceptible to the tornado. Damaging thunderstorms generally occur in South Dakota, Nebraska, Kansas, Oklahoma, northern Texas, and eastern Colorado. About 2000 people die every year due to tornadoes in the United States (Edward *et al.*, 2013).

Water based disasters

Water is the main constituent of the earth's surface and is important for all living beings. The disaster which occurs due to water is termed as water-based disasters. The types of water-based disasters depend on the flow of water and the level of availability. The major types are as follows:

Floods: Flood is the overflowing of water over dry land areas. This is a common phenomenon occurring in India and most damage due to flood is seen in Asian countries. It generally occurs due to the overflowing river breaking of the dam, excessive rainfall, storm melting of snow or ice (Tingsanchali, 2012). Floods are generally of three types i.e. Fluvial, Pluvial and Coastal flood. The fluvial flood is when water overflows from a water body and reaches the nearby area. It is also known as the river flood. Pluvial floods are when heavy rain occurs and excess water is not absorbed by the earth. It can be in the form of flash flood and surface flood. Coastal flood is the submerging of coastal area in water. Storm surge is the type of coastal flood in which heavy winds force water on the shore. Flood is generally caused by a combination of heavy rainfall causing water body to overflow. Constructions of dams, roads and bridges, irrigation channels, houses, factories, manufacturing plants, bridges and culverts, farmlands and other activities of man have paved the way for free-flowing water into water bodies which leads to flood during heavy rain (Nwigwe and Emberga, 2014). The recent event of floods occurred in many parts of the world in 2019 example Iran, U.S., Houston, Midwestern U.S. flood and many more. In 2019 India encountered a sequence of floods that affected over thirteen states in the second half of the year 2019, because of continuous heavy rains. In this flood, more than 1500 people were reported dead between the month of June and October 2019 and many were evacuated. The two most affected states were Karnataka and Maharashtra (India Today, 2019).

Tsunami: Earthquake tremors or volcanic eruptions under the ocean form the giant waves which is known as Tsunami. The earthquake up thrusts the upliftment of seafloor and causes displacement of tonnes of water to set up the tsunami waves (Fradin and Brindell, 2008). The changes in the speed of a wave depend on the varying depth of the ocean. The speed of waves in tsunami reply on the depth of the ocean instead of the distance from the foundation of the wave. The speed of tsunami waves is relatively similar to the speed of jet plane. The wave speed slows down as soon as it reaches shallow waters. The tsunami waves are believed to travel at a speed of 500 miles an hour in the open ocean and attains a great height before it hits the shore. They can cause widespread devastation in coastal areas especially after the earthquake. The Tsunami of 2011 in Japan was caused by the undersea earthquake on the Eastern coast. Japan tsunami has killed over 15000 citizens and the waves hit the Fukushima nuclear plant (Fukada, 2011). In March 1964, an earthquake of 9.2 magnitudes occurred in Prince William region of Alaska. This earthquake created a horizontal displacement on the South coast of Alaska the coastal areas were raised by thirty feet. The land area of about 130,000 square kilometers was damaged in the earthquake. The Alaska earthquake, precursor activities, impacts on local communities, and what can do to prepare the earthquake in the future.

Drought: Drought is natural hazards which consist of a dry period without rain for a longer period of time (Bradford, 2000). This may cause scarcity of drinking water, destruction of agriculture crops, etc. which may lead to social and economic damage to the society. This occurs when the weather is interrupted, causing a problem to the water cycle (Mishra and Singh, 2010). Drought has been classified in two ways such as water cycle-based and level of severity (Figure 3). There are generally of 4 types of droughts (NOAA, 2006; Wang *et al*., 2015; Swain *et al*., 2019).

- ***Meteorological drought*:** It depends upon the precipitation and is area-specific For example, the southwest of the United States receive an average less than 3 inches (7.6 centimeters) precipitation per year, while the Northwest receives more than 150 inches (381 cm) per year, according to the U.S. Department of Interior.

- ***Agricultural drought*:** It depends on the water available to crops during growth stages.
- ***Hydrological drought:*** It is occurring when the water available is in less volume in streams, rivers, and reservoirs. Hydrological drought is generally linked with meteorological droughts.
- ***Socioeconomic drought*:** It occurs when more water is needed than supplied (Tate and Gustard, 2017).

Levels of severity: The index of levels of severity was developed by Wayne Palmer which is called the palmer drought severity index. It is a demand and supply model developed for soil moisture (Palmer, 1965). Drought is categorized into five levels of severity i.e. abnormally dry, moderate drought, severe drought, extreme drought, and exceptional drought (Dai, 2004).

- Abnormally dry: It is denoted by D0. The value of PDSI is between -1.0 and 1.9.
- Moderate drought: It is denoted by D1. The value of PDSI is between -2.0 and -2.9.
- Severe drought: It is denoted by D2. The value of PDSI is between -3.0 and -3.9.
- Extreme drought: It is denoted by D3. the value of PDSI is between -4.0 and -4.9.
- Exceptional drought: It is denoted by D4. the value of PDSI is between -5.0 and -5.9.

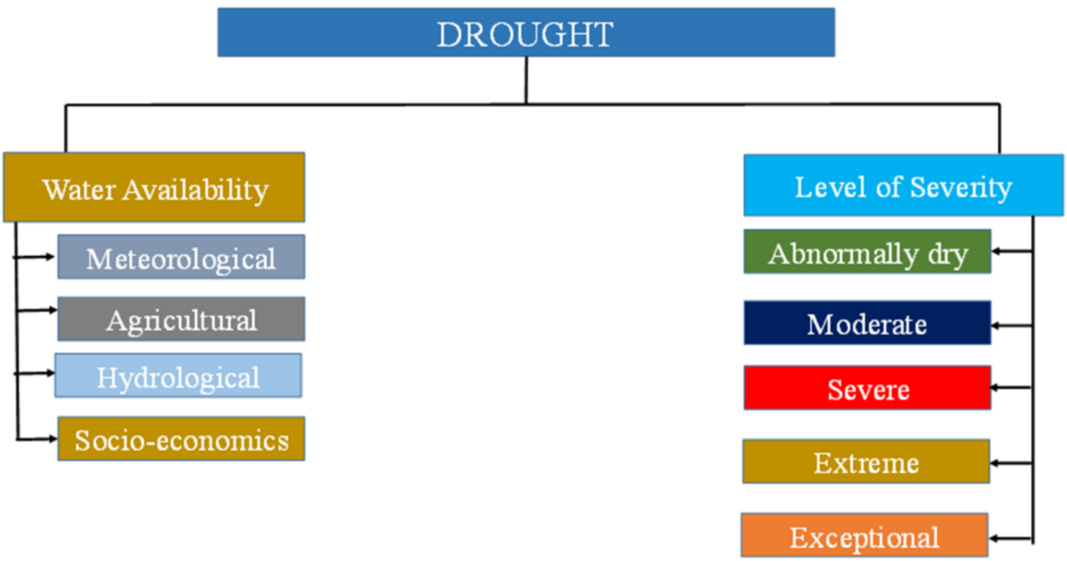

Figure 3. Types of drought.

Precautions, management, and mitigations

Above we have discussed the disasters which occur due to natural agencies and their effect. Besides this, we should also know the precautions to deal with these disasters. The mitigation measures are divided into three phases *i.e.* before the disaster, during a disaster and after disaster described by the American Red Cross Society and National Institute of Disaster Management (NIDM).

Before disaster: There are common precautions to be kept in mind in hazard-prone areas as:

- First aid and fire extinguisher should be kept handy.
- Alert and early warning should be taken care of.
- Financial arrangements should be made.
- Keeping knowledge about the risk.
- A plan for evacuation should be prepared.
- Insurance of life, property and hazard type should be checked.
- Plan and conduct a mock drill with local people.

During disaster: There are many precautions to be taken during the disaster depending on the type and the intensity and level of severity of the disaster.

After disaster: Some disasters cause a lot of damage to life and property. After a disaster, check yourself for injuries and help people who require special assistance, listen to local people's radio and TV information regarding the update of the disaster.

Some specific measures to be taken during the particular natural disasters:

Earthquake: Earthquake causes huge damage to life and property. There are precautions that are taken to be safe during an earthquake. The area which is prone to earthquake should keep first aid and fire extinguisher handy. Heavy objects should not be kept on the shelves. When the earthquake hit the area people should not panic, should stay away from doors and windows and stay outdoor away from power lines. After the damage is done gas and electric lines should be checked and amended. First aid should be given to the needy.

Landslide: In a landslide, mitigation slopes are artificially made with the goal to reduce its effect (Cruden and Varnes, 1996). There are commonly three methods *i.e.* geometric methods, in which the geometry of hillside is altered; hydrogeological methods is when the water content is reduced and chemical and mechanical methods, where shear strength of unstable mass is increased.

Volcanism: Volcanism cannot be prevented but some steps can be taken before, during and after the volcano to reduce its impact. Before the volcanic eruption it is advised to be aware of the risk, make a plan for evacuation; during volcano safe place for shelter should be located and after volcanos, special care must be taken to protect yourself from the after-effects of volcanism like livestock should be kept indoor, full sleeves shirts and pants should be worn and special care should be taken to protect eyes.

Forest fire: The forest fire has become a menace for the forest biodiversity. We should take care of the fuel of fire like leaf litter and pine needles which helps the fire to ignite, campfire should not be left unattended, no matchstick and cigarettes should be left in the forest. During a fire, fire extinguishers should be called as soon as possible also the local people should come forward and help in extinguishing the fire (Bradstock *et al*., 2012).

Avalanche: There are generally two ways of mitigation in case of avalanche i.e. structural and non -structural. In non-structural we avoid the avalanche by evacuation and artificial triggering which help in the protection of valuable property. Afforestation is generally done for the protection and conservation of forests. Structural include building up dams and structures to avoid the heavy flow of snow (Ganju and Dimri, 2004; Eckert, 2008; Holub and Fuchs, 2008).

Storms: Storms are the heavy or circular wind that affects life and property. During the storm do not take shelter under the trees or under construction and damaged building. Move to the other side plant and stay away from flying object which may pose danger to you. If you are driving, do not out drive the wind it may be dangerous (Godschalk,1989; FEMA, 2011). Doppler radar, satellites, weather balloons, and computer helps in predicting tornadoes.

Flood: For the management of the flood, the overflow of water should be maintained. Watershed should be made, reservoir and small checks dams to reduce flow discharge are prepared. The river water should be distributed evenly in the neighboring, water channels should be prepared and flood embankment of the area should be done to avoid overflowing during heavy rain (Vogt and Somma, 2013).

Tsunami: The effect of a tsunami can only be reduced it cannot be prevented. During the tsunami, it is advised to evacuate to higher areas from the location and carry food, important documents, first aid with you. During the tsunami lay down powerlines, and buildings should be avoided and after return to your place only when declared safe from authorities (Harada and Imamura, 2005; Bernard, 2006).

Drought: Drought is caused due to scarcity of water. Before the disaster, it is advised not to wastewater, and use energy-efficient and water-efficient appliances and do rainwater harvesting.

Conclusion

The present book chapter has focused on the natural disaster and its effect on the environment. The natural disaster in this paper is divided into three bases i.e. land, air, and water-based disasters. Due to the unsustainable use of natural resources the intensity of the natural disaster has increased. It has resulted in the degradation of the environment at an alarming rate. Mitigation plans are generally followed to protect the environment and reduce the adverse effect of disaster. They are divided into three phases that i.e. before, during and after a disaster. Some key mitigation measures such as keeping first aid handy, making evacuation plan and conducting mock drills. Also, public awareness through TV programs, radio and school education is the need of the hour.

Conflict of Interest

There is no conflict of interest.

Acknowledgment

The authors highly thank the Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya for providing the facilities and also to my supervisor (Dr. Nitin Kamboj) for guiding me.

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Cite this chapter as: Kamboj, N., Bisht, A., Kamboj, V., Pandey, N. and Bisht, A. (2020). Role of natural disasters in environmental degradation: An overview. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 21-35, https://doi.org/10.26832/aesa-2020-edcrs-02

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-03

CHAPTER [3]

Role of pesticide application in environmental degradation and its remediation strategies

Sudhanshu Bala Nayak[1*], Alok Kumar Sahoo[2], Elango K.[3] and K. Sankara Rao[1]

[1]Department of Entomology, CCS Haryana Agricultural University (CCSHAU), Hisar-125004, India
[2]Subject Matter Specialist (Agricultural Extension), KVK, Bargarh, OUAT, Gambharipali-768102, India
[3]Department of Entomology, Tamil Nadu Agricultural University, Coimbatore-641003, India

ABSTRACT

The modern agriculture is heavily dependent on agrochemicals like fertilizer, pesticides, micronutrients and plant growth regulators for food and livelihood security in the world. In India, the consumption pattern of pesticides includes insecticides (61.11%), herbicides (22.22%) and fungicides (11.11%). Cotton and vegetables are high pesticides consuming agro-products followed by staple food grains (Rice, Wheat, Corn, Millets). The inappropriate toxic chemicals exposure is not only poisoning & killing of farm families but also dispersing pesticide residues in the environment causing mass killings of nonhuman biotas, such as bees, birds, amphibians, fish, and small mammals. The organophosphate (diazinon, malathion, coumaphos) pesticides affect the nervous system of human beings. Many Pesticides are not easily digestible, they persist in soil, leach to groundwater and surface water and contaminate the wide environment. DDT and Methyl parathion, BHC like toxic residues are also found in humans and other mammals due to bio-accumulated in food chain causing serious health hazards. This book chapter deals with Role of pesticide application in environmental degradation and its remediation strategies.

KEYWORDS Bioremediation, Environmental degradation, Pesticides, Toxicants

Sudhanshu Bala Nayak, Email: nayaksudhanshubala@gmail.com

Introduction

Agriculture is the most important sector of the economy in India as it provides food and livelihood security. The industrialization of agriculture has favoured the use of plenty of agrochemicals including fertilizers, pesticides, micronutrients, and plant growth regulators in the agricultural fields (Bruinsma, 2017; Kumar and Kumar, 2019). Pesticides are an integral part of modern agriculture. The use of pesticides in agriculture is obvious for the prevention of crop-damaging pests, fungus, weeds and a number of crop-eating animals like rodents, etc. In India, consumption pattern of pesticides includes insecticides (61.11%), herbicides (22.22%) and fungicides (11.11%). Organophosphates are the most frequently used pesticides followed by neonicotinoid and pyrethroid. One study says that cotton is the high pesticide consuming agriproduct (93.27%) followed by vegetables (87.2%), wheat (66.4%), millet (52.6%) and mustard (12.6%) (Maurya and Malik, 2016; Yadav and Dutta, 2019).

Types of chemical pesticides

Organophosphate pesticides

These pesticides affect the nervous system by disrupting the enzyme that regulates acetylcholine, a neurotransmitter. Most organophosphates are insecticides. They were developed during the early 19th century, but their effects on insects, which are similar to their effects on humans, were discovered in 1932. Some of the OP compounds are diazinon, malathion, coumaphos (Ware and Whitacre, 2004; Jat *et al*., 2016).

Carbamate pesticides

These pesticides affect the nervous system by disrupting an enzyme that regulates acetylcholine, a neurotransmitter. The enzyme effects are usually reversible. There are several subgroups within the carbamates. Aldicarb, carbofuran, carbaryl, carbosulfan are the example of carbamates.

Organochlorine insecticides

These were commonly used in the past, but many have been removed from the market due to their health and environmental effects and their persistence effect. DDT, chlordane, aldrin, dieldrin, heptachlor are the common OC compounds.

Pyrethroid pesticides

These were developed as a synthetic version of the naturally occurring pesticide pyrethrin, which is found in chrysanthemums. They have been modified to increase their stability in the environment. Some synthetic pyrethroids are toxic to the nervous system. Deltamethrin, cypermethrin, and permethrin are some of the commonly used pyrethroid (Purdue *et al*., 2007).

Dynamics of pesticides in the environment

Many cases of intoxication of farmers, rural workers, and their families did occur during pesticide applications and were documented in reports on poisoning and the effects of synthetic chemicals on human health. It was reported that unintentional poisonings kill an estimated 3, 55,000 people globally each year, and such poisonings are strongly associated with excessive exposure and inappropriate use of toxic chemicals (Briceno *et al*., 2007; Carvalho, 2017). Dispersion of pesticide residues in the environment and mass killings of nonhuman biotas, such as bees, birds, amphibians, fish, and small mammals, were also reported. Early reports and structured incident reporting systems certainly helped to develop regulations for pesticide applications, including dosage of chemicals and best periods of application. Over the years, a considerable research effort was developed also to understand the behavior of these chemicals in the environment, including their cycling and fate as well as their toxicity to biota (Arias-Estévez *et al*., 2008; Bourguet and Guillemaud, 2016). The majority of pesticides are not specifically targeting the pest only and during their application. They also affect non-target plants and animals. Repeated application leads to loss of biodiversity (Table 1). Many pesticides are not easily degradable, they persist in soil, leach to groundwater and surface water and contaminate the wide environment. Depending on their chemical properties they can enter the organism, bioaccumulate in food chains and consequently influence also human health (Figure 1).

Table 1. Direct and indirect sources of environmental contamination by pesticides

Direct sources	Indirect sources
Application for pest-control in agriculture	Drift (air), rain, and snow
Application for pest-control in livestock	Animal dips
Soil treatments to control subterranean pests	Soil erosion
Water treatment to control weeds, mosquitoes, and others	Sanitation system carrying pesticides from washing and cleaning of equipment and containers
	Dumping of pesticides
	Industrial wastes from pesticides-manufacturing plants
	Pesticide spills

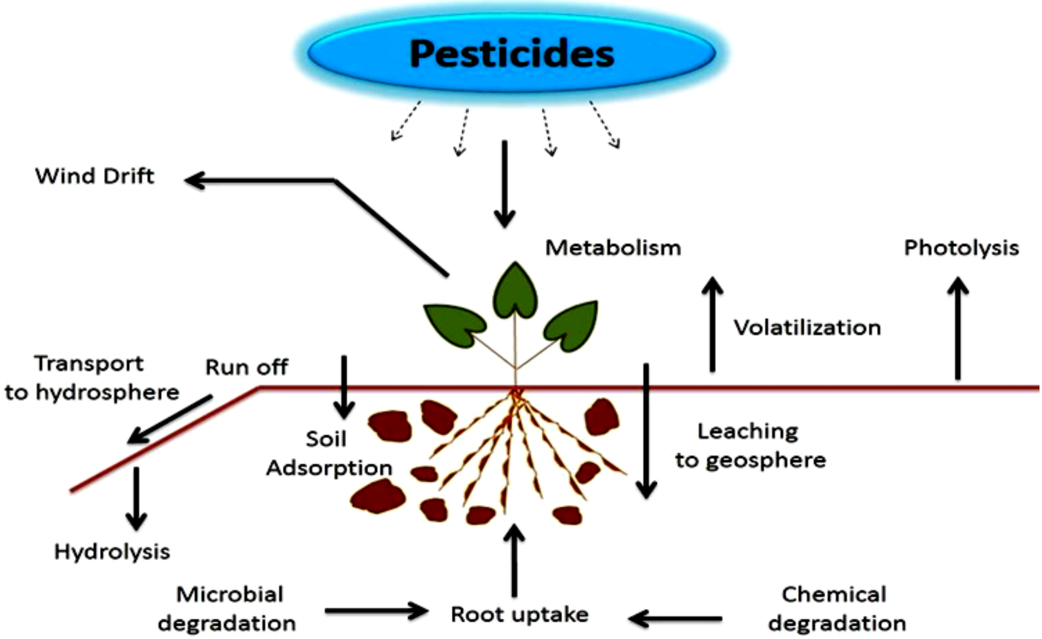

Figure 1. Schematic diagram representing pesticide dispersal in environment.

Environment impacts

Pesticides present the only group of chemicals that are purposely applied to the environment with the aim to suppress plant and animal pests and to protect agricultural and industrial products. Pesticides can contaminate soil, water, turf, and other vegetation. In addition to killing insects or weeds, pesticides can be toxic to a host of other organisms including birds, fish, and beneficial insects (Kumar *et al*., 2019). However, the majority of pesticides are not specifically targeting the pest only and during their application, they also affect non-target plants and animals. Repeated application leads to loss of biodiversity. Many pesticides are not easily degradable, they persist in soil, leach to groundwater and surface water and contaminate the wide environment. Depending on their chemical properties, they can enter the organism, bioaccumulate in food chains and consequently influence the environment

Soil contamination

Pesticides enter the soil via spray drift during foliage treatment, wash-off from treated foliage, release from granulates or from treated seeds in the soil. Some pesticides such as soil fumigants and nematicides are applied directly into the soil to control pests and plant diseases presented in soil. The transport, persistence or degradation of pesticides in soil depends on their chemical properties as well as the physical, chemical and biological properties of the soil. All these factors affect sorption/ desorption, volatilization, degradation, uptake by plants, run-off, and leaching of pesticides. Sorption is the most important interaction between soil and pesticides and limits degradation as well as transport in soil. Pesticides bound to soil organic matter or clay particles are less mobile, bioavailable but also less accessible to microbial degradation and thus more persistent. Soil organic matter is the most important factor influencing the sorption and leaching of pesticides in soil. The addition of organic matter to the soil can enhance sorption and reduce the risk of water pollution. The amount and composition of organic matter have a large impact on pesticide sorption. For example, soil rich on humus content is more chemically reactive with pesticides than non-humified soil. Changes in soil pH or the addition of nitrate fertilizers can induce a release of these residues. There exist also pieces of evidence that some organisms, e.g. plants and earthworms, can uptake and remobilize old tightly bound residues

Water contamination

Pesticides can get into the water via drift during pesticide spraying, by runoff from the treated area, leaching through the soil. In some cases, pesticides can be applied directly onto the water surface. Water contamination depends mainly on the nature of pesticides (water solubility, hydrophobicity), soil properties, weather conditions, landscape and also on the distance from an application site to a water source. Rapid transport to groundwater may be caused by heavy rainfall shortly after the application of the pesticide to wet soils. Pesticides detected in water bodies are pronofos, dimethoate, chlordane, diuron, prometryn, and fluometuron. Streams and rivers were frequently more polluted than groundwaters and more near the areas with substantial agricultural and/or urban land use.

Impacts on organisms

Soil organisms: Soil microorganisms are essential for the maintenance of soil structure, transformation, and mineralization of organic matter, making nutrients available for plants. Soil microorganisms are also able to metabolize and degrade a lot of pollutants and pesticides. Microbial degradation can also lead to the formation of more toxic and persistent metabolites. Although soil microbial populations are characterized by fast flexibility and adaptability to changed environmental conditions, the application of pesticides (especially long-term) can cause significant irreversible changes in their population. The inhibition of species, which provide key processes, can have a significant impact on the function of the whole terrestrial ecosystem. Fungicides are found to be toxic to soil fungi and actinomycetes and causing changes in microbial community structure. Other bacterial species, such as nitrification bacteria, are very sensitive to pesticides influence. Inhibition of nitrification was proved by sulphonylurea herbicides. Chlorothalonil and dinitrophenyl fungicides such as Mancozeb, Maneb or Zineb have also been shown toxic to nitrification and denitrification bacteria. Organochlorine pesticides suppress symbiotic nitrogen fixation resulting in lower crop yields. DDT and Methyl parathion at levels found in farm soils interfered signaling from the leguminous plants such as alfalfa, peas, and soybeans to symbiotic soil bacteria. This effect, loosely comparable to endocrine disruption effects of pesticides in humans and animals, significantly disrupts N_2 fixation. As a consequence, increased dependence on synthetic nitrogenous fertilizer reduced soil fertility and unsustainable long-term crop yields occur. The observations also may explain a trend in the past 40 years toward stagnant crop yields despite record-high use of pesticides and synthetic fertilizers worldwide

Soil invertebrates: Nematodes, springtails, mites and further micro-arthropods, earthworms, spiders, insects, and all these small organisms make up the soil food web and enable decomposition of organic compounds such as leaves; manure, plant residues and they also prey on crop pests. Soil organisms enhance soil aggregation and porosity and thus increasing infiltration and reducing runoff. Earthworms represent the greatest part of the biomass of terrestrial invertebrates (>80 %) and play an important role in the soil ecosystem. They are used as a bioindicator of soil contamination providing an early warning of the decline in soil quality. They serve as model organisms in toxicity testing. Earthworms are characterized by a high ability to cumulate a lot of pollutants from the soil in their tissues, thus they are used for studying bioaccumulation potential of chemicals. A recent review of pesticide effects on earthworms showed a negative reaction to the growth and reproduction of earthworms by many pesticides. A microcosm study conducted in orchards in South Africa indicated the adverse effects of spraying by pesticides (chlorpyrifos and azinphos methyl) on earthworm's biomass and cholinesterase activity. Earthworms were detrimentally affected by pesticides due to chronic and intermittent exposure. A laboratory experiment that reproduced vineyard conditions in France showed that a mixture of insecticides and/or fungicides at different environmental concentrations caused a neurotoxic effect in earthworms. After a long period of exposure or high concentrations, earthworms were physiologically damaged and could not cope with the high toxicity (Schreck *et al*., 2008). Chlorpyrifos causes several adverse effects at the cellular level (DNA damage) that indicates physiological stress in the earthworm.

Impact on non-target species: The negative impact of pesticides spraying on invertebrate communities might not be seen instantly but may produce detrimental effects afterward. Decrease in the number of spiders and diversity; and species richness of Collembolan after application of insecticide chlorpyrifos has been reported on grassland pasture in UK (Fountain *et al*., 2009). Impact of chemical treatment on arthropod community in the agriculture area near Everglades Nation Park, USA. Overall, more arthropod taxa were present in the non-sprayed field, with a higher number of predators such as coccinellids than on-field treated by broad-spectrum herbicides and insecticides eleven times during two years. The restriction of herbicides in crop edges has a positive influence on arthropod populations, especially for chick-food insects, Heteroptera, and other herbivores. Predatory insects may be affected indirectly by the exclusion of herbicides alone, or as a result of changes in their prey availability. The effect of pesticides on bees is closely watched because of their crop pollination. However, little is known about the impacts of pesticides on wild pollinators in the field. In a recent study conducted in the Italian agricultural area, monitored species richness of wild bees, bumblebees and butterflies were sampled after pesticide application (Meftaul *et al*., 2019). They detected the decline of wild bees after repeated application of insecticide fenitrothion. Lower bumblebee and butterfly species richness was found in the more intensively farmed basin with higher pesticide loads. Several articles reported the negative effects of pesticides and intensive agriculture on butterflies' populations and showed positive effects on organic farming. It has been shown that using herbicides to control invasive plants can significantly reduce survival, wing and pupa weight of butterfly at treated areas. The author highlighted the importance of careful consideration in the use of herbicides in habitats harboring at-risk butterfly populations. Reduction of adverse effect may be achieved by applications in late summer and early fall, post-flight season and during larval diapauses (Meftaul *et al*., 2019).

Amphibians and fishes: Carbaryl has been found toxic for several amphibian species; additional combination with predatory stress causes higher mortality. Herbicide Roundup, glyphosate, caused high mortality of tadpoles and juvenile frogs in an outdoor mesocosms study. Malathion is the most commonly applied insecticide around the world and can be legally directly sprayed over aquatic habitats to control the mosquitoes. A small concentration of malathion caused direct and also an indirect effect on the aquatic food web. Changes in plankton and periphyton abundance and composition consequently affected the growth of frog tadpoles and reduce predation rates on amphibians. Repeated low dose application causes a large impact than a single exposure. All these pieces of evidence might contribute to the explanation of a global decline in amphibian diversity.

Impact on birds: The decline of farmland bird species has been reported over several past decades and often attributed to changes in farming practices, such as increase agrochemical inputs, loss of mixture farming or unfarmed structures. Besides lethal and sublethal effects of pesticides on birds, concern has recently focused on the indirect effects. These effects act mainly via the reduction of food supplies (weeds, invertebrates), especially during breeding or winter seasons. As a consequence insecticide and herbicide applications can lead to the reduction of chick survival and bird population. The time of pesticide application plays also an important role in the availability of food. Several practices (generally Integrated crop management techniques) can be used to minimize unwanted effects of pesticides on farmland birds, such as the use of selective pesticides, avoiding spraying during breeding season when crops and weeds are in flower, minimize spray drift or creation of headlands.

Persistence of pesticides

Approximately 90 percent of pesticides used in agricultural practices never reach their target organisms instead, scattered through the air, soil, and water resulting in detection in air, surface and groundwater, sediment, soil, vegetables and to some extent in foods. To control soil-borne pests and pathogens soil-applied pesticides accumulated residues and metabolites in the soil at unacceptably high levels. (Shalaby and Abdou, 2010)**.** Depending upon the structure of the pesticide and availability of soil factors, pesticide persistence in the soil fluctuates from a week to several years. For instance, chlorinated hydrocarbon insecticides like chlordane persist at least 4-5 years and some times more than 15 years whereas toxic phosphates persist for three months (Niti *et al*., 2014). The persistence of pesticides poses a threat to livestock and human health.

Pesticide degradation

Pesticide degradation is the process by which a pesticide is transformed into simpler compounds such as water, carbon dioxide, and ammonia as a result of chemical reactions like hydrolysis, photolysis, and biodegradation (Ortiz-Hernandez *et al.,* 2013). Degradation of pesticides involves both biotic transformation processes—mediated by microorganisms or plants—and abiotic processes such as chemical and photochemical reactions. What transformation processes a given pesticide undergoes is determined by its structural affinity to specific types of transformation, and the environmental conditions it is exposed to as a result of its distribution and transport behavior. For instance, redox gradients in soils, sediments, or aquifers often determine which biotic and/or abiotic transformations can occur. Similarly, photochemical transformations are restricted to compartments exposed to sunlight—e.g., the topmost meter(s) of lakes or rivers, the surfaces of plants, or sub-millimeter layers of soil. The environmental dynamics of pesticides are influenced largely by the various factors operating in the environment and the physicochemical and biological properties of pesticides. The environment consists of the atmosphere (air), hydrosphere (water), lithosphere (soil), and biosphere (biota), each possessing its own physical and chemical and/or biological properties. The biotic and abiotic elements in each component influence the dynamics of pesticides. The environmental dynamics of pesticides are further influenced by the physicochemical properties of pesticides. Properties of pesticides such as hydrophilicity or lipophilicity, partition coefficients, adsorption, vapor pressure, and volatility determine the ultimate fate of pesticides in the living and nonliving portions of the systems (Kumar *et al.,* 2013; Vela *et al*., 2017).

Remediation strategies

Pesticides convert and degrade them into simpler non-toxic compounds by soil microorganisms' metabolic activities of bacteria, fungi, actinomycetes and plants process called biodegradation. Besides biodegradable pesticides in the soil, there are certain pesticides show complete resistance to biodegradation, called ―recalcitrant (Mulchandani *et al.*, 1999). Different techniques employed for bioremediation depend upon three basic principles i.e. the amenability of the pollutant to biological transformation (biochemistry), the accessibility of the contaminant to microorganisms (Bioavailability) and the opportunity for optimization of biological activity (bioactivity) (Dua *et al*., 2002). There are two broad ways of bioremediation i.e. in-situ remediation and ex-situ remediation strategies. Bacteria like Alcaligenes, Flavobacterium, Pseudomonas, and Rhodococcus have impressive capabilities of pesticide degradation (Boricha and Fulekar, 2009). Actinomycetes belonging to the genera Arthrobacter, Clavibacter, Noca-rdia, Rhodococcus, Nocardioides and Streptomyces have the potential for the degradation of the pesticides (DeSchrijver and DeMot, 1999). White-rot fungi also have played a significant role in the degradation of pesticides such as lindane, atrazine, diuron, terbuthylazine, metalaxyl, DDT, gamma-hexachlorocyclohexane (g-HCH), dieldrin, aldrin, heptachlor, chlordane, lindane, mirex, etc. (Watanabe *et al*., 2001). *Flammulina velupites, Stereum hirsutum,Coriolus versicolor,Dichomitus squalens, Hypholoma fasciculare, Auricularia auricula, Pleurotus ostreatus species fungi are effective against* triazine, phenylurea, dicarboximid, chlorinated organophosphorus compounds. (Uqab *et al*., 2016). There is another significant inexpensive, environmentally friendly and effective in-situ method called phytoremediation or plant-assisted bioremediation i.e. using plants to clean and restore soil and wastewater for removal of soil contaminants. Plant root systems along with uptake, transformation, volatilization, and rhizodegradation are the important processes used during phytoremediation (Bot and Benites, 2005; Niti *et al*., 2014). A favorable microenvironment is provided around plant roots to facilitate contaminant degradation (Reichenberger *et al*., 2007).

Conclusion

No doubt the current Indian agriculture is loaded with chemicals like pesticides for protecting crops for a larger population food security, the externalities involved in pesticide application created an extra burden on the environment and human societies. The intoxication has spread over many platforms starting from farm families to the tail end consumer in the food chain dynamics. The fate of pesticides has serious concern over environmental degradation due to soil, water, air, cropland pollution. The persistence of pesticides has an irreversible long-run negative impact on terrestrial and aquatic species. However, there should have several strategies for safe pesticide production and judicial safe use of pesticides by the farmers. Bioremediation and Phytoremediation can be an effective approach for pesticide degradation. Integrated Pest Management in the integration of other non-chemical practices for sustainable agriculture can be hope for future agriculture in India.

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Cite this chapter as: Nayak, S.B., Sahoo, A.K., K., E. and Rao K.S. (2020). Role of pesticide application in environmental degradation and its remediation strategies. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 36-46, https://doi.org/10.26832/aesa-2020-edcrs-03

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-04

CHAPTER [4]

A review on general characteristics, classification and degradation of river systems

Vishal Kamboj, Nitin Kamboj* and Amit Kumar Sharma

Department of Zoology and Environmental Science,
Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India

ABSTRACT

Rivers play an important role in the life of human beings. Most of the ancient cities are situated near the river systems and peoples were dependent on it for their livelihood needs, transportation, and raw material for construction, drinking and irrigation purpose. The degradation of the river system is based on river bed material and discharge of environmental pollution such as wastewater, agricultural runoff, and also tourism activities. Besides this, discharge of wastewater, tourism activity, and agricultural runoff into the river causes the eutrophication condition due to the discharge of nutrients in excess amount. The mining activity also affects the floodplain area and riparian zone of the river which causes the flood condition in the river. The mining activities led to change the channel morphology characteristic, increased the progressive degradation in upstream and downstream stretch and also it changes the sub-strate structure of the river. These activities directly affect the aquatic biodiversity and river regime. For preventing the river system some natural material and man-made methods such as plantation of vegetation and trees, training the river bank with stone, rocks. Therefore, this chapter emphasizes how the rivers system is classified on the basis of sources, geomorphological characteristics, river age, stream order, biotic zone classification and whitewater classification methods and also discuss the degradation of the river system by the river bed material and environmental pollution activities.

KEYWORDS

Environmental degradation, River classification, River degradation

Nitin Kamboj , Email: kambojgurukul@gmail.com

Introduction

Rivers, a vital part of the freshwater ecosystem usually known as a flow of natural watercourse that flows towards the sea, ocean and other areas. Rivers are the strip connecting the terrestrial environment with the ocean realm (Padmalal and Maya, 2014). Rivers are the prominent geological agent who transfers the materials from terrestrial to the ocean by erosion process. The flowing water collected in the river is a part of the hydrological cycle through these processes such as precipitation, surface runoff, melting of the glacier, groundwater, and natural springs. Flowing water is the main agent of the erosion process, creation of channel path and physical habitat in a river system (FAO 1998; Padmalal and Maya 2014). Flowing water create, destroy and re-creates the landforms, channel pattern, and habitat of the biotic community. In the entire world, most of the cities, villages are situated nearby the rivers for their daily needs like fresh water for drinking, irrigation purpose, food, transportation, and other activities.
Therefore, this chapter represents how the rivers system is classified on the basis of sources, geomorphological characteristics, river age, stream order, biotic zone classification and Whitewater classification methods and also discuss the degradation of the river system by the river bed material and environmental pollution activities.

Classification of river systems

Generally, the rivers are classified on the basis of the following characteristics (Figure 1):

On the basis of Source

Sources refer to the beginning point or path of the river and also called a course. The ending point of the river called mouths. The river is divided into two-part on the basis of water flow such as upstream (direction of flowing water towards the source) and downstream (direction towards the mouth of the river). The rivers are classified on the basis of source divided into three types.
Mountain River: The mountain rivers refer to those rivers which start from the mountains also called as glacier-fed rivers and Perennial river. In the northern part of India, most of the rivers start from the mountains. For example, the Ganga river started from Gangotri Glaciers, Yamuna river started from Yamunotri glacier, Alaknanda river started from the Satopanth glacier.
Subsurface streams: The subsurface streams refer to that river that flows underground in caves, glaciers and ice sheets. These rivers mostly found in the limestone geological formation region.
Seasonal or ephemeral rivers: Seasonal or Ephemeral rivers depending on the precipitation/ rainfall of that area. In this type of river, water flows occasionally in monsoon months. In other months, these rivers show a dry flow. In most of the Indian cities, these types of the river called

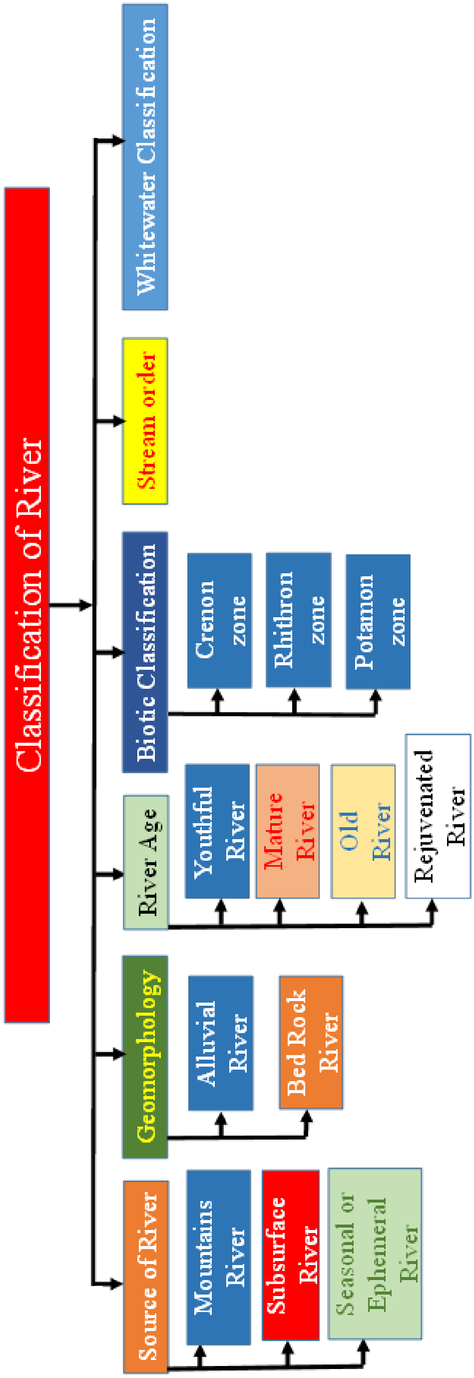

Figure 1. Classification of river systems.

Rao. For example, in the Haridwar district of Uttarakhand, many seasonal rivers are present namely Sukh Rao, Ranipur Rao, Chilla Rao, etc.

On the basis of geomorphology

In the entire world, rivers play an important role to transfer raw materials like sand, gravel, boulder and other debris loads from one point to another point (Kamboj *et al.*, 2017). The bed of the river is the combination of geomorphology materials like boulder, stone, sand, and silt. These types of the river maintain their watercourse by erosion. The rivers classified as on the basis of geomorphology characteristics as follows:

Alluvial rivers

The alluvial rivers refer on the basis of channel pattern, floodplain areas that are created, destroy and recreate by weakly consolidated sediments. Channel pattern refers to the path of the watercourse and floodplain area refers to the nearby area of the river which consists of sediments. The alluvial river also classified into five major types on the basis of channel pattern using calculate the sinuosity index (straight channel, sinuous channel, meandering channel) and on the geomorphological characteristics (braided channel and Anabranching channel) of the river (Leopold *et al.*, 1964; Miall, 1985).

Sinuosity Index: The sinuosity index is a method to know the pattern of the channel watercourse. The sinuosity index refers to the length of the channel water course divided by the straight length of the river from one point to other point in Table 1 and Figure 2. The formula for calculating the Sinuosity index is given below:

$$\text{Sinuosity index (SI)} = \frac{\text{Length of water course (Lw)}}{\text{Straight length of the river (SLw)}}$$

On the basis of the sinuosity index alluvial channel divided into three types such as straight channel, sinuous channel, and meandering channel.

a) Straight channel: The straight channel refers to when the sinuosity index value is less than 1.05. In the natural river system, the straight channel found only a short length at the upstream and source point of the river.

b) Sinuous channel: The sinuous channel is when the sinuosity index value lies between 1.05 to 1.50. Most of the alluvial rivers show the sinuous channel chrematistics.

c) Meandering channel: The meandering channel occurs when the value of the sinuosity index is greater than the 1.50. These types of channels found in almost the rivers. The meandering channel is consisting of riffles, pools and provides the habitat for aquatic organisms.

On the basis of geomorphological characters, alluvial rivers divided into two types such as Braided channel and Anabranching River Channel.

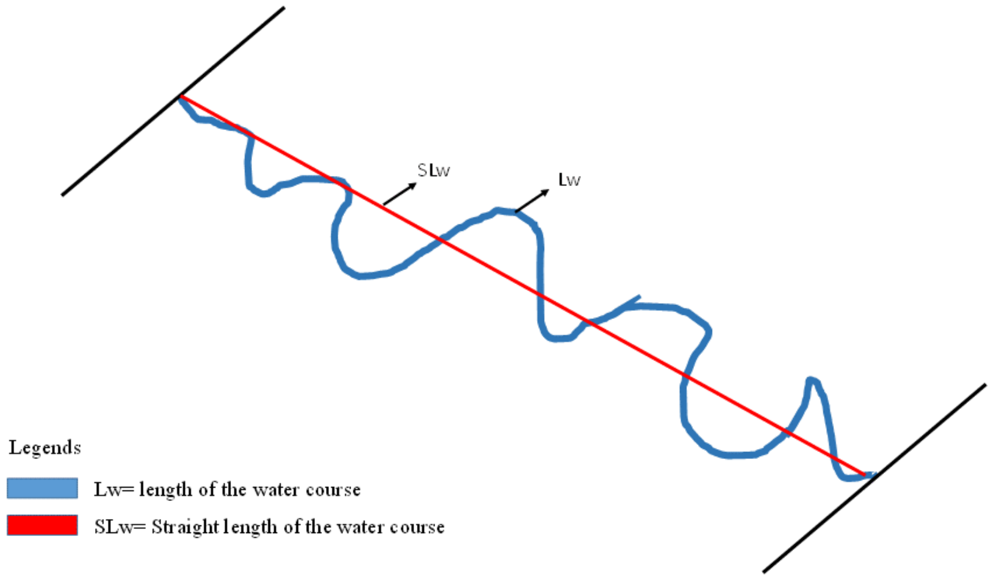

Figure 2. Method of calculating the sinuosity index.

Table 1. Types of the alluvial river on the basis of the sinuosity index.

Types of river	Sinuosity index
Straight Channel	>1.05
Sinuous Channel	1.05 to 1.50
Meandering Channel	< 1.50

a) Braided river channel: The braided channel defined as the separation of the main channel in many channels due to the permanent and temporary bars, islands. The condition of the braided channel is generally shown in most of the river system (Figures 3 and 4). The formation of a braided channel in a rivers system is due to the high sediment load, high water flow, high meandering pattern, weak bank and steeper slope (Schumm and Kahn, 1972).

b) Anabranching river channel: The anabranching channel mostly looks like the braided river channel. It consists of a number of the channel which is separated by the vegetation, alluvial island in the active channel not in the floodplain area (Nanson and Knighton, 1996). The formation of these types of rivers due to the low and high water flow and banks that are stable sediments. The anabranching river channel is divided into six classes on the basis of stream energy (flow of water), size of sediments, and morphological characteristics (Table 2).

Bedrock rivers

The formation of bedrock rivers is occurring where the flow of water passes through the new

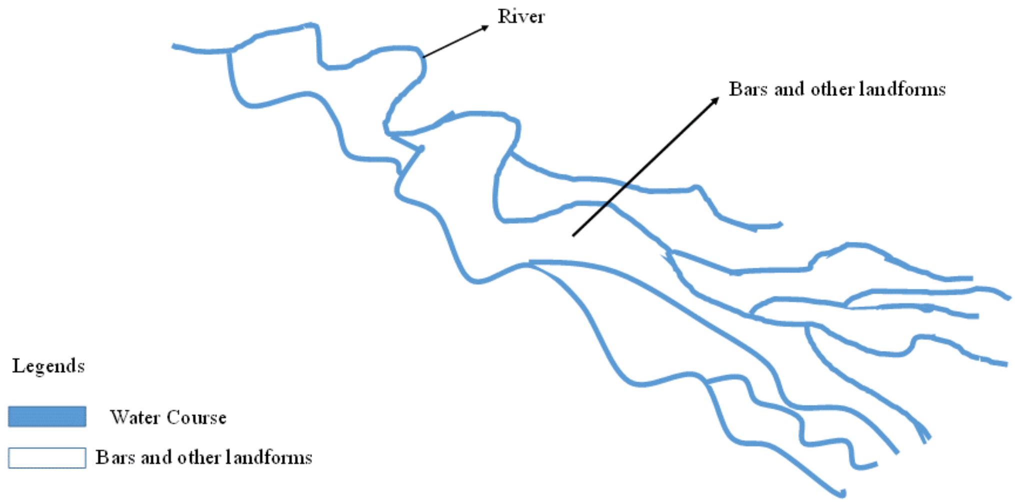

Figure 3. Sketch map showing the braided channel condition.

Figure 4. A satellite view of the Ganga river at Haridwar showing the braided channel condition.

Table 2. Type and condition of the anabranching river channel.

Type	Condition	Reference
Type 1	Lower energy, cohesive sediments, low width and depth	Nanson and Knighton 1996).
Type 2	Lower energy, sand dominated, island forming rivers	
Type 3	Lower energy, active meandering river, a mixed load of sediments	
Type 4	Higher energy, sand dominated, channel dividing ridges, long and parallel ridge forming rivers	
Type 5	Higher energy, gravel dominated, active system that lines the braiding and meandering in mountains part	
Type 6	Higher energy, gravel dominated, stable system, steep basin, and non-migrating channels	

level of sediments where bedrock is below. These types of rivers commonly found in upland and mountainous rivers where the earth's surface is shifting upwards. The formation of these types of rivers is due to the alluvial in nature, weakly sediments, and banks and the high flow of water. The best example of a bedrock river is the Colorado river (United States).

On the basis of river age

The study of river age also known as the chronological classification of rivers on the basis of study about the changing of river path and pattern of erosion. On the basis of a cycle of erosion developed by William Morris Davis, the rivers are classified into four types such as Mature rivers, Old rivers, Rejuvenated rivers, and Young channel. This theory is rejected by the geomorphologist because it does not produce a testable hypothesis and this theory is nonscientific (Castree, 2006). On the basis of Davis theory, the rivers are classified as:

Youthful river: According to the Davis theory, these types of rivers are steep gradient as well as they have few tributaries along with a rapid flow. The channel of these types of the river is deeper rather than wider. The examples of the youthful rivers are Brazos, Ebro and Trinity rivers.

Mature river: The formation of these types of rivers with a gradient that is not steep, in which flow of water is slower and also fed by many tributaries having more discharge as a comparison to the youth river. The channel of these rivers is eroding wider as opposed to deeper. The examples of mature rivers are Thames, Ohio, Danube and Mississippi rivers.

Old river: These types of the river are classified on the basis of their floodplain areas along with low gradient and low erosive energy. The examples of the old rivers are lower Ganges, Indus, lower Nile, and Yellow rivers.

Rejuvenated river: These types of the river have various gradient which is raised by the tectonic movement. The example of the rejuvenated river in Colorado and the Rio Grande rivers.

On the basis of biotic zones

Rivers are the example of a lotic ecosystem. It refers to the flowing water in a landscape include with the biotic community such as producers (plankton community), consumer (fishes) and decomposers (micro-organisms) as well as abiotic factors (Alexander and Fairbridge, 1999; Angelier, 2003).

In a river system, the zones are divided by the river bed gradient, velocity of the current and other abiotic factors such as temperature. Illies and Botosaneanu (1963) and Hawks (1975) divided the rivers into three primary zones according to the presence of abiotic and biotic factors as seen in Figure 5:

Crenon zone: The crenon zone is that area that is near the source of the river or where the river gets it to start. The crenon zone divided into two zones namely the eucrenon zone and hypocrenon zone. The eucrenon zone is the spring zone and hypocrenon zone is the headstream zone. In these areas, the temperature of the water, oxygen level and flow of water are low.

Rhithron zone: A rhithron zone is the upstream area of a river characterized by the presence of following conditions/factors such as steep gradient, narrow and shallow rapids, and riffles, deeper, flatter pools. In this zone, the flow of current is higher in riffles rather than the pools. In riffles, vegetation is attached with boulder, stone, rock. In pools, vegetation is attached to the fine material and some other rotting vegetation. In the rhithron zone, the temperature is low and the dissolved oxygen is high. In the rhithron zone, the main biotic community is consisting of plankton, periphyton, nekton and a variety of benthos. The rhithron zone absents in the tropical river and found relatively lengthy in temperate rivers.

Potamon zone: A potamon zone is the downstream area of a river with flat gradient, lower speed, lower oxygen content, the temperature of the water is warmer than the rhithron zone and the river bed is sandy. In the potamon zone, the presence of habitats is depending on the meanders of the channel as well as different the main channel and floodplain areas. The potamon zone is the more complex and differs environmentally from the rhithron zone based on the following aspects such as geomorphology of the channel, submerged vegetation, quality of water, biotic community and bacterial density is high.

Classification on the basis of stream order

Stream order is a method based on the number that shows how a number of tributaries link to a stream network. Most of the rivers are first order and second order rivers. For example, the Ganga river is the second-order stream and the Amazon river is the twelfth river. The concept of stream order method proposed by two scientists namely Strahler and Shreve.

Strahler stream order: The Strahler describes the stream order is the linking of tributaries in a stream network. according to this method, all the rivers start with the first order. When two first-order tributaries are linked together with a point after this the stream order is two. If the two order stream linked with another two order stream than it creates the third-order stream (Figure 5 and 6). This is the most common method of stream order (Tarboton, 1991).

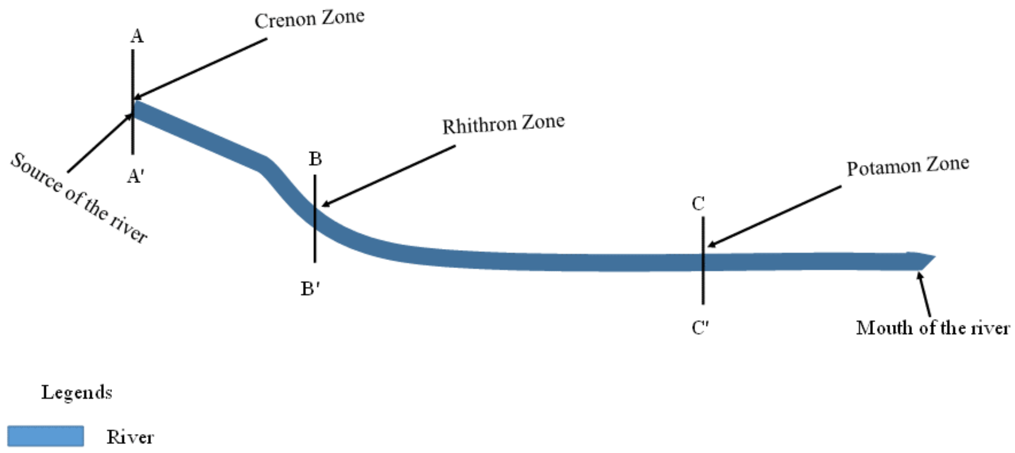

Figure 5. Diagrammatic representation of the longitudinal profile of the river course showing biotic zones.

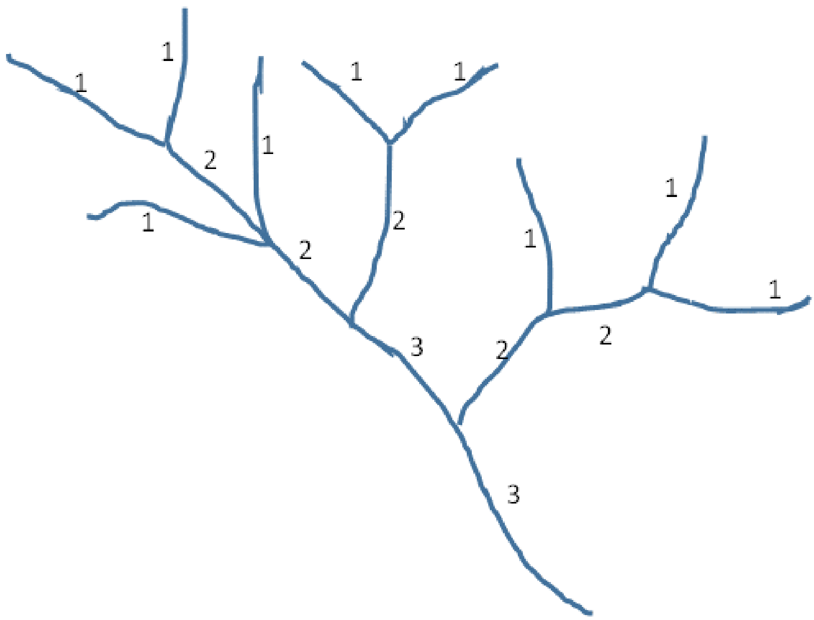

Figure 6. Diagrammatic map of Strahler stream order.

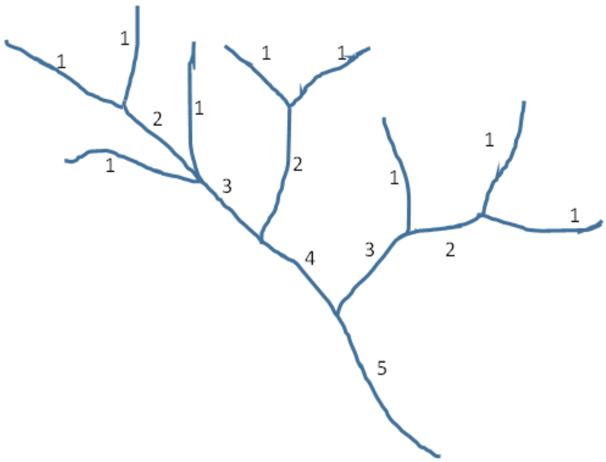

Figure 7. Diagrammatic map of Shreve stream order.

Shreve stream order: According to the Shreve stream order, all links in the network are accounts. In this method, all the orders are additive and all link which starts with the source assigned as the first order. The orders are additive sometimes referred to as magnitudes instead of orders and show the number of upstream links (Figure 7). The first-order stream is linked with the second-order stream than it creates third link stream and second-order stream linked with the third-order stream than it creates fourth-order streams and so on (Tarboton, 1991).

On the basis of whitewater classification

Whitewater classification is the classification method based on the navigation challenges, recreational activities and healthy ecosystem of a freshwater river (Table 3). The International scale of river difficulty divided the whitewater classification into six classes on the basis of some condition. The class I is the easiest and Class VI is the hardest class (Walbridge and Singleton, 2005).

Degradation of the river system

The term degradation refers to the erosion of the earth's surface due to the natural and anthropogenic activity. In a river system, two terms are used aggradation and degradation. Aggradation terms refer to the increase in land elevation due to the deposition of sediments in a river system, it occurs on that area where the supply of sediment is higher than the transport of other material (Gibling, 2005). Degradation is differing from the aggradation process, it refers to

Table 3. Classes of Whitewater classification (Source: ISRD, 2005).

Class name	Water flow/Swimming condition for peddlers	Conditions according to rapids and waves
Class I	Easy	Fast flow, small waves, easy to swim
Class II	Novice	Rivers are wide, waves are medium-sized,
Class III	Intermediate	Waves are irregular and intermediate the difficulty level
Class IV	Advanced	Rapids are intense and powerful but predictable, unavoidable waves, a good skill for swimming, risk of a swimmer is moderate to high
Class V	Expert	Rapids are extremely long, violent and obstructed; waves are large, unavoidable and hole or steep; scouting is recommended but swimming is dangerous, a good skill for swimming
Class VI	Extreme and exploratory rapids	Rapids/ run in this class are rarely attempted, very difficult and dangerous, swimming is done for expert only with good equipment

the lowering of the stream bed and floodplain area through an erosional process (Galay, 1983). Degradation is a vital part of channel network which maintain the sediments loads either than other materials loads by bedrocks erosion process.

Degradation types of a river system

On the basis of progressive degradation, it may be divided into two types i.e. upstream progressive degradation and downstream progressive degradation (Figure 8).

Upstream progressive degradation: The degradation of the upstream part of a river is generally the result of the three primary causes such as lowering of base level due to the increase in slope, decreasing the river length and removing the control point. Each of the primary causes of the upstream part is discussed on the basis of the type of river change and engineering work on that part.

a) Lowering of base-level: Lowering of base level in an upstream part of the river is happening due to some condition and works such as drop-in lake level, drop-in level of the main river, mining of bed material. In the downstream base level of a river, it may be a lake, a reservoir, and sea. The main reason for the drop in lake level is the steeping of river slope and higher velocity (Galay, 1983). The drop-in level of the main river regularly causes the degradation problem in the main river and its tributaries. The main cause of the lowering of base level in the upstream area is due to mining of river bed materials. The excavation of the river bed increases the slope, and degrade the natural ecosystem of the river (Kondolf, 1997; Kamboj *et al.*, 2017).

b) Decrease in river length: In the upstream part, the main reason for the decrease in river length is the cutoff of the river, channelization, and regulation of river and horizontal shift of base level.

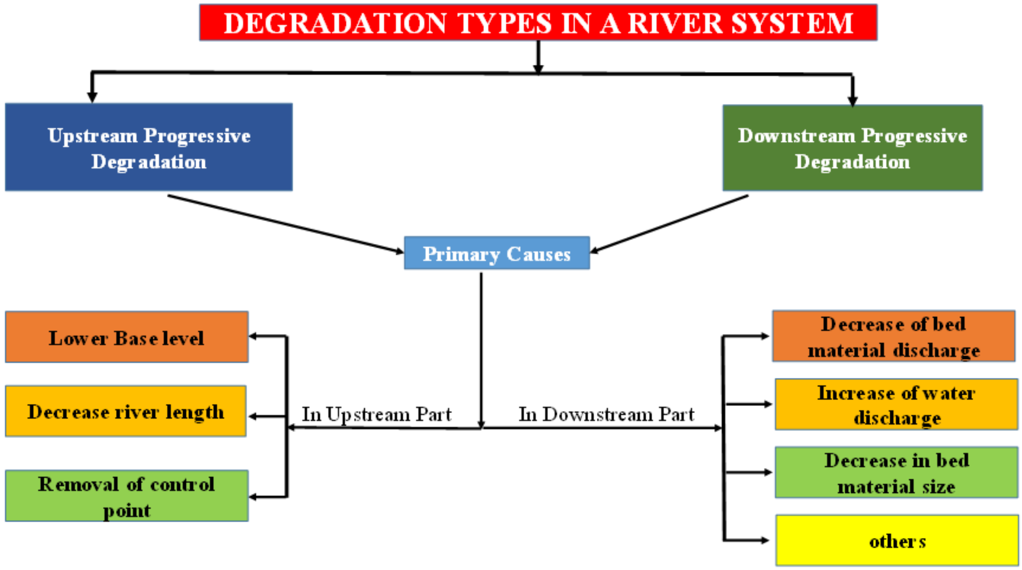

Figure 8. Types of river system degradation.

The cutoff of the river can be natural and man-made that leads to a decrease in river length by increasing the slope. The long series of cutoff separate the river into channelization. The channelization involves the uniform width and depth. Another primary cause of the decrease in river length is the horizontal shifting of the base level. It is the common situation on a river that is the removal of the alluvial part due to the erosion and high flow.

c) Removing the central point: Removing of the central point is done in two ways: 1) natural erosion 2) removal of dam or weir. A central point or Knickpoint usually causes a sudden drop in water level. The removal of the central point shows unstable conditions in the river and it stable itself by the upstream progressing degradation process. The other factor is the removal of the dam or weirs. In this process, the suddenly remove of the sediments from the reservoir cause the upstream degradation.

Downstream progressing degradation: The degradation of the river in the downstream part due to changes variables such as discharge, bed material size, and discharge. There are some factors such as the construction of a high and low dam, mining of bed materials, diversion of bed material, storage of bed material and change in land use show the decrease of bed material discharge downstream. Downstream part sometimes, the flow of water discharge is increase due to the diversion and rare floods. The downstream part of the river is the deposition zone in which the bed material size is less and mostly alluvial in nature. Due to this, the erosion rate in this area is increased. Some other factors such as emerging the river from lake, thawing the subsurface permafrost also show the degradation progressing in the downstream part of the river.

Environmental pollution: The river system is also degrading by environmental pollution such as mining, discharge of wastewater (sewage and effluent), tourism activity, agricultural runoff and many other activities (Warner, 1991). These activities affect the quality of water and also biota of the river system. Due to the mining activity, the turbidity level is increased and affects the other biological factors (Kamboj and Kamboj, 2019a). The mining activity also affects the floodplain area and riparian zone of the river which causes the flood condition in the river (Kamboj and Kamboj, 2019b). Discharge of wastewater, tourism activity, and agricultural runoff into the river causes the eutrophication condition due to the discharge of nutrients in excess amount (Kamboj *et al*., 2016; Kumar *et al*., 2018). These activities directly affect the aquatic biodiversity and river regime.

Mitigation strategies of river degradation

The erosion process is normally occurring in all type of aquatic system may be due to the high flow of water, steep slope, alluvial nature of river and river bed material, heavy sediments loads, river bed mining activities, cutoff nature of the river, construction of dams and other process also (Kondolf, 1997; Kamboj, 2013). In this part, we discussed some methods to protect the river basin from the erosion process. The methods or technique used for controlling the erosion are as follows

Natural material methods: In this method, we used natural materials and techniques to control the erosion process near the river bank. Some natural materials such as Coir Geotextile (use of coconut fibers), Brush mattress (bundles of sticks and other materials), Rootwad composites (combination of interlocking of tree roots and other vegetation), Tree revetment (small trees, shrubs, herbs, and grasses) are laid near the stream bank for protecting the river bank (Kamboj, 2012). The natural materials used to protect the riverbank are biodegradable and also it cannot affect aquatic organisms. These methods are not done in that area where the rate of erosion is higher.

Man-made/engineering methods: There are some methods that are based on natural and man-made materials for preventing the river bank. Some example of this methods are Gabions (create the big box type structure with combined use of stones and manufactured metal wires in the most eroded part of the river), Riprap (combine the rocks and other materials in a large area, this method is most expansive), Windrows and trenches (pilling of erosion-resistant material where the bank eroded), Sacks or blocks (filled with material, block the drainage and vegetation growth, used only in flooding condition), soil-cement (construction of the cement wall on the basis of wave condition *i.e.* if flow of wave is higher than cement wall is made up in stair-step pattern and if flow of wave is lesser than the cement walls is made up in parallel to the slope at the river bank (Hansen, 2000; Holste, 2013). This method is not used in the steep slope.

Conclusion

The present chapter discusses the general feature, characteristics, classification, degradation and preventing measures of a river system. The river system classified on the six major types such as source, geomorphological characteristics, stream order, biotic zone classification, river age, and whitewater classification. The river system is affected by some major conditions such as the flow of water body, slope, width, depth, type of biota, bank condition, sediment material, and floodplain area. The degradation of the river system is based on river bed material and discharge of environmental pollution such as wastewater, agricultural runoff, and also tourism activities. For preventing the river system some natural material and man-made methods such as plantation of vegetation and trees, training the river bank with stone, rocks.

Recommendations

- Nowadays, through satellite mapping and by the use of remote sensing and geographical information system (RS& GIS) technique, so that we could identify the proper location of the erosion part of the river system should be done.
- By this technique, calculation of the erosion rate, sediment transport and how much channel morphology is changed could be identified.
- Discharge of wastewater (sewage and effluent) should be banned and should be allowed only after proper treatment.
- On both side of the riverbank, plantation of vegetation, trees, grasses which highly prevent the bank from the erosion activity.
- Made up the gabions, riprap along the river bank where erosion rate is higher.
- The mining of the raw material from the instream and floodplain area is done in a sustainable way.
- For preventing the river from upstream and downstream progressive degradation due to the construction of the dam's project should include regular analysis of river aspects along the main river and its tributaries.

Acknowledgments

One of the authors (Vishal Kamboj) is highly grateful to the Department of Science and Technology (DST), New Delhi for financial Support through INSPIRE Fellowship (IF160805) and also grateful to the Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar for providing the lab facility.

Conflict of interest

There is no conflict of interest.

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Cite this chapter as: Kamboj, V., Kamboj, N. and Sharma, A.K. (2020). A review on general characteristics, classification and degradation of river systems. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 47-62, https://doi.org/10.26832/aesa-2020-edcrs-04

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-05

CHAPTER
[5]

Integration of treated agro-based wastewaters (TAWs) management with mushroom cultivation

Vinod Kumar[1], Madhumita Goala[2], Pankaj Kumar[1,*], Jogendra Singh[1], Piyush Kumar[1] and Sonika Kumari[1]

[1]Agro-ecology and Pollution Research Laboratory, Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India
[2]Nehru College, Assam University, Labocpar Part II, Cachar 788098 (Assam), India

ABSTRACT

The inefficient management of wastewater generated from agro-based industries has become a cause of environmental degradation. Treated agro-based wastewaters (TAWs) are characterized by higher nutrients load and therefore, utilizable in the agriculture and horticulture as irrigation source. Agricultural reuse of TAWs is the most common practice done by the farmers of developing countries. Using freshwater for substrate wetting has been creating an extra load on our drinking water resources. Globally, a huge volume of freshwater is utilized for substrate formulation in the commercial mushroom cultivation and integration of TAWs with mushroom cultivation has presented improvements in the mushroom productivity, signifying their cultivation more profitable. Furthermore, spent substrates can be used for biogas production, animal feed for mature castrated male sheep, post-weaning calves feeding, biodiesel production, bioethanol production, reducing sugar production, biofertilizer production, methane production, butanol production, etc. This book chapter deals with sustainable approaches to the potential use of TAWs in the formulation of mushroom's substrate material along with efficient management of spent mushroom substrate.

KEYWORDS

Bioremediation, Industrial wastewaters, Mushroom cultivation, Water usage

Pankaj Kumar, Email: kumarpankajgkv@gmail.com

Introduction

Mushrooms are macro-fungi existing on the earth for 300 million years. As a foremost part of animal nutrition, they have been a good source of food and medicinal products (Valverde *et al.*, 2015; Royse *et al.*, 2017). Most of the edible and medicinal mushrooms can be grown on the selective type of agricultural wastes including, manure, sawdust, hardwood, soy hulls, wheat straw, rice straw, corn husk, peanut husk, wood lodges, mustard stem, crop leaves, and sugarcane bagasse, etc. (Grimm and Wösten, 2018). These substrates are known as bulk mushroom substrates and need further processing (nutrients addition) before application in the commercial cultivation. However, a substrate having specific and optimum contents of nitrogen, carbon, and minerals may be supportive for maximizing the growth and yield performance of mushroom as they can be easily broken assimilated by fungal mycelia (Bellettini *et al.*, 2016). Therefore, substrate formulation is the first step in commercial mushroom cultivation which involves adjusting its nutrient content easily utilizable by mushrooms (Carrasco *et al.*, 2018). For this, mushroom substrate/compost technology offers agricultural waste management through utilization as feedstock for large-scale mushroom production (Gyenge *et al.*, 2016). Substrate formulation is achieved in a series of substantial steps such as substrate cutting, grinding, wetting, fertilizing, composting followed by pasteurization and sterilization. Sufficient water content in the substrate is essential for mushroom growth, therefore, freshwater is essentially used to wet the mushroom substrates commonly known as substrate wetting. It is estimated nearly 200 liters of fresh water are used to produce 1 Kg of white button mushroom (Udom *et al.*, 2016). Using freshwater for substrate wetting has been creating an extra load on our drinking water resources, therefore, there is a new interest in developing more efficient substrate formulating technologies by using treated agro-based wastewaters (TAWs) as an alternative of freshwater (Kalmış *et al.*, 2002; Kalmıs *et al.*, 2008; Avni *et al.*, 2017; Chang and Wasser, 2018).

Various agro-based industries such as sugar mill, palm mill, distillery, sago, oil-producing, dairy, food processing, molasses-based alcohol and beverages, tea and coffee, crop product processing, and biofertilizer producing industries are known to generate highly nutritive and less toxic wastewaters (Rebah *et al.*, 2007; Rattan *et al.*, 2015; Sadh *et al.*, 2018). The treated agro-based wastewaters (TAWs) have been recognized for their irrigational application in horticulture and agriculture (Kretschmer *et al.*, 2002; Shuval, 2012). The nutrient content accumulated in the agricultural soils after irrigating with such TAWs helps to enhance the growth and productivity of crop plants. It is estimated that nearly 20% of Mexico, 26% of Pakistan, 30% of India, 50% of Ghana, and 80% of Hanoi's agricultural land is being irrigated with both treated and untreated wastewaters generated from municipal and industrial sectors (Pedrero *et al.*, 2010).

The idea of integrating TAWs with mushroom cultivation is not new but only a few reports

(Kalmıs *et al*., 2008; Avni *et al*., 2017; Chang and Wasser, 2018) are currently available focusing on this aspect, therefore, it requires more attention for scientific exploration. The views in previously published reports deal with either utilizing such as TAWs for wetting mushroom substrate or blending some agro-based solid wastes with the mushroom substrate. However, not all kinds of wastewaters can be used for wetting the substrates, but only a few TAWs are suitable to formulate the substrate materials of both edible and semi-edible mushroom species. Following the above aspects, this book chapter focused on the potential utilization of TAWs with agricultural wastes to grow mushrooms and further management of the spent substrate.

Waste decomposition and nutrients utilization by mushrooms

The main carbon and nitrogen sources required for the growth of mushroom comes from dead animal and plants (lignocellulosic) biomasses (Sánchez, 2009). Nevertheless, dead animal and lignocellulosic biomasses have never been exhausted on the earth assisting mushrooms to be one of the most primitive and successful organisms. The growth of a mushroom is divided into two phases including spawn running or mycelium growth followed by flush production or vegetative growth where actual biomass is produced (Montoya *et al*., 2012; Bellettini *et al*., 2016). During the mycelium growth phase, the fungal spores start propagating and spreading over the substrate surface creating a threadlike network system. This mycelium network covers the substrate surface and secrets a number of extracellular enzymes resulting in the degradation of lignin and cellulose (Table 1 and Figure 1).

Table 1. Mechanisms and enzymes involved in ligninolytic and non-ligninolytic substrate degradation by mushrooms.

Substrate type	Enzyme(s) involved	Degradation mechanism(s)
Ligninolytic	Phenoloxidases	Hydroxylation, free radical action, mediator
	Peroxidases	Production of quinones followed by ring fission
	Glucoseoxidases	Production of hydrogen peroxide
	Methyltransferase	Methylation of the carboxyl group
Non-ligninolytic	Aryl alcohol oxidase, Aldehyde reductase	Production of aldehydes and alcohols
	Cytochrome P450	Hydroxylation
	Cellobiose dehydrogenase	Fenton reaction

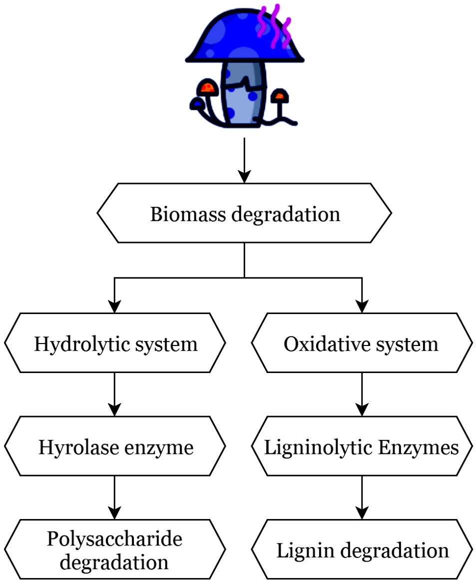

Figure 1. Mechanisms of lignocellulosic biomass degradation used by mushrooms.

The secretion of various intracellular and extracellular enzymes like peroxidases, ligninase, peroxidase, manganese, cellulases, pectinases, xylanases, and oxidases help them to breakdown the dead organic matter and convert them to lesser molecular and ionic forms which can be easily utilized by mushroom during its vegetative growth (Sánchez, 2009). Besides this, the process of breakdown is composite where multiple enzymes act to remediate a molecule from high molecular weight to low. These enzymes are induced by cytochrome P450 gene of fungi which have both ligninolytic and non-ligninolytic degradation capabilities (Kulshreshtha *et al*., 2014).
The nutrients, ions, and water contents are transported from substrate to mushroom body by means of both active and passive mechanisms (Smith, 1984; Randive, 2012). Specific physical and biochemical responses and stabilization for various nutrients in the mushroom are accomplished by myco-degradation, myco-stabilization, and myco-stimulation by mycelia, while bioaccumulation and myco-volatilization by the mushroom body (Chanda *et al*., 2016). However, certain abiotic and biotic factors such as temperature, humidity, relative substrate moisture, luminescence, atmospheric pressure, substrate pH, electrical conductance, available energy as carbon/nitrogen contents, minerals, interacting pests and pathogens, etc. may affect the nutrient transfer mechanism of mushrooms (Kulshreshtha *et al*., 2014).
There is an ultimate requirement of several micro and macronutrients for mushroom growth. In this regard, metal ions are transported to the mushroom body in the form of a metal-enzyme

complex. The process involves two sequential steps *i.e.* ion regulation and ion uptake in which certain fungal genes such as Vps, Rbt, Ftr, Fet, Fre, Sit, Zrt, Pho84, etc. The genes help in secreting the extracellular enzymes which help to bind and transport them into the fungal cell wall. However, these genes may vary according to the mushroom species. Therefore, there is an essential requirement metal ion in mushroom growth and virulence (Gerwien *et al*., 2017). Besides this, the C/N content of the substrate strongly regulates the decomposition process by mushrooms. It has been reported in recent studies that the amendment of C/N rich substrates and fertilizers actively affects the rates of substrate breakdown and further nutrient uptake (Migliore *et al*., 2012; Kumar *et al*., 2019).

Nutrient values of treated agro-based wastewaters (TAWs)

Even after secondary treatment of wastewater from agro-based industries, a non-negligible amount of such utilizable nutrients is left. Despite, farmers prefer to use them as irrigation water due to their high nutrient values which results in rapid soil fertilization and high crop yields (Gothwal *et al*., 2012). It is found that long term soil irrigation using treated wastewaters having has shown excessive micronutrient accumulation, which affects microbial diversity and plant growth. However, mixing these TAWs with the mushroom substrate is a one-time practice, therefore, lesser will be the chances of excessive micronutrient accumulation. Below are the elementary nutrient values of TAWs which makes them useful for mushroom's substrate formulation.

Organic load: Organic content of TAWs is the total biodegradable dry biomass present in the suspended form (Kretschmer *et al*., 2002). The organic contents of TAWs come from the processed agro-based materials (organic compounds, complexes, microorganisms, residual biomass, etc.). Moreover, plant-based materials such as plant leaves, root, stem, fruits, juice, extracts, litter are also helpful to enrich TAWs with organic load (Kumar *et al*., 2018). The most common parameters of organic load are biological oxygen demand (BOD) and chemical oxygen demand (COD). Organic load of TAWs presents in both fixed and non-fixed forms which have been playing a crucial role in providing fertilizer values to the crops through wastewater irrigation. Microorganisms continuously feed and breakdown organic particles. As a result of redox reactions of microbial enzymes, these particles are converted into smaller and utilizable (by plant) molecular forms (Kwak *et al*., 2009). Therefore, the organic content of TAWs may be helpful in increasing the mushroom's substrate value, which may be helpful for increasing their growth and productivity.

Micronutrients: The elements required in trace quantity for life are known as micronutrients. Despite the proper functioning and metabolism of fungi, they perform an essential role in balanced mycelium growth. These elements include copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), and molybdenum (Mo). Micronutrients are the foremost part of agro-based residues. TAWs contain sufficient micronutrients that can provide fertilization to the mushroom substrate. During the raw crop processing, these micronutrients are released in the wastewater. However, a significant amount of micronutrients is removed during the wastewater treatment process, therefore, TAWs are known to have a permissible level of micronutrients suitable for irrigation (Kumar *et al*., 2018). These micronutrients play a critical role in microbial growth and development.

Macronutrients: Macronutrients includes nitrogen (N), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and phosphorus (P). Macronutrients essentially play an important role in fungal growth and development. N play role in constructing the genetic material and protein synthesis while, Ca, Mg, K, and P have their own specified roles in various metabolic, growth, pathogen defense, and virulence (Gothwal *et al*., 2012). In TAWs, a significant quantity of these nutrient elements present. Higher amounts of macronutrients in discharged wastewaters may contribute essentially to fungal growth.

Other problems: Besides having the above utilizable contents, TAWs often come with numerous ion toxicity, heavy metals, microbial contamination, pesticide residues, and radioactive elements (Australia Standards, 2012). The fecal coliforms, fungi, bacteria, viruses, nematodes, protozoans are also the foremost part of discharged wastewaters.

Integration of treated agro-based wastewaters (TAWs) with mushroom cultivation

The integration of TAW with mushroom cultivation has given promising results. Agro-based substrates are supplemented with nutrients from different TAWs for enhanced mushroom productivity (Phan *et al*., 2012; Hanafi *et al*., 2018). However, there are only a few studies related to this, therefore, there is a strong need to explore the potential of certain TAWs in enhancing the nutrient values of mushroom substrates. The TAWs can be utilized as substrate moistening agents as an alternative to regular water supply (Figure 2 and Table 2). However, the substratum formulated by this method must be thoroughly sterilized before inoculated with mushroom spawn (BARC, 2018). Previously, certain experiments have been conducted to assess the effect of TAWs on mushroom productivity. Out of them, Wang *et al*. (2001) enhanced the efficiency of wheat straw by supplementing spent beer effluent for the cultivation of *Pleurotus ostreatus* mushroom. Olive mill wastewater was useful for the enrichment of wheat straw used to grow different *Pleurotus sp*. Kalmis and Sargin (2004). Distillery effluent was helpful for supplementation of wheat straw and bagasse used to grown three *Pleurotus* strains

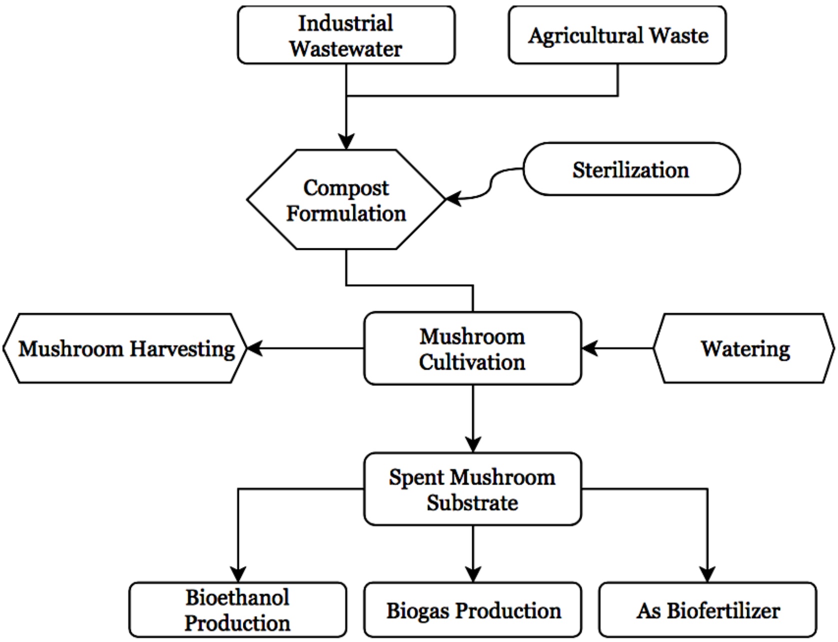

Figure 2. Integrating agro-based industrial wastewater with mushroom cultivation.

Table 2. Industrial wastewaters (effluents) used for the cultivation of mushrooms.

Effluent/wastewater	Substrate	Mushroom species	Reference
Spent beer effluent	Wheat straw	*Pleurotus ostreatus*	Wang *et al*. (2001)
Olive mill wastewater	Wheat straw	*Pleurotus sp*.	Kalmis and Sargin (2004)
Distillery effluent	Wheat straw and bagasse	*Pleurotus florida* Eger (EM 1303), *Pleurotus pulmonarius* (Fries) Quelet (EM 1302) and *Pleurotus sajor-caju* (Fries) Singer (EM 1304)	Pant *et al.* (2006)
Maize wastewater	Wheat straw	*Pleurotus ostreatus* and *Pleurotus floridae*	Loss *et al*. (2009)
Agro-food industry wastes	Wheat straw, cotton waste, and peanut shelf	*Pleurotus sp*., *Lentinula edodes*	Philippoussis and Diamantopoulou (2010)
Olive mill waste	Wheat straw	Seven *Pleurotus* strains	Ruiz-Rodriguez *et al*. (2010)
Distillery wastewater	Sugar cane bagasse	*Pleurotus flabellatus* and *Pleurotus sajor-caju*	Gothwal *et al*. (2012)
Dairy wastewater	Sugar cane bagasse	*Pleurotus flabellatus* and *Pleurotus sajor-caju*	Gothwal *et al*. (2012)
Fruit packaging industry effluent	Wheat straw	*Pleurotus ostreatus*	Karas *et al*. (2016)

Pant *et al*. (2006). Besides this, maize processing wastewater, agro-food industry wastes, olive mill waste, distillery wastewater, dairy wastewater and fruit packaging industry effluent have been successfully tested for the cultivation of certain edible mushroom species (Loss *et al*., 2009; Philippoussis and Diamantopoulou, 2010; Ruiz-Rodriguez *et al*., 2010; Gothwal *et al*., 2012; Karas *et al*., 2016).

Assets in sustainable development

Besides the benefits of utilizing TAWs in mushroom cultivation, there are a few problems associated with integrating it. There might be the presence of certain heavy metals, toxins, pesticides, persisting aromatic hydrocarbons, etc. Therefore, prior testing and confirmation of their presence are recommended (EPA, 1993). However, the acceptable limits. Table 3 provides Australian Standards recommended by EPA for finished substrate/compost products (Australia Standards, 2012). However, not all kinds of TAWs may contain all these toxic substances in higher amounts, a better example is dairy, bakery and palm oil wastewater, they comprise most of the non-toxic constituents. The EPA recommends that the following Australian Standards be adopted in setting environmental goals and quality parameters for compost products:

- AS 4454–2012 for compost, soil conditioners, and mulches
- AS4419–2003 for foils for landscaping and garden use
- AS 3743–2003 for potting mixes
- AS/NZS 5024 (INT)–2005 for potting mixes, composts, and other matrices: examination for legionellae.

Table 3. Australian Standards recommended by EPA for finished substrate/compost products (Sources: Australian Standards, 2012; EPA, 2019).

Chemical contaminant	Maximum permissible limit
Aldrin	0.02 mg/Kg
dieldrin	0.02 mg/Kg
Arsenic	20.00 mg/Kg
Cadmium	1.00 mg/Kg
Chromium	100.00 mg/Kg
Copper	150.00 mg/Kg
Lead	150.00 mg/Kg
Mercury	1.00 mg/Kg
Nickel	60.00 mg/Kg
Zinc	300.00 mg/Kg
Glass, metal and rigid plastics	0.50 % dry matter (w/w)
Plastics–light and flexible or film	0.05 % dry matter (w/w)

Further utilization of spent mushroom substrates

SMS, which has less lignin due to the digestion process by extra-cellular lignocellulosic enzymes during mushroom production, is merit for biofuel production. The lower lignin content but high nitrogen and ash content make the SMS more easily digested by microbial degraders to yield more reducing sugars. Indeed, the resulting polysaccharides act as a suitable substrate for hydrolysis, since the production of SMS itself has served as a form of pre-treatment. Table 4 provides previously published reports on the utilization of SMS for various purposes. These include biogas production, animal feed for mature castrated male sheep, post-weaning calves feeding, biodiesel production, bioethanol production, reducing sugar production, biofertilizer production, methane production, butanol production, etc. (Kumar *et al.*, 2020).

Conclusion

Mushroom production represents a source of extra income for farmers and can be grown on a diverse range of lignocellulosic wastes including agricultural residues and agro-based industrial wastes. The spent mushroom substrates have great potential for bioenergy production. The left-over material after cultivation can be used for the generation of biogas, biodiesel, and bioethanol, etc. Non-residual and non-fractional materials may also be used as a fed-stock for composting and using as an effective biofertilizer.

Table 4. Spent mushroom substrate (SMS) used for various purposes.

Spent substrate	Purpose	Reference
Wheat straw	Biogas	Bisaria *et al.* (1990)
Wheat straw	Mature castrated male sheep feeding	Fazaeli and Masoodi (2006)
Cotton waste-based substrate	Biodiesel production	Kwak *et al.* (2009)
Hydrolysates of corncob-based substrate	Bioethanol production	Oguri *et al.* (2011)
Sawdust	Post-weaning calves feeding	Kim *et al.* (2011)
Wheat straw	Sugar production	Kapu *et al.* (2012)
What straw	Biogas production	Sonia *et al.* (2013)
Alkali treated wheat straw	Reducing sugar and biofertilizer production	Zhu *et al.* (2013)
Dairy manure and wheat straw	Modeling of methane production	Shi *et al.* (2014)
Yard trimmings and wheat straw	Biogas production	Lin *et al.* (2014)
Wheat straw	Butanol and biodiesel production	Zhu *et al.* (2016)

Acknowledgement

This research was academically supported by the Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar, India.

Conflict of interest

The corresponding author on behalf of all co-authors declares that there is no conflict of interest.

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Cite this chapter as: Kumar, V., Goala, M., Kumar, P., Singh, J. and Kumar, P. (2020). Integration of treated agro-based wastewaters (TAWs) management with mushroom cultivation . In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 63-75, https://doi.org/10.26832/aesa-2020-edcrs-05

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-06

CHAPTER
[6]

Alkalotolerant consortium as a potential degrader of dioxin-like compounds of pulp and paper mill wastewater

Shweta Sahni

Department of Microbiology, School of Basic and Applied Sciences,
Shri Guru Ram Rai University, Dehradun-248001, Uttarakhand, India

ABSTRACT

Nowadays, the industrialized world is confronted with the contamination of soils, water sources, and air with hazardous and toxic xenobiotics. Polycyclic aromatic hydrocarbons (PAHs) are toxic pollutants that have accumulated in the environment due to a variety of anthropogenic activities . In this study, an alkalotolerant bacterial consortium was developed by continuous enrichment in the chemostat in presence of dibenzofuran (DBF) as sole carbon source. Six different types of bacterial isolates were isolated on agar plates. Among the six isolates tested for degradation of DBF, strain C of alkalotolerant bacterial community had better potency to degrade dibenzofuran. Alkalotolerant bacterial consortia introduced in soil microcosm for evaluation of survival of most suitable isolates and degradation of dioxin-like compound indicated more than 90% degradation of dibenzofuran after 45 days by the bacterial consortia enriched for 180 days in the chemostat at pH 10, however, microbial community, not enriched in the chemostat, was not competent to utilize even 50% DBF after day 30. This suggests that the microbial community adapted for a longer time in chemostat had better efficiency for the degradation of DBF. Degradation of dibenzofuran in soil microcosm indicates that the community is competent enough to survive and retain its degrading potency even *in*-situ conditions.

KEYWORDS Alkalotolerant, Dibenzofuran, Consortia, Degradation, Microcosm

✉ Shweta Sahni, Email: drshwetasahni@gmail.com

Introduction

Pollution of the environment has been one of the largest concerns for science and the general public in the last years. Nowadays, the industrialized world is confronted with the contamination of soils, water sources, and air with hazardous and toxic xenobiotics. Polycyclic aromatic hydrocarbons (PAHs) are toxic pollutants that have accumulated in the environment due to a variety of anthropogenic activities (Barkovskii and Adriaens, 1996). Bioremediation using various microorganisms is one of the approaches tested for the removal of PAHs from the environment. Bioremediation is a process by which living organisms degrade or transform hazardous organic contaminants to less toxic compounds (Arun *et al*., 2008). Halogenated dibenzo-p-dioxin and dibenzofuran are the most toxic group of persistent organic pollutants (POPs) having carcinogenic, immunosuppressive, endocrine disruptive and teratogenic properties (Adriaens *et al*., 1996; Mandal, 2005). Dioxins are an unintentional by-product of various industrial activities. Pulp and paper industry is one of the major sources for dioxin contamination (Thacker *et al*., 2007). Very few microbial strains have the capability to metabolize dioxin-like compounds due to its planar structure, acute hydrophobicity, less bioavailability (Nojiri and Omori, 2002). Many bacterial strains, Pseudomonas sp. strain HH69 (Fortnagel *et al*., 1990); *Brevibacterium* sp. strain DPO 1361 (Strubel *et al*., 1989; Strubel *et al*., 1991), Sphingomonas sp. strain RW1 (Wittich *et al*., 1992), *Pseudomonas aeruginosa* and *Xanthomonas maltophilia* (Ishiguro *et al*., 2000), Terrabacter sp. strain YK3 (Iida *et al*., 2002), *Serratia marcescens* (Jaiswal and Thakur, 2007) and *Pseudomonas* sp. strain ISTDF1 (Jaiswal *et al*., 2011) have been isolated and catabolic potential for degradation of dibenzofuran has been evaluated. But very few reports are available for in-situ bioremediation of dioxin-like compounds in the environment (Haack *et al*., 1995; Kumar *et al*., 2019).

The highly alkaline nature of industrial effluent necessitates the search for bacteria that can survive and degrade dioxin in such extreme conditions. Because of the relatively low cost and minimal impact on the environment, dioxin degrading bacteria have been isolated by using dibenzofuran (DF) as a model substrate in enrichment culture (Fortnagel *et al*., 1996). The indigenous community is the actual player which persistently exists in such a hostile environment. Gradual adaptation of native bacteria under increasing alkaline conditions could be useful for efficient in-situ bioremediation of dioxin including other persistent organic pollutants (POPs) (Kao *et al*., 2001). The bioremediation of dioxin-like compounds under alkaline conditions is of interest because the alkalinity of effluent will change gradually after release in the environment which is a very critical factor for biodegradation. In addition, they have higher sorption capability in soil, and toxicity decreases as pH increases, owing to the increased conversion of undissociated (more toxic) to the dissociated form (Kishino and Bayashi, 1995). In general, populations of bacteria decline the following introduction into natural soil and the growth of introduced populations is poor in microbiologically undisturbed soil. For successful bioaugmentation, there is the need to identify, and properly manage, the environmental conditions controlling the survival and activity of introduced micro-organisms. Microcosms are used to study biodegradation and the fate and effect of introduced micro-organisms (Wagner-Do¨bler *et al*., 1992). This can lead to a better understanding of the effect of factors controlling soil microbial inoculation, especially with regard to indigenous micro-organisms and to study the capability of inoculated micro-organisms to degrade certain chemicals.

Study area

Sludge effluent and sediment samples were collected from Century pulp and paper mill, Lalkua, Nainital, Uttaranchal, India (29°24' N, 79°28' E). The site was effluent discharging canals and premises of the industry. The sludge with liquid effluent was collected in clean plastic bags and stored at 4°C in a refrigerator until used for further analysis.

Characterization of effluent

The effluent was characterized for various physical and chemical parameters like pH, temperature, TDS, TSS, color, DO, BOD, COD and lignin content. pH was measured with the help of pH meter (Cyberscan 51), temperature by using portable digital multi-stem thermometer (Hanna Instrument Co. Italy) with external sensing probe on the sampling sites, TDS and TSS were estimated as described in APHA (2005), color by 2120 C Cobalt-platinate method (APHA, 2005), DO (Wrinkler's method), COD (5220 B open reflux method) and BOD were estimated as per APHA (2005). Lignin content was estimated according to Pearl and Benson (1940). Dibenzofuran was detected by GC-MS as described later.

Chemostat: enrichment of bacterial consortium

The reactor vessel consists of a 22×7 cm glass vessel, effective volume 1 litre, provided with an inlet for the entry of fresh sterile medium and an outlet for the removal of spent medium. Another inlet was provided specifically for the alkaline solution which maintained the pH of culture from 7 to 10. Sterile air was passed into the culture vessel by way of using aeration pump and sinister glass filter. The culture vessel was kept over a magnetic stirrer which was capable of maintaining the temperature at 28°C to 30°C. The composition of mineral salt medium (g/l) was: Na_2HPO_4, $2H_2O$. 7.8; KH_2PO_4, 6.8; $MgSO_4$, 0.2, ammonium ferric acetate, 0.01; $Ca(NO_3)_2$, $4H_2O$, 0.05; $NaNO_3$, 0.085, trace element solution with 4-chlorosalicyclic acid (CSA) (5Mm) / dibenzofuran (1Mm) as described (Thakur, 1995). The sediment and sludge containing bacterial cell populations served as inoculum in the chemostat. Initially, the bacteria were adapted in the presence of 4-CSA. After stabilization of the bacterial growth as determined by O.D. at 595 nm, the CSA in the medium was replaced by DBF (dibenzofuran). The pH of the chemostat was gradually increased from pH 7 to pH 10. The culture medium was collected from chemostat at pH 7, 8, 9, and 10 after stabilization of the bacterial growth determined by O.D. at 595 nm. Four samples thus collected were centrifuged at 7000 rpm for 10 min. The bacterial pellet thus obtained was used for the determination of DBF utilization.

Monitoring of substrate depletion by gas chromatography

Utilization of dibenzofuran was tested in Erlenmeyer flasks containing mineral salt medium supplemented with 1mM dibenzofuran (DBF crystals dissolved in dimethylsulfoxide, 100 mg/L) as the sole source of carbon and energy, and incubated at 30^{O}C on an orbital shaker at 150 rpm. The samples were removed after 0, 6, 12, 24, 48, 120h growth of bacterial strains and the utilization of carbon source was determined. Bacterial cells were removed by centrifugation at 7000 rpm for 10 min. DBF concentration was determined by gas chromatography (GC). The culture medium (25 ml) was dissolved in DMSO and then extracted with double volume ethyl acetate (Jaiswal and Thakur, 2007). The organic phase (extract) was separated by a separating funnel, and the extract was finally concentrated on a rotary evaporator. Ethyl acetate was evaporated and the residue was re-dissolved in 100 µl ethyl acetate. The concentration of DBF was identified by using gas chromatography (GC) (GCPerkin Elmer) equipped with a capillary column (DB5 MS; 30 m · 0.25 mm film thickness · 0.25 mm I.D. · 30 m long). One µl of each extract was analyzed by GC at condition (splitless mode; initial temperature 80°C for 1.5 min; temperature increased 80–230°C at a rate of 20°C min^{-1} and 230 to 250°C and kept it at 250 °C for 4.5 min).

Isolation of bacteria from chemostat sample at pH 10

The enriched bacterial community from chemostat at pH 10 was diluted in tenfold serial dilution and spread on LB-agar plates. After 14 hrs incubation, colonies that appeared on Luria Bertani agar plates were characterized by morphological observation. Six dominant and morphologically distinct colonies were isolated.

Survival pattern of each strain

Morphologically distinct colonies were isolated and inoculated in MSM (Minimal Salt Medium) having dibenzofuran (1mM) dissolved in DMSO. Survival pattern of each colony was drawn on the basis of absorbance at 595nm on spectrophotometer Cary, 100 Bio (Varian Co., Australia) as described by Fortnagel *et al*. (1990). DBF utilization by each strain was determined by gas chromatography (Jaiswal and Thakur, 2007).

Bacterial growth and culture conditions

After adaptation in a chemostat, the bacterial consortium obtained at pH 10 was inoculated in

Luria Bertani medium at 5% (v/v). The culture was incubated till 1.0 optical density (OD) at 595 nm and then centrifuged at 6000 rotation per minute (rpm) for 6 minutes at 4°C. The bacterial pellet, thus obtained, was transferred to the minimal salt medium with dibenzofuran (1mM) at pH 10 for agitation in the orbital shaker. After 6, 12, 18, 24, 30 and 36 hours, samples were collected and OD was measured at 595 nm. MSM samples were centrifuged at 6000 rpm for 6 minutes. Its supernatant was taken for biodegradation studies.

Utilization of dibenzofuran

Culture supernatant was extracted with double volume ethyl acetate and split it into two equal volumes. One was acidified with 6N HCl to approximately pH 2.0 and other at pH 7 (Jaiswal and Thakur, 2007). The organic phase (extract) was separated by a separating funnel, and the extract was finally concentrated on a rotary evaporator. Ethyl acetate was evaporated and the residue was re-dissolved in 100 µl acetonitrile. The concentration of DBF was identified by using gas chromatography (GC) (GC-Perkin Elmer) equipped with a capillary column (DB5; 0.25 mM film thickness · 0.25 mm Internal diameter. 30 meters long). One µl of each extract was analyzed by GC at condition (splitless mode; initial temperature 80°C for 1.5 min; temperature increased 80–230°C at a rate of 20°C min^{-1} and 230 to 250°C and kept it at 250 °C for 4.5 min). Concentration was derived from the standard plot between peak area and concentration of DBF.

Microcosm soil analysis

The soil moisture content, water holding capacity (WHC), and pH were determined as described previously by Vinas *et al*. (2005). To determine the best soil water content for use in the microcosm experiments, five different water contents (5%, 20%, 40%, 60%, and 75% WHC) and autoclaved soil as an abiotic control were assayed for 15 days in triplicate in miniaturized microcosms. The best results were observed with 60% WHC (70% biodegradation of DBF). Thus, water content was established as a key factor for biodegradation activity, and 60% WHC was defined as the optimal water content for soil microcosm experiments.

Microcosm design

Microcosms were prepared according to Gautam *et al*. (2003) and modified as follows: soil grits (100 gm) were placed on the bottom of a sealed plastic jar, then sand (100 gm) formed the middle layer and soil (300 gm) formed the top later. Experiments were performed using sterile soil and non-sterile soil. Eight sets of microcosms were prepared as described in Table 1. The soil was treated as described by Megharaj *et al.* (1997). Four sets of soil microcosms were sterilized by autoclaving at 121 °C for 45 min on three consecutive days. Sterility was checked afterward by streaking dilutions of soil suspensions on LB agar plates. Sterile soil and non-sterile soil were then treated with either DBF at a final concentration of 1 mg/g soil from 50-mg/ml stock solutions

Table 1. Microcosms inoculated with the bacterial community which is non-adapted or adapted at different pH levels.

Label	Description
A	Control with Unautoclaved soil
B	Control with Autoclaved soil
C	Unadapted Bacterial Community + Unautoclaved soil
D	Unadapted Bacterial Community + Autoclaved soil
E	Bacterial Community Adapted at pH 7.0 + Unautoclaved soil
F	Bacterial Community Adapted at pH 7.0 + Autoclaved soil
G	Bacterial Community Adapted at pH 10.0 + Unautoclaved soil
H	Bacterial Community Adapted at pH 10.0 + Autoclaved soil

made in analytical grade acetone. The acetone solvent was evaporated and soils were rigorously mixed and allowed to equilibrate at 25°C for 6 h. Controls were similarly treated with acetone. Microcosms containing non-sterile soil were pre-incubated at 30°C, prior to the experiment, to allow the indigenous microorganisms to reach an equilibrium state, avoiding a thermal artifact at time zero of the experiment (Lafuente *et al*., 1996). Bacteria were grown with shaking at 30°C in Luria-Bertani (LB) broth to the late exponential phase. Cells were harvested by centrifugation, resuspended in mineral salt medium and then inoculated in the soil at a level of 10^7-10^8 cells/g dry soil, partly following recommendations of Comeau *et al*. (1993). Sterile distilled water was added to the soil to reach a final moisture content of 60% (v/wt), rigorously mixed and kept at 30 °C.

Sampling

Chemical, microbial, and molecular analyses were carried out on sampling days 0, 03, 07, 15, 30, 45, and 90. At each sampling time, 25 g of soil was extracted as a composite sample from five points in each microcosm and stored at -20°C prior to most analyses; the only exception was microbial counting, which was performed immediately after sampling.

Monitoring the depletion of dibenzofuran in soil microcosm

The extraction of metabolites was performed by a modified method described by Jaiswal and Thakur (2007). 25 ml of acetonitrile with 2% H_3PO_4 was added to 10gm of soil and agitated for 60 min. The particles were settled down, and the supernatant was passed through a polytetrafluoro-ethylene membrane filter (0.2 µm). One µl of each extract was analyzed by Gas chromatography-mass spectroscopy (GC-MS) (Varian) equipped with a capillary column (DB5 MS; 30m × 0.25um film thickness × 0.25mm I.D. × 30 meter long) at splitless mode; initial temperature 80°C for 1.5 min; temperature increased from 80 to 230°C at a rate of 20°C /min and 230 to 250°C and kept it at 250°C for 4.5 min. The head pressure of the helium carrier gas was 80 kPa helium flow rate 1.1ml/min as described by Iida *et al*. (2002).

Physical and chemical properties of effluent

The effluent collected from pulp and paper industry, Lalkuan, Uttarakhand showed the following physical and chemical characteristics. It was dark in color with high COD, BOD and DO and was alkaline in nature. The effluent was found to be contaminated with dibenzofuran (2 ppm) (Table 2). Each value represents the mean of three replicates ± SEM.

Utilization of dibenzofuran by the bacterial community at different pH

The effluent from the industry was used as inoculum in chemostat containing MSM with CSA, followed by MSM with DBF where the bacterial community was adapted for a pH range from 7 to 10. Samples collected at each pH were inoculated in MSM with DBF and monitored for the depletion of DBF. Gas Chromatogram of samples collected from MSM at different time intervals revealed adaptation has enhanced the degradation ability of the indigenous bacteria. Adapted culture degraded more dibenzofuran than non-adapted culture. While non-adapted culture degraded only 35% DBF in 264 hrs, culture adapted at pH 7 degraded 45%, pH 8 degraded 50%, and pH 9 degraded 70%. The culture at pH 10 showed maximum degradation potential, which is more than 90% in 264 hrs (Figure 1).

Isolation of bacteria from pH 10 sample

The sample collected of pH 10 culture was used as inoculum to spread on LB plates. Six colonies were selected on the basis of morphological differences. The colonies were labeled as Strain A,

Table 2. Physico-chemical characterization of effluent used in this study.

Parameter	Value
pH	10.4 ± 0.2
Temperature	30.5 ± 01°C
TDS (mg l^{-1})	1243 ± 11.3
TSS (mg l^{-1})	285.9 ± 1.9
Color of effluent (coloring units)	62385 ± 70.23
DO (in ppm)	0.0 ± 0.0
BOD (in ppm)	53216 ± 13
COD (in ppm)	204358 ± 81.20
Lignin (in ppm)	153741 ± 91.20
Dibenzofuran (in ppm)	2.00 ± 0.32

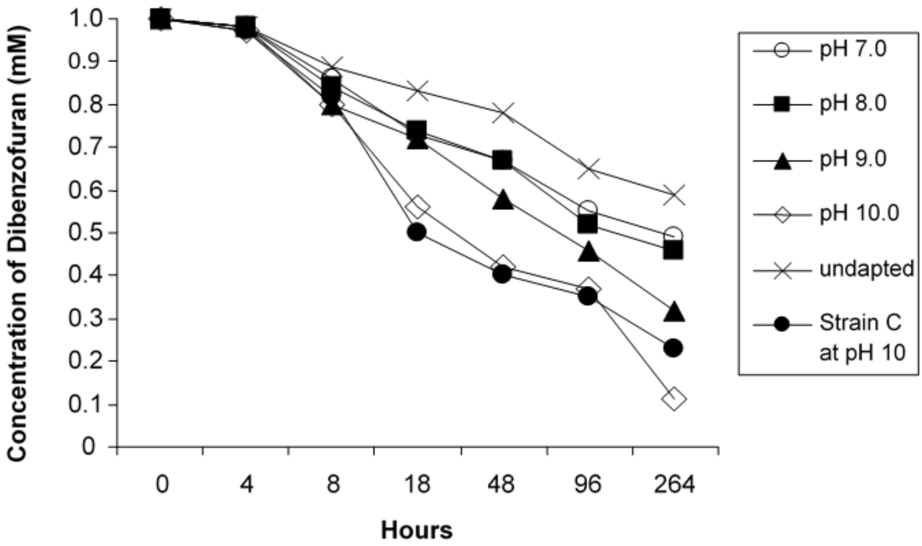

Figure 1. Comparison of utilization of dibenzofuran by total bacterial community enriched at gradually increasing pH

Strain B, Strain C, Strain D, Strain E, Strain F.

Utilization of dibenzofuran

The utilization of dibenzofuran by all six strains was then analyzed. Each strain was inoculated in MSM containing DBF and samples were collected at different time intervals and the concentration of DBF was calculated by peak formed during GC. The concentration of DBF was plotted against the time interval as shown in Figure 2. The survival pattern of each strain was also estimated and Strain C was found to be most effective. It degraded approximately 50% DBF in 260 hrs. As shown in Figure 2, strain C gives a maximum peak of absorbance indicating maximum growth. Strains A and F were found to be least effective on DBF while strains B, D, and E gave good results.

Thus, the bacterial community obtained through chemostat was found to be capable of growing and degrading DBF at pH 10. The community consists of strains A, B, C, D, E, and F. Among which strain C was found to be most potent DBF degrader followed by B, D and E. Strains A and F were not found to be efficient DBF degrader. Still, they are present in the stable bacterial community. This indicates that they might be involved in the degradation of lower metabolites.

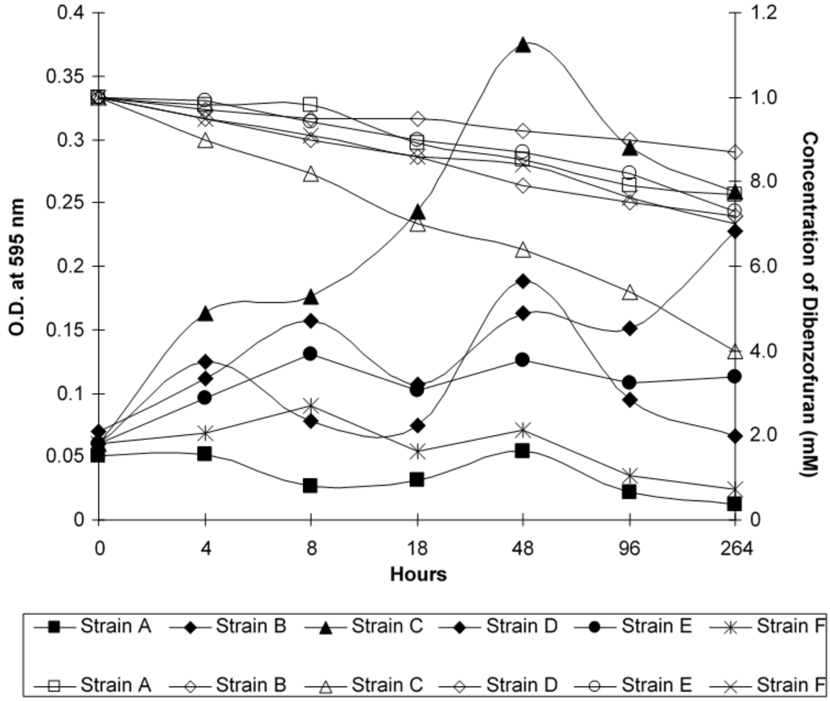

Figure 2. Growth pattern of six bacterial isolates from pulp and paper industry effluent determined at 595 nm. pH 7.0. A, B, C, D, E and F represents bacterial strains in minimum salt medium and dibenzofuran (1mM) as sole carbon source in the chemostat.

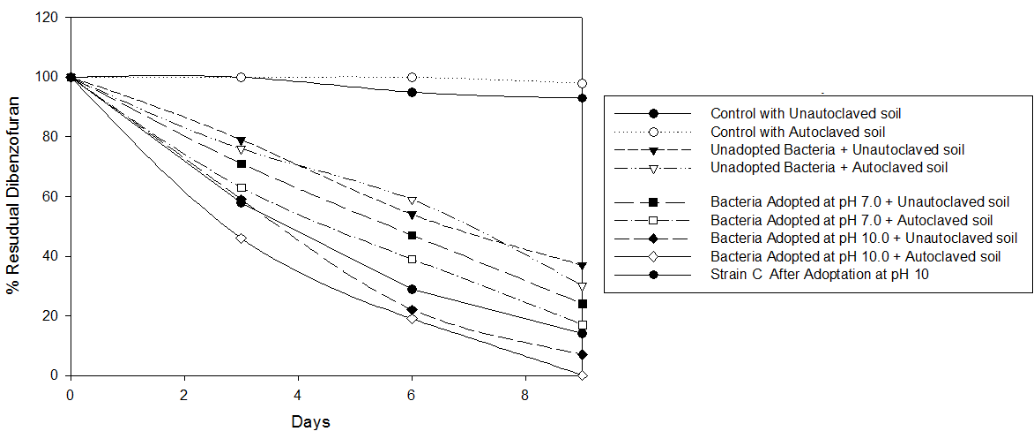

Figure 3. Degradation of dibenzofuran under different plans in microcosm along with controls.

Biodegradation of dibenzofuran in soil microcosm

The *in vivo* efficiency of the community was tested through soil microcosm. After 90 days, the amount of dibenzofuran left in the soil was tested in each microcosm. Almost, no degradation was found in the case of control with autoclaved soil (microcosm A). The concentration of DBF in the soil at 0 days was taken as 100%. Control with autoclaved soil (microcosm B) showed the presence of 70% DBF. Likewise, microcosm labelled as C, D, E, F, G, H showed 36.8%, 36.59%, 9.7%, 7.5%, 2.1% and 1.9% DBF respectively. Maximum degradation was seen in the case of microcosm inoculated with consortia adopted at pH 10 as shown in Figure 3.

Conclusion

Microbial community isolated from sludge and sediment of pulp and paper mill was enriched in a chemostat with gradually increasing pH from 7 to 10. Based on morphological dissimilarity, six strains were isolated from the chemostat at pH 7.0 with the highest diversity on LB plates. One of these strains, strain C, enriched at pH 10.0 was found to be most efficient evaluated by growth rate and dibenzofuran degrading potency. The microbial community adapted in chemostat for different time duration was inoculated in soil microcosm. 180 days adapted community showed maximum degradation which makes it sufficient time for adaptation. GC analysis reflects that within 90 days, almost all dibenzofuran were metabolized. The best degradation results were shown by 180 days of adapted strain in a chemostat. Whereas 45 days and 90 days adapted community also showed significant results but not better than 180 days adapted community in a chemostat. The unadapted community is also degrading but not significantly as compared to the aforementioned community. This suggests that the microbial community adapted for a longer time in chemostat had better efficiency for the degradation of DBF. Degradation of dibenzofuran in soil microcosm indicates that the community is competent enough to survive and retain its degrading potency even *in*- situ conditions.

Acknowledgment

We thank the Council of Scientific and Industrial Research, New Delhi, India, for providing funds in the form of research projects.

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Cite this chapter as: Sahni, S. (2020). Alkalotolerant consortium as a potential degrader of dioxin-like compounds of pulp and paper mill wastewater. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 76-87, https://doi.org/10.26832/aesa-2020-edcrs-06

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-07

CHAPTER
[7]

SWOT analysis of agro-waste based adsorbents for persistent dye pollutants removal from wastewaters

Bashir Adelodun[1,2,*], Fidelis Odedishemi Ajibade[3,4], Taofeeq Sholagberu Abdulkadir[5], Hashim Olalekan Bakare[6] and Kyung Sook Choi[1,7,*]

[1]Department of Agricultural Civil Engineering, Kyungpook National University, Daegu, Korea
[2]Department of Agricultural and Biosystems Engineering, University of Ilorin, PMB 1515, Ilorin, Nigeria
[3]Department of Civil and Environmental Engineering, Federal University of Technology, Akure, Nigeria
[4]Research Centre for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China
[5]Department of Water Resources and Environmental Engineering, University of Ilorin, PMB 1515, Ilorin, Nigeria
[6]Department of Chemical Engineering, University of Ilorin, PMB 1515, Ilorin, Nigeria
[7]Institute of Agricultural Science & Technology, Kyungpook, National University, Daegu, Korea

ABSTRACT

Dyes, especially from textile industries, are significant pollutants in water and wastewater, which have become pervasive in the environs to which they are discharged. The effluents containing different types of dyes have become ubiquitous in the environment. While several treatment techniques have been developed to address the removal of recalcitrant dyes from water and wastewater, the adsorption technique is highly preferred due to its many advantages. However, selecting the appropriate alternative adsorbents with high adsorption capacity to costly activated carbon has continued to receive great attention. This book chapter reviewed the applicability of adsorptive techniques of agro-waste based adsorbents for the removal of dye pollutants from water and wastewater. The mechanisms of persistent dye pollutant removals based on the adsorption processes were adequately described. Further, the strengths, weaknesses, opportunities and threats (SWOT) of using agro-waste materials as alternative adsorbents are also accounted.

KEYWORDS

Agro-waste adsorbent, Dye pollutants, Adsorption mechanism, SWOT analysis

Bashir Adelodun; Kyung Sook Choi, Email: adelodun.b@unilorin.edu.ng; ks.choi@knu.ac.kr

Introduction

Due to the global water resources scarcity, the reuse of wastewater has recently been considered as a sustainable alternative to address the increasingly stiff competition of the limited resource, especially for agricultural activities, in many water-scarce regions (Libutti *et al*., 2018; Mounira *et al*., 2016). Hence, the need to ensure the adequacy of the quality of the treated wastewater for irrigation purposes and sustainable aquatic ecosystems (Kumar *et al*., 2019; Adewumi and Ajibade, 2019; Baharvand and Mansouri Daneshvar, 2019). However, the increasing discharge of the generated wastewater into the environment without adequate treatment has been an utmost concern as it is related to human health and potential threats to aquatic lives (Lim and Aris, 2014). The rising population, changing consumption patterns and advances in industrialization are a few of many factors that are continually changing the diversities, patterns and quantities of wastewater generation. Moreover, the diversity of the wastewater sources have hindered the efficiency of some of the targeted treatment techniques. For instance, organic pollution generated from organic compounds originates from diverse sources, including domestic sewage, municipal wastewater, urban run-off and agricultural and industrial effluents (Adelodun *et al*., 2019; Rashed, 2013). Most of the persistent organic pollutants are products of daily anthropogenic activities that have widespread in the environment (Katsoyiannis and Samara, 2004).

Although organic pollutants can be traced to various sources, wastewaters from industrial discharges are, however, regarded as highly toxic, carcinogenic and contain persistent organic pollutants (Doruk *et al*., 2016). The industrial activities, especially textile processing is one of the high water-intensives which aided pollution of water bodies with high concentrations of dyes, total dissolved solids, chemical oxygen demand, biochemical oxygen demand, heavy metals, surfactants and many other toxic organic compounds and also contributes to the depletion of available water resources (Vergili *et al*., 2012; Tehrani-Bagha *et al*., 2010; Salleh *et al*., 2011). Among these organic pollutants, dyes are found to be the most common, recalcitrant, challenging to biodegrade and noxious pollutants (Peng *et al*., 2016; Ali *et al*., 2019).

The effluents containing different types of dyes have become ubiquitous in the environment as they can be found in the point source discharges of most of the industries, including textiles, paper and pulp, pharmaceutical, tannery, paint, food and et cetera. The dye pollutants pose undesirability in the aesthetic, obstructing sunlight into the water and degradation of the water environment where they are discharged (Nidheesh *et al*., 2018). In fact, the excessive use of dyes has been linked to the various sources from which the persistent organic pollutants are produced (Shalla *et al*., 2018).

Textile industries are the major sources of organic dyes. The dyeing operations, a significant component of textile activities, involve the use of poorly biodegradable dyes and other auxiliary organic materials, including soda ash, detergents and salts (Vergili *et al.*, 2012), which produce mutagenic and carcinogenic byproducts (Iqbal, 2016). The complexities in molecular structures of dye chemicals and the recalcitrant nature of textile effluents due to their diversity from manufacturing processes of different forms of textile products require highly efficient treatment techniques.

These treatment techniques and materials need to be affordable and be able to provide solutions to reuse the treated wastewater without any potential health‑related issues to both humans and ecosystems. For these reasons, the treatment techniques, with high efficiency without secondary waste, are limited. Nevertheless, considering the toxicity of organic dye pollutants to our environment, both human and aquatic, it has, therefore, become increasingly important to intensify efforts towards the treatment of effluent containing dyes before their discharge into water bodies. Moreover, the reuse of adequately treated wastewater from textile industries can address the scarcity of water resources in the regions on concerns.

There has been rapid development in the treatment of wastewater containing dye pollutants in recent times. Consequently, several treatment techniques have been developed for their removal from water and wastewater. These include coagulation, biological treatment, chemical oxidation, electrochemical and membrane processes, aerobic microbial degradation and adsorption (Salleh *et al.*, 2011). While some of the methods are touted to be relatively effective, they are however expensive, high energy demand, incapable of removing different variety of dyes effectively and are found to produce byproducts which require further treatment (De Andrade *et al.*, 2018; Mezohegyi *et al.*, 2012; Pokhrel and Viraraghavan, 2004).

Moreover, some of these treatment techniques have limited applications in many parts of developing counties where indiscriminate point source discharges of persistent organic pollutants from industries, including dyes, persist (UNESCO, 2017). However, adsorption method is generally found to be effective for the removal of recalcitrant organic pollutants, including different forms of dyes, due to its simple operating design and conditions, no sort of unwelcoming secondary wastes and low cost of operations especially when non-conventional alternative adsorbents are used (Siddiqui *et al.*, 2019; Chang *et al.*, 2017).

The quality of the treated dye effluents largely depends on the type of adsorbents used and well-designed sorption processes, among many other factors (Salleh *et al.*, 2011). The major problem lies in selecting the appropriate adsorbents with an applicable adsorptive technique for the removal of dye pollutants from water and wastewater (Gupta and Suhas, 2009). This study, therefore, aimed to review the selected agro-waste based adsorbents used for the treatment or remediation of selected persistent organic dyes with their corresponding adsorptive techniques. In this study, we described and comprehensively compared some conventional adsorbents based on the strength of the adsorptive technique, used to remediate the wastewater pollution containing dye pollutants using the SWOT analysis.

Adsorption mechanisms for dyes removal from wastewater

Adsorption refers to the accumulation of pollutants, including dyes in the wastewater at the surface of the adsorbents. The physical and chemical interactions of adsorption processes occur at the interface of the two media i.e., adsorbent and wastewater. The pollutant molecules that are retained on the surface during the adsorption process are referred to as adsorbates while the materials upon which they are retained are called adsorbents. The bonding of adsorbates on the adsorbent surface is characterized by either Van der Waals, electrostatics and /or hydrogen bonds due to the presence of both carbonyl and hydroxyl groups on the adsorbents (Wakkel *et al.,* 2019).
Several factors aid the adsorption performance of any selected adsorbent in removing pollutants from wastewater. Aside the absorbent properties including high carbon or oxygen contents required of a suitable absorbent, other characteristics include large surface area with porous structure, high abrasion resistance and thermal stability and other operating conditions such as adsorbent dose, contact time, pH of the wastewater containing the dye pollutants and initial dye concentration (Ali *et al.,* 2012; Chandane and Singh, 2016; Aljeboree *et al*., 2017).

Adsorption kinetics

The adsorption kinetics is a process used to investigate the adsorption mechanism. The adsorption rate using the kinetic study evaluates the best material choice of the adsorbent. The process explores the important kinetic parameters responsible for the sorption rate of the dye pollutants by the adsorbent. Further, the efficiency of the adsorption process can be assessed while also enable its applicability to industrial use and commercial applications. The kinetic models that are mostly used to describe adsorption mechanism for the dye pollutants removal are pseudo-first-order for simple adsorption kinetic analysis (Lagergren, 1898), pseudo‐second-order based on adsorption equilibrium capacity (Ho and McKay, 1999), Elovich for chemisorption processes and also applicable to systems with heterogeneous adsorption surface (Low, 1960) and intra-particle diffusion for the identification of diffusion mechanism (Weber, 1963), using Eqs. (1) to (5).

$$q_t = q_e[1 - exp(-k_1 t)] \quad (1)$$

$$q_t = \frac{k_s q_e^2 t}{1 + k_s q_e t} \quad (2)$$

$$h_0 = k_s q_e^2 \quad (3)$$

$$q_t = \left(\frac{1}{\beta}\right) ln(\propto.\beta) + \left(\frac{1}{\beta}\right) ln(t) \tag{4}$$

$$q_t = k_{id}\sqrt{t} + 1 \tag{5}$$

where q_t (mg g^{-1}) is the amount of dye pollutants adsorbed at time t; q_e (mg g^{-1}) is the adsorption capacity of the dye pollutants at equilibrium; k_1 (min^{-1}), k_s (g gm^{-1}) and k_{id} (mg g^{-1} min$^{-1/2}$) are the adsorption rate constants for pseudo-first-order, pseudo-second-order and intra-particle diffusion models, respectively; t (min) is the contact time; h_0 (mg g^{-1} min^{-1}) is the initial sorption rate which can be obtained when approaches zero value.

Adsorption isotherms

The adsorption capacity can be enhanced using different forms of activation methods, which involve either physical activation such as carbonization of material or chemical activation using chemical activating agents (Adegoke and Bello, 2015). The effectiveness of the adsorption mechanisms in terms of relative adsorption capacity and equilibrium concentration of adsorbent through its interactions with adsorbate can be described using adsorption isotherms. The dye pollutant distribution between the two inter-surface media can be described using adsorption isotherm at a particular temperature when the equilibrium is reached (Aljeboree *et al.*, 2017). The commonly used adsorption isotherms are:

Freundlich isotherm is an empirical model that describes the multilayer adsorption based on the assumption of energy distribution on the adsorption surface (Freundlich and Heller, 1939). The adsorption rate varies with the strength of energy on the adsorption surface. The Freundlich isotherm model is expressed by the Eq. (6).

$$q_e = K_f \,.C_e^{1/n} \tag{6}$$

where q_e (mg g^{-1}) is the unit adsorption capacity; C_e (mg/L) is the dye concentration at equilibrium; K_f and n [mg g^{-1} (L mg^{-1})^n] are Freundlich constants.

Langmuir isotherm model is based on the monolayer adsorption on the homogeneous surface with weak intermolecular forces (Langmuir, 1918). It is assumed that the adsorption rate decreases with increasing dye molecules on the adsorption surface (Aljeboree *et al.*, 2017). The Langmuir isotherm model is represented using Eq. (7).

$$q_e = \frac{q_{max}\, K_L\, C_e}{1 + K_L\, C_e} \tag{7}$$

where q_{max} is maximum dye pollutants adsorbed; K_L (L mg^{-1}) is the Langmuir constant for adsorption energy and binding affinity of the adsorption surface.

Tempkin isotherm model describes the interaction effects of both adsorbent and adsorbate based on the assumption that the strength of energy on the adsorption surface decreases with coverage (Tempkin and Pyzhev, 1940). The Tempkin isotherm model is expressed using Eq. (8).

$$q_e = \frac{RT}{b} \log(K_T C_e) \tag{8}$$

where b (kJ mol^{-1}) and K_T (L mg^{-1}) are the Temkin constants for adsorption energy and maximum binding energy, respectively. The detailed wide-ranging of isotherm models that have been extensively employed over the years is presented in Table 1.

Agricultural waste-based adsorbents for removal of dye pollutants

There have been several developed adsorbent materials for the removal of dyes from water and wastewater, with activated carbon regarded as the best of all and highly preferred (Martins and Nunes, 2015). However, the high cost of procurement, sludge production and regeneration problem have been the most significant constraints in the use of activated carbon as pollutant removal, including dyes. Moreover, Walker *et al.* (2003) reported the ineffectiveness of the activated carbon in the removal of both disperse and vat classes of dyes. The locally-sourced agricultural waste materials with high pollutant binding capacities have, however, been suggested and explored as alternative low-cost adsorbents (Salleh *et al.,* 2011; Adegoke and Bello, 2015).

Agricultural wastes are discarded in large quantities and these include rice husk, maize cob, peanut husk, soybean hull, eggshell, sesame hull, potato peels, citrus peels and many more. The agro-waste can be classified into plant-based and animal-based, depending on the origin of the waste materials. Living organisms such as algal and microbial biomass were also reported to have been used as pollutant adsorbents in water treatment (Siddiqui *et al.,* 2019). The agro-waste based adsorbents are used either in their raw forms or as composites for the removal of different classes of dyes. The presence of functional carboxyl, carbonyl and hydroxyl groups present at the surface of the agricultural wastes make them suitable adsorbent candidates for dye removal, most notably the cationic dyes (Salleh *et al.*, 2011; Wakkel *et al.,* 2019).

The removal of various types of dyes using some selected agro-waste based adsorbents with their adsorption capacities is presented in Table 2. The adsorption capacities were observed to vary significantly among the different adsorbents used in removing different dye pollutants, while adsorption mechanisms for which the maximum adsorption capacities occurred were mostly based on Pseudo-second order for adsorption kinetic and Freundlich and Langmuir for adsorption isotherms.

Table 1. List of linearized and non-linearized equations for adsorption isotherms models (Foo and Hameed, 2010)

Isotherm models	Linear form	Non-linear form	Plot	Reference
Langmuir	$\frac{C_e}{q_e} = \frac{1}{bQ_o} + \frac{C_e}{q_o}$	$q_e = \frac{Q_o b C_e}{1 + bC_e}$	$\frac{C_e}{q_e}$ VS C_e	Langmuir (1916)
	$\frac{1}{q_e} = \frac{1}{Q_o} + \frac{1}{bQ_o C_e}$		$\frac{1}{q_e}$ VS $\frac{1}{C_e}$	
	$q_e = Q_o - \frac{q_e}{bC_e}$		q_e VS $\frac{q_e}{bC_e}$	
	$\frac{q_e}{C_e} = bQ_o - bq_e$		$\frac{q_e}{C_e}$ VS q_e	
Freundlich	$log\ q_e = log K_F + \frac{1}{n} log C_e$	$q_e = K_F C_e{}^{1/n}$	$log\ q_e$ VS $log C_e$	Freundlich (1906)
Dubinin-Radushkevich	$\ln(q_e) = \ln(q_s) - k_{ad}\varepsilon^2$	$q_e = (q_s) exp(-k_{ad}\varepsilon^2)$	$\ln(q_e)$ VS ε^2	Dubinin and Radushkevich (1947)
Tempkin	$q_e = \frac{RT}{b_T} + \left(\frac{RT}{b_T}\right) \ln C_e$	$q_e = \frac{RT}{b_T} \ln A_T C_e$	q_e VS $\ln C_e$	Tempkin and Pyzhev (1940)
Flory-Huggins	$\log\left(\frac{\theta}{C_o}\right) = \log(K_{FH}) + n_{FH} \log(1-\theta)$	$\frac{\theta}{C_o} = K_{FH}(1-\theta)^{n_{FH}}$	$\log\left(\frac{\theta}{C_o}\right)$ VS $\log(1-\theta)$	Horsfall and Spiff (2005)
Hill	$\log\left(\frac{q_e}{qs_H - q_e}\right) = n_H \log(C_e) - \log(K_D)$	$q_e = \frac{qs_H C_e^n H}{K_D + C_e^n H}$	$log\left(\frac{q_e}{qs_H - q_e}\right)$ VS $\log(C_e)$	Hill (1910)

Table 1. Continued...

Redlich-Peterson	$\ln\left(K_R\frac{C_e}{q_e}-1\right)=g\ln(C_e)+\ln(a_g)$	$q_e=\frac{K_R C_e}{1+a_R C_e^g}$	$\ln\left(K_R\frac{C_e}{q_e}-1\right)$ VS $\ln(C_e)$	Redlich and Peterson (1959)
Sips	$\beta_S\ln(C_e)=-\ln\left(\frac{K_S}{q_e}\right)+\ln(a_S)$	$q_e=\frac{K_S C_e^{\beta_S}}{1+a_S C_e^{\beta_S}}$	$\ln\left(\frac{K_S}{q_e}\right)$ VS $\ln(C_e)$	Sips (1948)
Toth	$\ln\left(\frac{q_e}{K_T}\right)=\ln(C_e)-\frac{1}{t}\ln(a_T+C_e)$	$q_e=\frac{K_T C_e}{(a_T+C_e)^{1/t}}$	$\ln\left(\frac{q_e}{K_T}\right)$ VS $\ln(C_e)$	Toth (1971)
Koble-Corrigan	$\frac{1}{q_e}=\frac{1}{AC_e^n}+\frac{B}{A}$	$q_e=\frac{AC_e^n}{1+BC_e^n}$	-	Koble and Corrigan (1952)
Khan	-	$q_e=\frac{q_S b_K C_e}{(1+b_K C_e)^{a_K}}$	-	Khan *et al.* (1997)
Radke-Prausnitz	-	$q_e=\frac{a_{RP} r_R C_e^{\beta_R}}{a_{RP}+r_R C_e^{\beta_R-1}}$	-	Vijayaraghavan *et al.* (2006)
BET	$\frac{C_e}{q_e(C_S-C_e)}=\frac{1}{q_S C_{BET}}+\frac{(C_{BET}-1)C_e}{q_S C_{BET}\,C_S}$	$q_e=\frac{q_S C_{BET} C_e}{(C_S-C_e)[1+(C_{BET}-1)\left({C_e}/{C_S}\right)]}$	$\frac{C_e}{q_e(C_S-C_e)}$ VS $\frac{C_e}{C_S}$	Bruanuer *et al.* (1938)
FHH	-	$\ln\left(\frac{C_e}{C_S}\right)=-\frac{\alpha}{RT}\left(\frac{q_S}{q_e d}\right)^r$	-	Hill (1952)
MET	-	$q_e=q_S\left(\frac{k}{\ln\left({C_S}/{C_e}\right)}\right)^{1/3}$	-	McMillan and Teller (1951)

Table 2. Adsorptive techniques and capacities of selected agro-waste material-based adsorbents

Adsorbent	Dye pollutant	Adsorption kinetic	Adsorption isotherms model	Adsorption capacity (mg g^{-1})	Removal efficiency (%)	References
Walnut shells	Methylene blue	Pseudo-second-order	Langmuir	178.90		Miyah *et al.* (2018)
Rice bran-based composite	Malachite green	Pseudo-second-order	Freundlich	22.32	-	Bhatti *et al.* (2017)
Egg shells	Methylated blue Congo red	Pseudo-second-order	Freundlich	94.90 49.50	-	Abdel-Khalek *et al.* (2017)
Citrus limetta Peels	Methylene Blue Malachite Green Congo red	Pseudo-second-order	Langmuir	6.36 8.73 6.60	-	Singh *et al.* (2017)
Zea Mays Cob	Methylene Blue Malachite Green Congo red	Pseudo-second-order	Langmuir	4.44 16.72 8.42	-	Singh *et al.* (2017)
Cationic surfactant -modified peanut husk	Light green	Pseudo-first-order	Freundlich	146.20	-	Zhao *et al.* (2017)
Breadnut (*Artocarpus camansi*) peel	Methylene blue	Pseudo-second-order	Langmuir	409.00		Lim *et al.* (2017)
Bengal gram (*Cicer arietinum*) seed husk	Congo red Methylene blue Rhodamine-B Acid blue 25	Pseudo-first order	Langmuir	78.12 333.33 133.34 5.56		Somasekhara Reddy and Nirmala (2017)
Fish scales waste	Azo	Pseudo-second-order	Langmuir	157.30		Ooi *et al.* (2017)
Carboxylic acid pretreated Sesame straw (*Sesamum indicum L.*)	Methylene blue	Pseudo-second-order	Langmuir	650.00		Feng *et al.* (2017)

Table 2. Continued...

Cedrela odorata seed chaff	Methylene blue Congo red Methyl violet Methyl orange	Pseudo-second-order	Langmuir	111.88 128.84 121.23 68.23	-	Babalola *et al*. (2016)
Soybean hull	Safranin	Pseudo-second-order	Temkin	47.00	89.5	Chandane and Singh (2016)
Dragon fruit peels	Alcian blue Methylene blue	Pseudo-second-order	Langmuir	71.85 62.58		Mallampati *et al*. (2015)
Calcined egg shell	Basic yellow 28	Pseudo-second-order	Freundlich	28.81	93.2	Slimani *et al*. (2014)
Peanut husk	Drimarine Black CL-B	Pseudo-second-order	Langmuir	38.00	-	Noreen *et al*. (2013)
Cocoa shell-based activated carbon	Methylene blue	Pseudo-second-order	Freundlich	212.72	-	Ahmad *et al*. (2012)
Peanut hull	Reactive black 5 (RB5)	Pseudo-second-order	Langmuir	55.55	-	Tanyildizi (2011)
Sesame hull	Methylene blue	Pseudo-second-order	Langmuir	359.88	92.79	Feng *et al*. (2011)
Rice husk treated with NaOH	Malachite green	Pseudo-second-order	Freundlich	17.98	98.9	Chowdhury *et al*. (2011)

SWOT analysis and perspectives

The summary of strengths, weaknesses, opportunities and threats of the agro-waste based adsorbents for the removal of dye pollutants from water and wastewater is presented in Table 3. The analysis indicated the use of agricultural waste as adsorbents for dye removals are highly beneficial not only in terms of water and wastewater treatment of dye pollutants but also as an opportunity for waste management. The agricultural waste materials are generated in large quantities and are of zero economic value, constituting environmental burdens. They are considered as the best alternative to other costly material based adsorbents.

Table 3. SWOT analysis of the agro-waste based adsorbents as dye pollutant removal.

Strength	**Weakness**
• Applicability to remove variety of dyes (Babalola *et al*., 2016). • Relatively cheap to procure the materials (Chowdhury *et al*., 2011). • Readily available (Bhatti *et al*., 2017). • It is energy efficient process (Abdel-Khalek *et al*., 2017). • Relatively good equilibrium time and rapid kinetics (Adegoke and Bello, 2015). • High carbon content (Singh *et al*., 2017). • Good biodegradable and regeneration properties (Singh *et al*., 2017).	• Chemical activation using NaOH, KOH, $ZnCl_2$, etc are required to improve porous structure of the adsorbents (Abdolali *et al*., 2014). • Adsorption capacity of the same adsorbent vary with different dye pollutants removal (Abdel-Khalek *et al*., 2017). • Not all the agro-wastes adsorbent based perform efficiently under natural conditions (Zhao *et al*., 2017).
Opportunities	**Threats**
• Valorization of agricultural waste with low economic values. • Disposal problems associated with agricultural waste is reduced (Babalola *et al*., 2016). • Cost of disposal of agricultural waste is eliminated. • Commercialization of agricultural waste as excellent adsorbent. • High profitability when explored at industrial scale.	• Spent adsorbents and removed dyes could cause environmental discomfort if not properly managed (Adegoke and Bello, 2015). • Adjustment of pH level for optimum adsorption process using some chemicals can create economic burdens on the use of agro-waste materials as adsorbent for dye pollutant removal (Lim and Aris, 2014). • Activation process using chemicals to improve the porous structure of some agro-waste materials require technical expertise.

Similarly, the adsorbents made from agro-wastes are efficient and the processes required to convert them to adsorbents are eco-friendly as they can be produced without going through any industrial process. Despite the numerous advantages of agricultural waste materials as adsorbents for dye pollutants removal, some plant-based agro-wastes, though with functional cellulose structures for trapping the pollutants, are found to release some toxic organic compounds into the water bodies being treated. The release of organic carbon can cause further deterioration of water quality through enhancement of the biological oxygen demand, chemical oxygen demand and total organic carbon contents.

Further, the adsorbents made from plant-based agro-wastes tend to attain saturation faster due to the coverage of interface by the dye molecules, thereby preventing further adsorption process. Although altering the pH of the dye solution using either acid or base can offer solutions to the stated problem, this process, however, requires technical expertise and costly instrumentation to achieve the desorption before regeneration occurs (Siddiqui *et al.,* 2017). Modifications of agro-waste through chemical pretreatments or their usage in composites form were reported to have enhanced adsorption capacities, unlike when the agro-waste materials are used as adsorbents in their raw forms (Feng *et al.,* 2017; Chowdhury *et al.,* 2011). However, this assertion is only applicable to some selected agro-waste materials targeting particular dye pollutant classes or types.

Conclusion

This study explored the use of agricultural waste materials as adsorbents for the removal of dye pollutants in wastewater and water treatment. The detailed review of the literature was carried out on the adsorption mechanisms of selected agricultural waste-based adsorbents considering different adsorption kinetics and isotherms with their corresponding adsorption capacities. The SWOT analysis was further carried out, highlighting some of the advantages and disadvantages of using agro-waste based adsorbents for the removal of persistent organic dye pollutants under their strengths and opportunities and weaknesses and threats, respectively. While there are abundant of agro-waste materials, including both plant and animal origins, which have been used as adsorbents, particularly to treat dye polluted wastewater, the adsorption capacities were found to vary widely with different dye pollutants. Meanwhile, the Pseudo-second-order type of adsorption kinetics and both Langmuir and Freundlich isotherm models resulted in maximum adsorption capacity of different dye pollutants among the majority of the agro-waste based adsorbents. The SWOT analysis revealed some disadvantages of using agro-waste materials as adsorbents for dye pollutant treatment, which are majorly on some improvements required to enhance the adsorption capacity. However, the advantages which are based on the strengths and opportunities outweigh the weaknesses and threats associated with the use of agro-waste based adsorbents, which make them highly preferred as sustainable materials for the treatment of dye polluted water and wastewater.

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Cite this chapter as: Adelodun, B., Ajibade, F.O., Abdulkadir, T.S., Bakare, H.O. and Choi, K.S. (2020). SWOT analysis of agro waste-based adsorbents for persistent dye pollutants removal from wastewaters. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 88-103, https://doi.org/10.26832/aesa-2020-edcrs-07

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-08

CHAPTER [8]

Current status of water pollution by integrated industrial hubs (IIHs) in India

Vinod Kumar, Piyush Kumar*, Jogendra Singh and Pankaj Kumar

Agro-ecology and Pollution Research Laboratory, Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India

ABSTRACT

Integrated industrial hubs (IIHs) are the major cause of water pollution in India. This chapter reveals the issues of industrialization and its causes and consequences to the environment in total and water in particular. Environmental pollution is a worldwide problem, now receiving worldwide attention. The majority of the solid wastes and wastewaters are released into the soil and water bodies. Fundamental contributors of the surface and groundwater contamination are the results of different manufacturing units, for example, textile, metal, dying chemicals, pesticides, cement, petrochemical, fertilizers, energy, sugar processing, construction, leather, steel, engineering, food processing, mining and others. Water and human health are correlated wherein one affects the other, and the magnitude of the problem is such that its solution invites an integrated approach. Thus, proper treatment and disposal of IIH wastewater should be done to mitigate its environmental impacts. Therefore, this book chapter deals with the characteristics and potential effects of integrated industrial hubs (IIHs) on surface and groundwater quality in India. The information provided suggests implementing effective measures to mitigate their wastewater disposal impacts.

KEYWORDS Effluent, Heavy metals, Industrial pollution, Industrial hubs, Water pollution

Piyush Kumar, Email: kumarpiyushgkv@gmail.com

Introduction

Water is important for all life forms and comprising up 50-97% of the mass of all plants and animals and about 70% of the human body (Allan, 1995). Additionally, water is a fundamental asset for horticulture, manufacturing, transportation and numerous other human exercises. In spite of its significance, water is the most ineffectively managed resource on the planet (Chutter, 1998). The accessibility and nature of water have consistently assumed a significant role in deciding the quality of life. Water quality is firmly connected to water use and to the condition of commercial growth (Chennakrishnan *et al*., 2008). Ground and surface waters can be polluted by numerous sources. In urban regions, the indiscreet transfer of industrial discharges and different wastes may contribute enormously to the low quality of water (Mathuthu *et al*., 1997). The vast majority of the water bodies in the regions of the developing world are the endpoints of effluents released from industries. The changes in the nutrient concentrations of water may have prompt harmful impacts on the humans and other forms of life. Most substantial metals in water streams are usually connected with manufacturing discharges and practically heavy metals in industrial wastes have aggregate poisons to aquatic life (Mdamo, 2001). The physico-chemical factors of a water body not just reveal the kind and variety of aquatic biota yet, in addition, the water quality and contamination (Birley and Lock, 1999). Industries are the chief sources of pollution in all environments. Based on the kind of industry, many levels of pollutants can be discharged into the environment directly or indirectly through public sewer lines (Kumar *et al*., 2018; Kumar *et al*., 2019a).

Integrated industrial hubs (IIHs) are established to attain the demand of the growing people in the country. The introduction of manufacturing units at one side produces useful products but at the same time, it generates unwanted wastes in solid, liquid or gaseous form that is responsible for the creation of hazards, contamination and losses of energy. The majority of the solid wastes and wastewaters are released into the soil and water bodies. Fundamental contributors of the surface and groundwater contamination are the results of different manufacturing units, for example, textile, metal, dying chemicals, pesticides, cement, petrochemical, fertilizers, energy, and power, sugar processing, construction, leather, steel, engineering, food processing, mining and others (Mdamo, 2001). Therefore, the release of manufacturing wastes, municipal sewage, farm and urban trashes carried by sanitation and canals to streams worsen and increase water contamination. The major problem begins when elevated levels of contaminants in stream water causes an expansion in biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), and other toxic contents of heavy metals such as Cr, Cd, Ni and Pb with fecal coliform and thus make such water inappropriate for drinking, irrigation and aquatic life. Chillers and Henrik (1996) has been reported that 60 % of the population in developing nations has no access to unadulterated drinking water. In India, both surface and groundwater assets are under pressure. One of the causes for this is the considerable increment in the quantity of grossly polluting industries (GPI). It is estimated that from 2011 to 2018, nearly 11% of these enterprises keep on ridiculing pollution control standards in the nation; about half of these are in Uttar Pradesh, India (Pandey, 2019).

Numerous individuals in developing countries of the world still depend on untreated surface water as their basic source of local water supply. Therefore, this issue is worsened in rural regions. Besides this, surface water is progressively under excessive worry because of population explosion and expanded industrialization. It happens due to the availability of surface water settles on them the best decision for wastewater release. Wastewater from IIHs which involves microbes, heavy metals, radionuclides, nutrients, pharmaceutical, and personal use items all discover their approach to surface water resources making permanent damage to the aquatic biological system and to people like the aesthetic value of such water is undermined. These contaminants decrease the quality of useable water, rise the charge of cleansing it, pollute aquatic resources, and disturb food supplies (Edokpayi *et al*., 2014). Besides this, the lowering in ecological quality is the major sign of environmental degradation (Agarwal, 2005; Georgy, 2011). Environmental laws have been established by the legislature and implemented through its regulatory structures worldwide (Faure, 1995).

Therefore, this book chapter deals with the characteristics and potential effects of integrated industrial hubs (IIHs) on the surface and groundwater quality in India. The information provided suggests implementing effective measures to mitigate their wastewater disposal impacts.

Characters of effluent generated from IIHs in India

The industrial effluents comprise both inorganic and organic pollutants. The major problem of IIHs began with its small area and inefficient sewer system. Indeed, even today most of the industries don't have appropriate wastewater treatment plants or enough capacity to treat wastewater therefore, they discharge industrial effluents in unlined channels and streams. As a result, the highly colored and toxic effluents join the nearby water bodies which degrade surface as well as groundwater quality. The nature of IIH effluent may not be the same throughout the year. It depends on the type of operating industries within the cluster (Figure 1). The major characteristics of effluent generated from IIHs are provided below:

Physical characteristics

The key physical characteristics of IIH wastewater are:

Solid contents: The total solids in wastewater comprise of the insoluble or suspended solids and

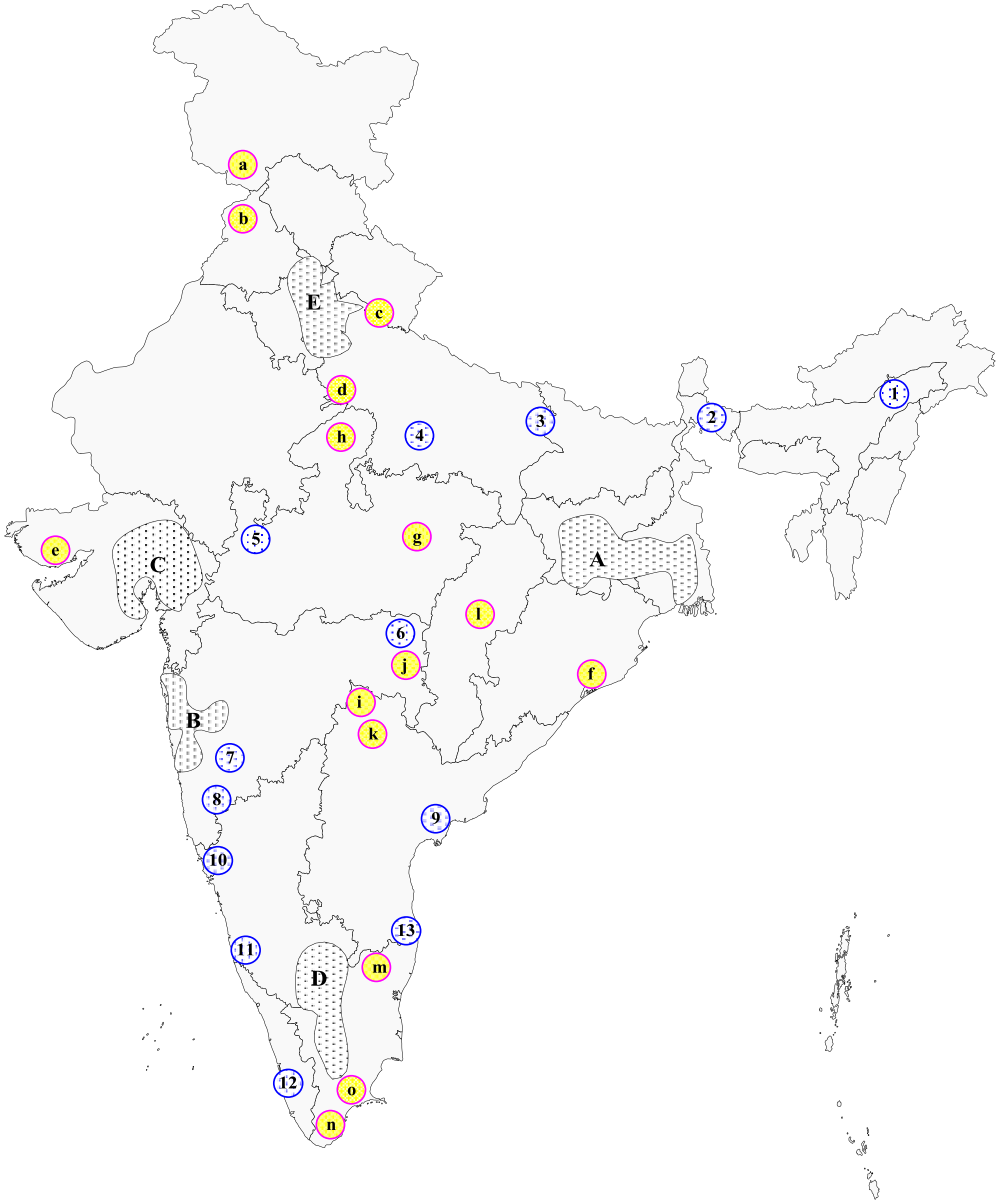

Figure 1. Major industrial hubs of India (a-o: minor hubs; A-E: major hubs; 1-13: manufacturing districts; Source: http://www.geographynotes.com/industries/6-major-industrial-clusters-regions-of-india/1058)

the solvent mixes from different types of industries. The suspended solids content is found by drying and evaluating the remains displaced by the separating of the example. At the point when this residue is burned off the unstable or volatile solids are burnt off. Volatile solids are supposed to be organic matter, while some organic matter won't consume and some inorganic salts separate at high temperatures. The organic matter contains primarily carbohydrates, proteins and fats (Munter, 2003; Kumar *et al*., 2019b).

Color: Color of IIH effluent is a qualitative character that can be used to measure the overall state of wastewater. Light brownish colored wastewater is generally less than 6 hours old, though wastewaters that have suffered from a degree of decomposition or that have been in the collection unit for a while, a medium grey color is characteristic of that wastewater. The wastewater which is typically poisoned, having undergone wide microbial decomposition under anaerobic circumstances, lastly, the color is dark grey or black (Munter, 2003). The darkening of wastewater is frequently because of the formation of various sulfides, mainly, ferrous sulfide. This happens when hydrogen sulfide generated under anaerobic conditions combines with divalent metal, like iron, which may be present.

Odor: The odor of IIH wastewater is typically aggressive. Various other compounds like skatol, indol, mercaptan and cadaverine formed during anaerobic situations or present in the wastewater of pulp and paper industries (dimethylsulphide, hydrogen sulfide, mercaptan, etc.), may also originate a slightly aggressive odor.

Temperature: Temperature is a significant indicator of water quality with concerns about the survival of water organisms. The temperature of IIH effluent is usually higher than that of the water supply due to warm civic water has been added. The wastewater temperature depends on the procedure of manufacture in the industries.

Chemical characteristics

Inorganic chemicals: The major inorganic chemicals present in IIH effluents include nitrogen, nitrates, nitrites, phosphorus, and inorganic phosphorus. Nitrogen and phosphorus are significant because these two nutrients are accountable for the growth and development of water plants. Other tests such as sulfate, chloride alkalinity and pH, are achieved to measure the suitability of re-consuming treated wastewater and in supervisory the several treatment procedures. Trace elements, which comprise some heavy metals, are not measured regularly. All living beings need different quantities of some trace elements, such as copper, iron, cobalt and zinc for appropriate growth. Heavy metals can also impose poisonous effects; consequently, measurements of the amounts of heavy metals are particularly significant where, the further use of treated effluent or sludge is to be assessed (Munter, 2003).

Organic chemicals: The BOD and COD of IIH wastewater may be very high as compared to other wastewaters. Throughout the years, various different tests have been discovered to find the organic content of wastewaters. The BOD, COD and TOC tests are gross proportions of organic content and thusly don't reflect the reaction of the wastewater to different sorts of biological treatment technologies It is hence necessary to divide the wastewater into various categories (Munter, 2003).

Water pollution by IIH industries in India

Chemical industry

Chemicals industry in India is exceptionally enhanced, covering in excess of 80,000 commercial items. It is extensively ordered into bulk synthetic chemicals, specialty synthetics, petrochemicals, agrochemicals, fertilizers, and polymers. India's closeness to the Middle East, the world's foundation of petrochemicals feedstock, makes for economies of scale. India is a worldwide dye supplier, representing roughly 16% of the world generation of dyestuff and color intermediates. Chemicals industry in India has been de- authorized excluding for limited dangerous chemicals. The chemical industry in India is projected to touch 304 billion dollars in 2025. India ranks 8th in import and 14th in the export of chemicals (Excluding pharmaceuticals products) worldwide. The demand for chemical items is predicted to grow at around 9% per year throughout the following 5 years. More than 2 million peoples are employed in the Indian chemical industry. The market size of the Indian chemicals industry in 2017-18 is mounted at 163 billion dollars. With a growth of 4.15% over 2017-18, the total manufacture of main chemicals and petrochemicals mounted at 27,847 Metric tons throughout 2018-19. Alkali chemicals occupy the major share in the Indian chemical industry in with around 69% portion in the total production (Invest India, 2019c). The rundown of chemical wastes can be reached out to a few thousand, among them; the fundamental toxins are alkalies, acids, sulfates, phosphorus, nitrates of metals, fluorine, silica and suspended particles. Any processing plant creating synthetic substances is releasing into our water system of one or more kind of lethal chemicals (For model, phosphate industry produces discarded water containing essential fluorine, phosphorus, silica and a lot of suspended solids).

Textile industries

In India, the textile industry has strengths across the whole value network from yarn, fiber, fabric to apparel. It is extremely expanded with a varied range of sectors reaching from yields of traditional handloom, wool and silk products, handicrafts to the organized textile industry. The structured textile industry is characterized by the use of capital-intensive technology for bulk production of textile items and comprises weaving, spinning, processing, and apparel manufacturing. The national textiles and apparel industry rose at 140 billion dollars in 2018 (together with handicrafts) of which 100 billion dollars was nationally consumed though the leftover portion worth 40 billion dollars was shipped to the world market**.** In India's Growth Domestic Product (GDP), the national textiles industry contributes 2.3% to and 13% to the industrial production and 12% of India's export earnings. In India, the textiles and apparel industry is the second-largest employer in the nation providing employment to 45 million people. It is predictable that this amount will increase to 55 million by 2020 (Invest India, 2019a). One textile plant can utilize as many as 2000 diverse chemicals, from dyes to transfer agents (Khan and Malik, 2014). According to Govindarajalu (2003), the water utilization of an average-sized textile unit (production of 8000 kg of fabric/day) is nearly 1.6 million liters per day. This type of textile mill can also produce up to 200–350 m^3 of wastewater per ton of finished products (Ranganathan *et al*., 2007), causing in average contamination of 100 kg chemical oxygen demand (COD) per ton of fabric (Jekel, 1997).

Food-related Industries

At a cumulative average growth rate (CAGR) of 14.6%, the processed food industry in India is estimated to grow to 543 billion dollars in 2020 from 322 billion dollars in 2016. Food processing occupies a significant linking role for Indian farmers to consumers in the national and international markets. Across the value chain, the Ministry of Food Processing Industries (MoFPI) is putting all hard work to encourage investments. The industry involves roughly 1.85 million individuals in around 39,748 registered divisions with secure assets of 32.75 billion dollars and a collective output of around 158.69 billion dollars. Food processing industries consist of grains industries, sugar industries, edible oils industries, beverage industries and dairy products manufacturing industries **(**Invest India, 2020). Food-processing industries generate wastes like poultry wastes, dairy wastes, meat, sugar processing wastes, canning etc., all are highly degradable and are oxygen (DO) depleting and water supply damaging in much the same way as per domestic sewage. These industries discharge the organic contaminants high in fats, proteins and pathogens. The dairy plants discharge a high volume of effluent (Ramjeawon, 2000), food processing industries consume large quantities of water and are therefore a nuisance to the environment. Effluents from food processing units have moderate to high biological oxygen demand, high chemical oxygen demand, high suspended and dissolved solids and great nutrient content such as nitrogen, phosphorous, heavy grease and oil. This wastewater is amicable to non-chemical biological treatment including anaerobic management like Hybrid Up-flow Anaerobic Sludge Blanket Reactor (HUASBR) trailed by aerobic treatment.

Paper and pulp Industry

India's share worldwide in paper demand is progressively increasing as the national requirement is growing at a steady pace while requirement in the western countries is shrinking. At a CAGR of 6.4%, the national requirement in India increased from 9.3 million tons in 2008 to 15.3 million tons in 2016. Despite the constant development observed by the industry, the paper utilization in India stands at a slight over 13 kg per capita which is far lower the international average of 57 kg and expressively below 200 kg in North America. According to IPMA's (Indian Paper Mills Association) evaluates, this industry contributes roughly 4,500 crore rupees to the exchequer and gives work to more than 5 lakh individuals crosswise over around 750 paper plants. There are four major segments of the paper industry: printing and writing (PandW), packaging paper and board, specialty papers and others, and newsprint.

The paper production process needs a huge quantity of water for the manufacture processes; therefore it is a water exhaustive process. The basic raw materials are utilized for the manufacturing processes are vegetables, rice husk, wood, cellulose, fibers and as well as waste-papers. This generates a large amount of wastewater. The poisonous effects on the biota are exhibited by the dark color of the waste paper and it obstructs the photosynthetic process by decreasing the sunlight (Swamy *et al*., 2011). Paper and pulp factories, notwithstanding being air polluters, produce a lot of inorganic contaminations, for example, sulfides, drying alcohols, and natural toxins including cellulose filaments, bark, wood sugars, and organic acids (PrintWeek India, 2018).

Leather industry

The Leather business in India represents around 12.9% of the world's leather manufacture of stows away/skins and handles a hearty yearly creation of around 3 billion square feet of leather. The nation represents 9% of the world's footwear manufacturer. The industry is known for its reliability in high trading earnings and it is among the chief ten overseas exchange earners for the nation. India has a bounty of crude materials with access to 20% of the world's cows and buffalo and 11% of the world's population of goats and sheep. The Leather business is an employment serving industry giving employment to in excess of 4 million individuals, generally from the weaker sections of the general public**.** Female engagement is leading in the leather items industry with about 30% portions. The Leather business in India has probably the most youthful workforce with 55% of the workforce underneath 35 years old. The Leather business tends to create 250 employments for each 0.2 million dollar venture (Invest India, 2019d). The tanneries generate a lot of salts, solids, chromium, sulfides, alkalinity, lime and so on., all of which have to be discarded in water bodies, which is the main cause of contamination of water bodies. The tannery waste is renowned by its odor, strong color, high biological oxygen demand (BOD), high chemical oxygen demand (COD), high total dissolved solids (TDS), high total suspended solids (TSS) and high pH.

Rubber and plastic industries

The plastics business in India has developed and enhanced altogether since its initiation in 1957. The Indian plastics industry showcase has now developed to get one of the main segments in the nation's economy, comprising of more than 30,000 firms and engaging in excess of 4 million individuals. India is one of the world's top exporters of plastics items worldwide. The plastics industry produces and exports an assortment of crude materials, overlays, electronic accessories, therapeutic products, and consumer goods. These plastic items are sent out to in excess of 150 nations, chiefly in Africa, Europe and Asia (BizVibe, 2019). The plastics industry in India additionally gives plastic materials to a few different enterprises like the car, shopper bundling, and electronic gadgets manufacturers.

In the course of the most recent couple of decades, the interest for and use of plastics in numerous industries have expanded immensely. In the course of the recent 5 years, the Indian plastic industry has developed by 13% every year. A parallel growth level was expected to continue and the size of the industry was expected to reach around 25 billion dollars by 2016-17. Plastic industries produce organic matter and other hydrocarbons. Phenolic compounds pollute water and are results from industries like oil refineries, petrochemicals, leather and textile manufacturing, rubber, pesticides, pharmaceuticals, plastic and insecticide manufacturing (Srivastava *et al*., 2006).

Metal industries

The Indian metal industry is categorized into 2 primary divisions - the iron-based and non-iron-based metal ventures. The iron-based section incorporates the assembling of 3 various types of steel, for example, carbon steel, ferrochrome steel, and hardened steel. The non-iron-based class incorporates the making of copper, metal, tin, zinc, lead, manganese and aluminum. In the Indian metals industry, the primary tasks of the industries are mining of minerals, refining of the ores, alloying, casting, sheet, and folding into foils. India essential metals industry experienced vast changes during the 90s with the beginning of the progression and open market strategies. With the new structure and sources of ventures, the foundation relating to the businesses was modified. Increasingly proficient and mechanically propelled strategies improved the production practices and thusly the yield of the industry expanded alongside the quality of the items. Fundamental metals industry of India is growing up with the inventive skills as it is helping the product market to amplify. A portion of the famous strategies utilized for the manufacturing of metals is open hearth, oxygen incinerators, blast furnaces, electric arc boilers, and so on (MOI, 2015). Steel industries produce excess water from the positioning of coal, vent (fireplace), washing of blast boiler, gases, and others. These waste be likely to be acidic and contain cyanogens, phenols, coke, metal, soluble bases, limestone, oils, and fine suspended solids. Metal enterprises associated with formulating of chromium, lead, nickel, zinc, silver, cadmium, copper, etc., additionally create acids, antacid cleaners and oil.

Petroleum and oil industry

India is the fourth biggest merchant of liquefied petroleum gas (LNG). India expended 213.2 MMT petroleum-based commodities and 60,747 MMSCM natural gas. The import reliance of unrefined oil and LNG during 2018 was 82.59% and 45.89% individually. During 2018 with a growth of 27% over 88 billion dollars during 2017 - 18, and 23.42% of all-out gross import of the country, the petroleum import bill was 112 billion dollars. India's anticipated oil demand is going to raise at cumulative average growth rate (CAGR) of 4% during 2016 - 2030 in contradiction of the world average of 1%, however, the anticipated oil request will be far lower when compared with the US and China (Invest India, 2019b).

Petroleum products pollute water at each stage of their manufacturing, storing and transportation. They produce pollutants like oil spillage and saline water. The main causes of water pollution with phenolic mixtures are manufacturing like petrochemicals, oil refineries, textile and leather manufacturing, plastic, rubber, pharmaceuticals, pesticides, and insecticides (Srivastava *et al*., 2006). The release of phenolic wastes conveys a carbolic odor to water systems and cause a poisonous effect on plants, aquatic life and humans. Tumor formation, cancer and mutation are some of the side effects accelerated by them.

Mining industry

India holds a reasonable benefit in the cost of making and conversion costs in alumina and steel. Its tactical position empowers profitable exports to develop as well as the fast-developing Asian markets. India produces 95 minerals–4 fuel-related minerals, 23 non-metallic minerals, 10 metallic minerals, 3 nuclear minerals and 55 minor minerals (counting building and different minerals). The rise in infrastructure expansion and automotive manufacture is driving progress in the segment. Power and cement enterprises are likewise supporting growth in the metals and mining region. India is the third biggest manufacturer of coal. Coal production in the nation rose at 688.8 million tons in FY18. It remained at 576.00 million tons from April 2018 to March 2019. India ranks fourth in iron ore manufacturing worldwide. Manufactured iron ore was 210 million tons in FY18. India has around 8 percent of the world's stores of iron metal. India turned into the world's second-biggest unrefined steel maker in 2018 with yield 106.5 million tons. As per the Ministry of Mines, India has the seventh biggest bauxite assets- nearly 2,908.85 million tons in FY17. Aluminum manufacture was 1.33 million metric tons during April-August 2018 and is anticipated to become 3.33 million tons in FY20 (IBEF, 2019). The contagions of mining are chlorides, ferric hydroxide, sulphuric corrosive, ferrous sulfate, hydrogen sulfide, suspended solids, chlorides, and others.

Current status of ground and surface water pollution by IIHs

Previous reports have concluded that effluent discharges from IIH or individual industry has an extreme impact on ground and surface water quality. Out of them, Tariq *et al*. (2006) analyzed the characteristics of industrial effluents and their influences on quality of underground water and concluded that the characteristics of effluents were different according to the industry. The pH of effluent from aluminum industry was beyond and of the remaining industries was within the permissible limit whereas total suspended solids (TSS) of effluent of Pepsi industry was within and of the remaining industries were above the permissible limits compared with NEQS (National Environmental Quality Standards). In almost all of the effluents, the biochemical oxygen demand (BOD) was exceeding the permissible limit. Heavy metals like cadmium, chromium, copper, iron and zinc were in the permissible limits in all but manganese, nickel and lead were beyond the permissible bounds in some effluents. Shankar *et al*. (2008) studied the impact of industrialization on groundwater quality – a case study of Peenya industrial area, Bangalore, India and revealed that almost 77% of the samples are polluted and unhealthy for domestic use. The results visibly show that the groundwater is getting polluted terrifyingly due to quick industrialization. The inquiries along with the consultations held with the official health centers and local public of the region, evidently point out to the severe pollution of the groundwater in the locality of the industries.

Tariq *et al*. (2010) observed the dispersal and distribution of some metals in effluents from tannery and found that the groundwater and soil systems in the locality of these tanneries were contaminated by chromium (Cr), cobalt (Co), cadmium (Cd), nickel (Ni), lead (Pb), manganese (Mn), sodium (Na), potassium (K), calcium (Ca) and iron (Fe), to the amount that they pose a hazard to the surroundings. These metals and chemicals initiate from many procedures such as tanning/retaining, liming/delimbing and finishing steps of leather manufacture. The greater chromium levels were mainly dangerous for human health. Additionally, raised sodium (Na) levels could turn the groundwater into the saline water, thus disturbing its appropriate use for commercial, irrigation, and drinking purposes. Brindha and Elango (2012) determined the effect of tanning industries on groundwater quality near a metropolitan city in India and concluded that Na-Cl was the prevailing groundwater type. A big proportion of groundwater samples collected from this study site is of saline water type based on the concentration of total dissolved solids (TDS). From all the samples collected only 28% samples were desirable for drinking purpose and thus a larger portion of groundwater is not appropriate for domestic use.

A large share of groundwater of this zone is hard water. In 86% of the groundwater samples chromium was exceeding beyond the permissible limit. The composition of groundwater was alike to that of the treated effluent. Generally, the groundwater in this zone had been concentrated with the hazardous chemicals that were utilized during the tanning procedure, which specify the influence of effluent discharged by the tanning activities. Singh *et al*. (2013) observed the effect of polluted surface water on groundwater and revealed that the quality of the surface water at different sections of Budha Nullah had been decreased as the stream headways through the city. Human settlements and untreated wastes from the industries are found to be the main source for degradation of the water quality in Ludhiana. The surface water investigation of Budha Nullah exposed high values of total dissolved solids (TDS) up to 1642 mg/L, chlorides ranged to 400 mg/L, chemical oxygen demand (COD) reached up to 448mg/L, biochemical oxygen demand (BOD) was fluctuating between 52-195 mg/L, most potable number (MPN) varied from 240+ upto 2400+/100 ml, heavy metal like Chromium (Cr) in the Budha Nullah was 0.084 mg/L, Iron (Fe) 0.913 mg/L, Manganese (Mn) 0.095 mg/L and Nickel (Ni) 0.222 mg/L. According to the water quality standards specified by Central Pollution Control Board (CPCB), the water quality of Budha Nullah came under E class of water which was not appropriate for drinking purpose, bathing, irrigation and industrial cooling, propagation of wildlife and fisheries. Bhadra *et al*. (2013) studied the impact of industrial effluents on groundwater around Pali city, Rajasthan and revealed the impact of contaminants on the croplands. The very red/black coloured industrial effluent was carried by Bandi River, which is alkaline and rich in organics and other soluble salts. With growing concentration of total dissolved solids (TDS), chloride, sulphate etc., the salinity of water increased. Up to a distance of 50 kilometers in the downstream direction, the current of effluent of Bandi River had impacted the quality of groundwater in wells from Pali city to Nerda dam. Sodium (Na), total dissolved solids (TDS), chloride (Cl^-) and sulphate (SO_4^{2-}) were very high in groundwater. It had been incidental that extreme damage to the croplands had taken place between 1979 and 2005, on equating the quality factors of different sources. Nirgude *et al*. (2015) performed the physico-chemical analysis of some industrial effluents from Vapi industrial area, Gujarat, India and concluded that total dissolved solids (TDS), electrical conductivity (EC), chlorides sulphates (SO_4^{2-}), chemical oxygen demand (COD), biochemical oxygen demand (BOD), sodium (Na) and calcium (Ca) were very high in concentration compared to the standards set by WHO. Additionally, they also recommended that such effluent must not be discharged in to the nearby water bodies or soil without any treatment. Such effluents were unhealthy for irrigation purpose. The elevated level contamination of the industrial effluents causes natural issues which would influence plant, animal and human life. Copaciu *et al*. (2015) did the assessment of industrial effluents quality and their possible impact on surface water and found that the analyzed physicochemical parameters were diverse significantly with the source of effluent.

The assessment showed a seasonal difference for some parameters. The quality of the assessed effluents was below the limits set by Romanian and UE legislation in some cases. Some parameters exceeded the limits set by legislation but parameters like the total dissolved solids

(TDS), chloride (Cl^-), sulphate (SO_4^{2-}) and detergents content of the effluents were found within the permissible limits for surface water discharge. Chowdhury *et al*. (2015) performed the characterization of the effluents from leather processing industries and found extremely high values of total suspended solids (TSS), total dissolved solids (TDS), total solids (TS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), sulphate (SO_4^{2-}), sodium (Na), chromium (Cr), arsenic (As), cadmium (Cd) and lead (Pb) in the effluents sampled from various manufacturing phases in the three different selected leather industries. The values were far exceeding the permissible limits. The results also indicated that the main physico-chemical parameters of all complex effluents at three monitoring points surpassed the standard discarding limits. The order of concentration of metals in the sludge from high to low was chromium (Cr), sodium (Na), calcium Ca, sulphur (S), manganese (Mg), copper (Cu), zinc (Zn), lead (Pb), arsenic (As), cadmium (Cd). Noukeu *et al*. (2016) analyzed characterization of effluent from food processing industries and did stillage treatment trial with *Eichhornia crassipes* (Mart.) and *Panicum maximum* (Jacq.). The investigation revealed that effluents from food processing industries had enormously great levels of chemical oxygen demand (COD), total suspended solids (TSS), biochemical oxygen demand (BOD), phosphate (PO_4^{3-}) and nitrate (NO_3^-). These values were mostly exceeding the limits set by WHO They proposed that without treatment, those effluents were not appropriate to be discharged into natural environments. Their biological treatment could be done as they had high values of organic materials.

Afzal *et al*. (2018) performed characterization of industrial effluents and groundwater of Hattar industrial estate, Haripur and concluded that the effluents were highly contaminated with heavy metals, humiliating the groundwater quality and making it unsuited for irrigation. Additionally, the groundwater in the locality of industrial estate was hugely contaminated by industrial effluents and considered as inappropriate for consumption. Internationally, Santucci *et al*. (2018) studied industrial waste as a source of surface and groundwater pollution in the Río de la Plata coastal plain (Argentina) and revealed that environmental alterations due to heavily polluted soils from industrial activity caused in chemical alterations in surface water and groundwater. The penetration of waste resulting from the industrial area is the basis of the increased concentrations of sulphates ($SO4^{2-)}$ in water. According to the results found in this study, the sulfuric acid ($H_2SO_{4)}$ industry waste uncontrolled half a century ago were still a source of soil and groundwater pollution and they posture a hazard to human wellbeing.

Ahsan *et al*. (2019) studied chemical and physicochemical characterization of effluents from the tanning and textile industries in Bangladesh and found that tanneries and textile dyeing in the study area discharge effluents comprising numerous poisonous contaminants at a noteworthy level. Effluent samples disclosed high concentrations of total suspended solids (TSS), electrical conductivity (EC) and total dissolved solids (TDS) which surpassed the Bangladesh standard limits. Despite the fact that most heavy metal concentrations were inside the point of confinement with the exception of chromium (Cr) concentration in the tannery effluents. Textile dyeing effluents had elevated level of NO^{3-}, NO^{2-} and pH though tannery effluents had lower dissolved oxygen (DO) and pH values, and higher biochemical oxygen demand (BOD), chloride (Cl^{-}), sulphate ($SO_4{}^{2-}$) and Chromium (Cr) concentrations than the standard limits. Now a days wastewaters from IIHs are being effectively treated by biological processes including phytoremediation and bioenergy production (Kumar *et al*., 2019a; Kumar *et al*., 2020)

Conclusion

From the above reports, it is concluded that clustered industrialization is responsible for environmental pollution and consequential human health hazards, it is necessary to curb the worst excesses committed by IIHs, by way of legal restrictions on the processes and the use of its wastewater. Therefore, in a developing country like India, with alarming conditions of environmental pollution, lack of awareness of its causes and consequences, if unattended, mere enactments and amendments of legislation are not enough. Water and human health are correlated wherein one affects the other, and the magnitude of the problem is such that its solution invites an integrated approach. Thus, proper treatment and disposal of IIH wastewater should be done to mitigate its environmental impacts.

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Cite this chapter as: Kumar, V., Kumar, P., Singh, J. and Kumar, P. (2020). Current status of water pollution by integrated industrial hubs (IIHs) in India. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 104-119, https://doi.org/10.26832/aesa-2020-edcrs-08

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-09

CHAPTER [9]

ZnO nanostructures and nanocomposites as promising photocatalysts for the remediation of wastewater pollution

Satinder Pal Kaur Malhotra

ICFAI Tech School, ICFAI University Dehradun,
Rajawala Road, Selaqui, 248197, Uttarakhand, India

ABSTRACT

Recently, hierarchical 3D nanostructures have attracted attention due to their multiple advantages, such as large surface area, porous structures, as well as enhanced light harvesting ability. Zinc oxide is a promising photocatalyst alternative to TiO_2 used for environmental remediation of wastewater pollutants due to its high photosensitivity, non-toxic nature, low cost, and environmental friendliness. ZnO can be crystallized in three forms under different conditions i.e., wurtzite, zinc-blende, and rock-salt structures. ZnO exhibits a higher quantum efficiency and has a similar bandgap as TiO_2 as it has a larger number of inherent active defect sites on the surface, which makes it capable of absorbing a larger fraction of the solar spectrum. Various approaches have been used to efficiently utilize the solar radiation and to enhance the efficiency of zinc oxide photocatalyst. These techniques enhance the photocatalytic performance ZnO under visible light by shifting the bandgap energy, suppressing the recombination rate of electron-hole pairs, increasing charge separation efficiency. In future there is a need of developing green, scalable, low-cost and highly efficient hierarchically ZnO nanostructures and nanocomposites photocatayst for remediation of wastewater pollution. In this chapter the emphasis has been on the advantages, fabrication methods, and photocatalytic applications of hierarchical ZnO nanostructures for the degradation of organic contaminants present in wastewater.

KEYWORDS Fabrication, Hierarchical nanostructure, Photocatalysis, Zinc oxide

Satinder Pal Kaur Malhotra, Email: malhotrasatinder@gmail.com

Introduction

Over the past few decades, industrial effluents discharged into rivers and oceans have been the major sources of water pollution. Conventional methods used to treat organic effluents such as physical, biological or chemical are ineffective as they are non-destructive, since they just transfer organic compound from water to another phase, thus causing secondary pollution and requiring further treatment (Janotti and Van de Walle, 2009; Malhotra *et al*., 2019; Kumar *et al*., 2019). Heterogeneous photocatalysis is a promising technique to control environmental pollution harnessing cheap solar energy whereby toxic organic compounds can be effectively degraded into completely into green by-products i.e., H_2O, CO_2, and mineral acids without bringing secondary pollution, through a process called photocatalysis using semiconducting nanostructures. In recent years, various semiconductors with hierarchical nanostructures have been fabricated to achieve efficient photocatalysts owing to their multiple advantages, such as high surface area, porous structures, as well as enhanced light harvesting. (Li *et al*., 2016). Zinc oxide is a promising photocatalyst alternative to TiO_2 used for environmental remediation of wastewater pollutants due to its high photosensitivity, non-toxic nature, low cost, and environmental friendliness (Chen *et al*., 1998; Reynolds *et al*., 1999).

ZnO as a photocatalyst

In the field of photocatalysis, titanium dioxide (TiO_2) is undoubtedly the material most extensively studied (Huang *et al*., 2008; Mahendra *et al*., 2008). Due to the high price and rareness in existence of TiO_2 its large-scale application in industrial wastewater treatment operations is very non-economic (Daneshvar *et al*., 2004). Zinc oxide is a promising photocatalyst used for environmental remediation of wastewater pollutants than TiO_2 due to its high photosensitivity, non-toxic nature, low cost, and environmental friendliness. ZnO exhibits a higher quantum efficiency and has a similar bandgap as TiO_2 as it has a larger number of inherent active defect sites on the surface, which makes it capable of absorbing a larger fraction of the solar spectrum (Qiu *et al*., 2008; Chen *et al*., 2009; Yogendra *et al*., 2011).

Crystal structure of ZnO

ZnO can be crystallized in three forms under different conditions i.e., wurtzite, zinc-blende, and rock-salt structures (Ozgur *et al*., 2005; Moezzi *et al*., 2012). ZnO hexagonal wurtzite is thermo-dynamically the most stable at ambient conditions and hence most common among the three structures. Cubic zincblende, however, can be stabilized by growing ZnO on cubic substrates.

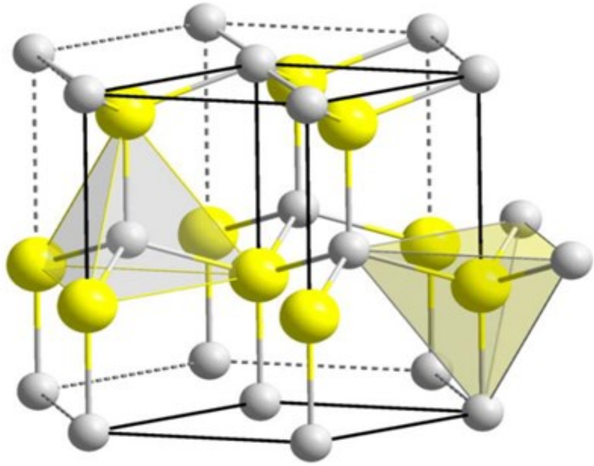

Figure 1. Wurtzite of ZnO.

ZnO will exist in the rock salt structure only at relatively high pressures (Ozgur *et al.*, 2005). The hexagonal wurtzite structure possesses lattice spacing a = 0.325 nm and c = 0.521 nm, the ratio c/a * 1.6 that is very close to the ideal value for hexagonal cell c/a = 1.633. Each tetrahedral Zn atom is surrounded by four oxygen atoms and vice versa (George *et al.*, 2009). ZnO is generally an intrinsically n-type semiconductor with the presence of intrinsic defects such as oxygen vacancies (V_O), zinc interstitials (Z_{ni}), and zinc vacancies (V_{Zn}), which will affect its optical properties and electrical behavior (Boukos *et al.*, 2012). It has been noted that a greater V_O can provide more electron charge carriers (Figure 1).

Classification of ZnO nanostructures

In the past decade, many different strategies have been employed to synthesize ZnO nano-materials rich in morphologies due to the availability of cheap and versatile routes of fabrication of zinc oxide nanostructures. From the point of dimensionality, zero-dimensional (0D) ZnO includes quantum dots, one-dimensional (1D) which includes nanorods, nanofibers, nanowires, nanotubes, and nanoneedles, while two-dimensional (2D) and three-dimensional (3D) nano-materials include nanosheets and nanoflowers, respectively. Processes leading to three dimensional (3D) hierarchical ordered structures are still not perfectly understood and therefore attract attention from the research community. As the photocatalytic activity of semiconductors generally depends on crystal size, surface area, morphology and native defects, the abundancy in morphologies makes ZnO representative material in the research field of photocatalysis.

Synthesis of 3D ZnO hierarchical nanostructures

Different synthesis methods have been used to obtain 3D ZnO hierarchical nanostructures which include physical, chemical and biological methods (Banerjee *et al*., 2012). Among the various methods used to synthesize ZnO nanostructures, solution phase synthesis is widely used for the synthesis of 3D ZnO hierarchical nanostructures as it is the simple and less energy consuming. Through this synthesis route, the morphology of the nanostructures can be easily controlled by manipulating the experimental factors such as type of solvents, starting materials and reaction conditions (Banerjee *et al*., 2012). Solution-based methods used to synthesize ZnO nanostructures include hydrothermal, sol-gel, precipitation, microemulsion, solvothermal, electrochemical deposition process, microwave, polyol, wet chemical method, flux methods and electrospinning. Solution phase synthesis has attracted increasing interest for the synthesis of 3D ZnO hierarchical nanostructures due to their advantages, such as low cost, low temperature (<200°C) required for synthesis, scalability, and ease of handling.

Advantages of hierarchical ZnO nanostructures and nanocomposites

High surface area and porous structures

The photocatalytic activity of semiconductor is affected by its specific surface area (Yuan *et al*., 2003; Wang *et al*., 2005; Zhang *et al*., 2007). Hierarchical nanostructures with a high surface area (Yu *et al*., 2009; Cai *et al*., 2010; Cheng *et al*., 2011) showed better photocatalytic properties than low dimensional ZnO nanostructures, such as nanoparticles, nanorods, nanosheets, nano-tetrapods, etc. (Guo *et al*., 2011). High surface areas offered by hierarchical ZnO nanostructures make them a popular choice in solar photocatalysis, as more pollutant could be easily adsorbed and a higher rate of degradation can be achieved, enhancing the photocatalytic activity (Mukhopadhyay *et al*., 2015).

Enhanced Light scattering of photocatalyst

Hierarchical porous and hollow nanostructures increase the light-harvesting ability of photo-catalysts. The interconnected pores in their structures increase the number of light traveling paths and thereby facilitate their light-harvesting ability (Wang *et al*., 2005). The mesoporosity structures not only act as distribution channels increasing absorption of visible light but also create an ideal environment for mass transportation of electrons. Due to these facts 2D ZnO nanoflowers and porous 3D hierarchical ZnO nanostructures possess better light scattering properties when compared to ID nanorods. Sinha *et al*. (2010) showed hierarchical ZnO hollow spheroids exhibited enhanced photocatalytic in dye degradation due to efficient utilization of light through the multiple reflections of light in their hollow structures.

Synergistic nano-building blocks and multi-components

Hierarchical nanostructures are composed of 3D self-assembly of primary structure e.g., nano-particle, nanorod, nanotube or nanosheets in nanoscale. 3D hierarchical structures inherit the excellent properties of the single nano-sized building blocks and also possess superior photo-catalytic performance due to charge transfer and separation among the well-organized nanoscale building blocks (Han *et al*., 2015; Ko *et al*., 2011).

Problems associated with photocatalytic applications of ZnO

First, the recombination of photogenerated electron-holes pairs which deteriorates the charge transport leading to low reaction efficiency at the ZnO photocatalyst surface. Another problem associated with ZnO photocatalyst is its limited light harvesting efficiency. ZnO has a large bandgap (3.37 eV) which restricts its light absorption only in ultraviolet region and thus, limits the practical applications of ZnO photocatalysts for solar light harvesting. Therefore, intense efforts have been made to improve the photocatalytic activity of ZnO under solar illumination by minimizing the bandgap energy and inhibiting the recombination of photogenerated electron-hole pairs.

Fabrication of hierarchical ZnO nanostructures and nanocomposites

The development of visible-light active zinc oxide photocatalyst is one of the key challenges in the field of semiconductor photocatalysis. Various techniques have been used to improve the -photocatalytic efficiency of ZnO such as coupling of ZnO with either wide band or narrow band semiconductors, surface modification of ZnO with noble metals, metals/non-metal doping of ZnO, etc., which are discussed below:

Coupling ZnO with other semiconductors

Coupling ZnO-based composites with either wide band or narrow band semiconductors serve as an attractive alternative for enhancing the photoactivity. Chiang and Lin (2012) have shown that the increased charge separation was due to an extended lifetime of charge carriers by inter-particle electron transfer between the conduction bands of nanocomposites leading to a larger number of electrons involved in a photo-degradation reaction. Nur *et al*. (2007), showed that highly active photocatalysts can be obtained by coupling two semiconductors having different band gaps. Coupling of different semiconductor oxides can reduce the band gap,

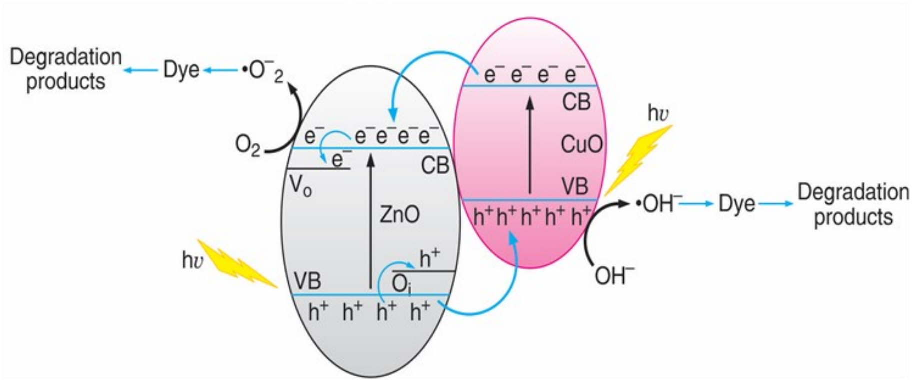

Figure 2. Schematic diagram of the ZnO-CuO nanocomposite showing the charge transfer process.

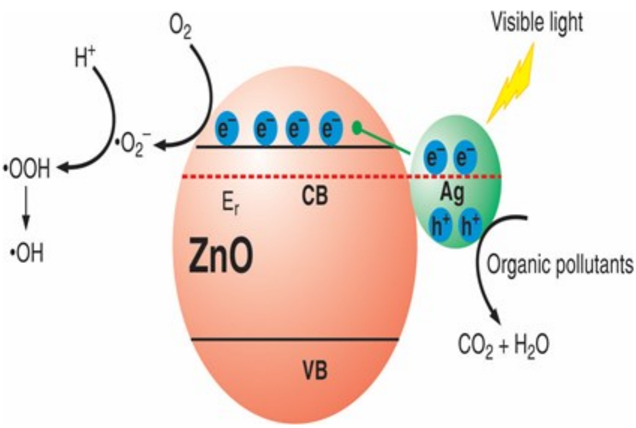

Figure 3. Schematic diagram of the Ag-ZnO nanocomposite showing charge transfer process

extending the absorbance range to visible region leading to electron–hole pair separation under irradiation due to photoinduced electrons that are transferred away from the photocatalyst. When ZnO-CuO nanocomposite is irradiated by photons, electrons flow to the conduction band of ZnO while the holes flow to the valence band of CuO and efficient charge separation is maintained (Li *et al.*, 2010). For example, Xiao *et al*. (2014) prepared branched hierarchical ZnO nanorod-TiO_2 nanotube array heterostructures via a two-step assembly method. Various combinations of wide band semiconductors, such as a TiO_2 nanobelt/ZnO nanorod hierarchical nanostructure (Pan *et al.*, 2013), branched hierarchical TiO_2/ZnO hierarchical nanostructures (Athauda *et al.*, 2012), ZnO-SnO_2 hollow spheres (Wang *et al.*, 2007) were developed, which showed an enhanced photocatalytic property (Figure 2).

Noble metal loading

Plasmonic photocatalyst is usually prepared by incorporating noble metal nanoparticles such as Au, Ag, Pt, etc., onto the ZnO semiconductor to improve its photocatalytic performance under both UV and visible light illuminations. Fermi levels of these noble metals are lower than that of ZnO, which results in the effective transfer of the photogenerated electrons from the conduction band of ZnO to metal particles, which serves as a passive sink for electrons and therefore it hinders the recombination of electron-hole pairs. The enhanced photoactivity of plasmonic photocatalysis is due to Schottky contact and localized surface plasmon resonance (LSPR) (Zhang *et al*., 2013). The Schottky contact formed at the interface between noble metal and the semiconductor enhances the migration of photogenerated electrons and holes in opposite directions. The electron-hole recombination is reduced and the charge transfer would be facilitated by the noble metal anchored at the surface. LSPR improves the photocatalytic activity by extending light absorption of semiconductor to longer wavelengths, increasing the scattering of visible-light. Since LSPR takes place at the surface of the anchored noble metal and the size of the noble metal nanoparticles is very small, it enables the fast electrons or holes transfer to the surface. Ahmad *et al*. (2011) synthesized hierarchical flower-like ZnO-Au nanostructures via an electrochemical method. Nanoplate-built ZnO hollow microspheres decorated with Au nanoparticles were produced by Xia *et al*. (2015) through solvothermal route. The enhanced photocatalytic activity of Ag-ZnO indicates that the Ag NPs anchored at the surface of p-ZnO behave like an electron sink, which could increase the separation of the photogenerated electron-hole pairs and inhibit their recombination (Figure 3).

Non-metal doping

Recent studies (Figure 4) have demonstrated that non-metal dopants such as nitrogen, carbon, sulfur and fluorine can shift the bandgap of ZnO upwards and narrow the bandgap energy to the ultraviolet-visible region and thus, enhance solar energy utilization of ZnO photocatalyst (Liu *et al*., 2011). Due to their smaller band gaps, ZnO hierarchical photocatalysts doped N and C have been found to exhibit better absorption of light in both visible and ultraviolet regions (Yu *et al*., 2016). Liu *et al*. (2011) reported better photocatalytic decomposition of the RhB dye by hierarchical flower-like C-doped ZnO superstructures in aqueous solutions than ZnO due to their enhanced solar light absorption.

Coupling of nanocarbon component to ZnO

ZnO hierarchical structures have been synthesized (Figure 5) by combining it with reduced graphene oxide (r-GO) and carbon nanotube (CNT) due to their good conductivity and large surface area. The heterojunction of ZnO with carbon nanotubes (CNTs) can enhance the performance of nano-composites by acting as electron scavenging agents (Fan *et al*., 2012) while

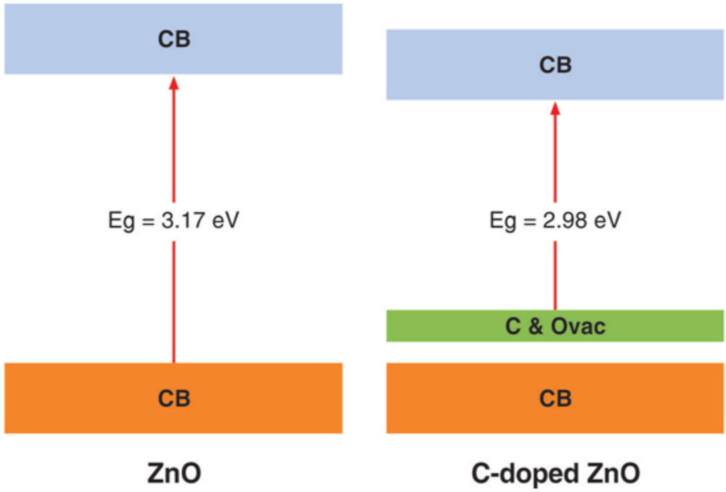

Figure 4. Schematic band structures of ZnO and C-doped ZnO crystals. (Adapted from Ahmad et al., 2015).

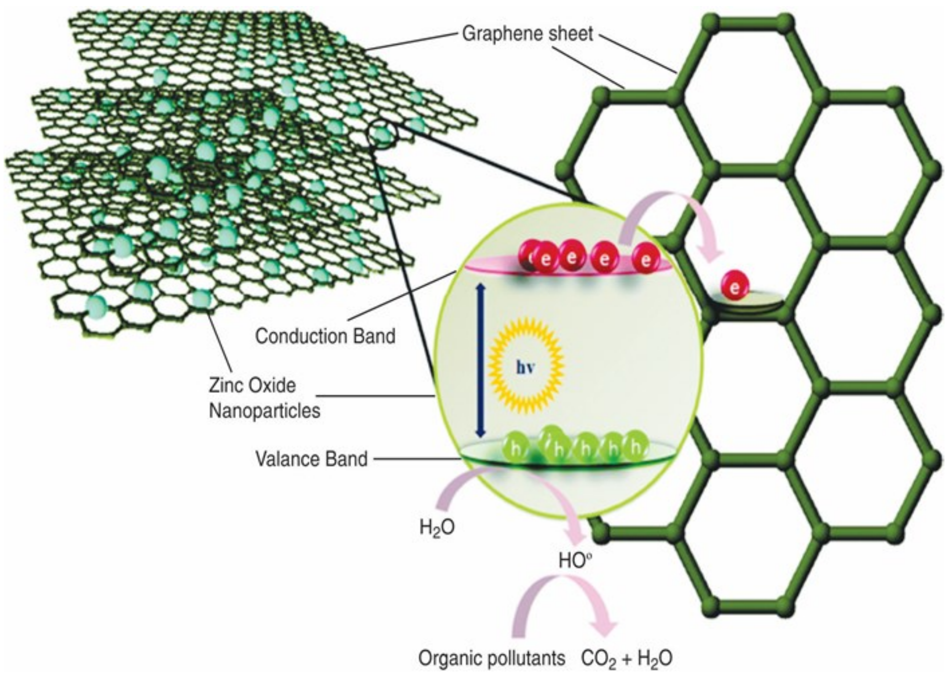

Figure 5. Mechanism of electron transfer from conduction band of zinc oxide to graphene sheets

heterostructure of ZnO/GO has greater carrier transport efficiency due to the graphene encapsulation, specific surface area and electrical transport properties (Li *et al*., 2012) Luo *et al*. (2012) preapred rGO-hierarchical ZnO hollow sphere composites via ultrasonic method to enhance the photocurrent and photocatalytic activity due to the conjunction between rGO and ZnO could be attributed to electronic interaction between the components. Zhang *et al*. (2006) prepared a ZnO-CNT heterostructure via hydrothermal method in which ZnO nanowires were grown on carbon nanotube (CNT) arrays serve as the nucleation sites for the growth of the ZnO nanowires.

Metal doping

Recently, metals like transition metals, rare earth metals and other metals have shown advantages in tuning the morphology of ZnO in photocatalytic applications. Metal doping of ZnO can improve the photoactivity of catalyst by increasing the trapping site of the photo-induced charge carriers and thus decreasing the recombination rate of photoinduced electron-hole pairs (Rezaei *et al*., 2013). In order to decrease the bandgap energy of photocatalysts, metal dopants such as Ce, Nd, Cu and Al have been used in in dye degradation.

Photocatalytic degradation of organic contaminants

When the ZnO semiconductor is excited by solar light greater than its bandgap energy, an electron is excited from the filled valence band (VB) to an empty conduction band (CB), creating an electron-hole pair (e^-/h^+). The electron-hole pairs move to the ZnO photocatalyst surface and take part in redox reactions (Figure 6). The H^+ reacts with water and OH^- ions to produce hydroxyl radicals while e^- reacts with oxygen to produce superoxide radical anions then hydrogen peroxide which further reacts with superoxide radicals to form hydroxyl radicals. The resulting hydroxyl radicals, which are powerful oxidizing agents, attack the pollutants adsorbed on the surface of ZnO to rapidly produce intermediate compounds that get mineralized to green products such as CO_2, H_2O and mineral acids.

The photoexcitation of ZnO semiconductor by UV light irradiation, followed by the formation of electron-hole pairs can be expressed below (Rauf *et al*., 2009; Rajamanickam *et al*., 2016):

$$ZnO + hv \rightarrow ZnO\,(e^-_{(CB)}) + (h^+_{(VB)})$$

The photogenerated holes are involved in oxidation reaction and electrons are involved in reduction reaction, as illustrated by the following reactions:

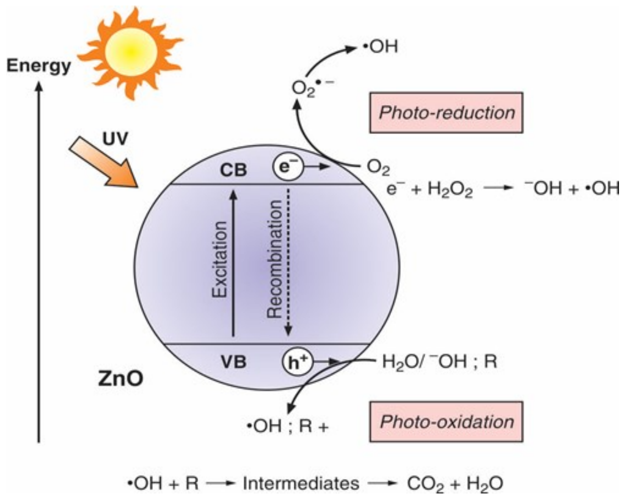

Figure 6. A schematic diagram illustrating the principle of photocatalysis

Photooxidation reactions:

$$ZnO(h^{+}_{(VB)}) + H_2O \rightarrow ZnO + H^+ + OH\bullet$$
$$ZnO(h^{+}_{(VB)}) + OH^- \rightarrow ZnO + OH\bullet$$

Photoreduction reactions:

$$ZnO(e^{-}_{(CB)}) + O_2 \rightarrow ZnO + O_2\bullet^-$$
$$O_2\bullet^- + H^+ \rightarrow HO_2\bullet$$
$$HO_2\bullet + HO_2\bullet \rightarrow H_2O_2 + O_2$$
$$ZnO(e^{-}_{(CB)}) + H_2O_2 \rightarrow OH\bullet + OH^-$$
$$H_2O_2 + O_2\bullet^- \rightarrow OH\bullet + OH^- + O_2$$
$$H_2O_2 + hv \rightarrow 2OH\bullet$$
$$\text{Organic pollutants} + OH\bullet \rightarrow \text{Intermediates}$$
$$\text{Intermediates} \rightarrow CO_2 + H_2O$$

During the photocatalytic process, free electrons/holes, and reactive oxidizing species (ROS) such as $HO_2^\bullet$, $HO^\bullet$ and $O_2^{\bullet-}$ react with the surface adsorbed impurities including inorganic, organic compounds, and biological species (bacteria, virus *etc*.) leading to their decomposition. Recombination of the separated electron and hole can occur in the volume of the semiconductor particle or at the surface within nanoseconds after the generation of electrons and holes by photon illumination and the energy is usually dissipated as heat. The electrons on the surface semiconductors can react with oxygen to form superoxide anion and prevents the recombination of electron-hole pairs.

Conclusions

ZnO nanostructures have been shown to be a promising photocatalyst for visible light photodegradation process of organic pollutants due to its low production cost, non-toxic and ability to absorb larger fraction of solar spectrum. Hierarchical ZnO nanostructures have been fabricated to achieve efficient photocatalysts due to their multiple advantages, such as large surface area, porous structures, as well as enhanced light harvesting ability. Various methods that have been attempted to enhance photoresponse of ZnO nanostructures such as coupling of two semiconductors, surface modification of ZnO with noble metals, and doping with metals/ non-metals. These techniques enhance the photocatalytic performance ZnO under visible light by shifting the bandgap energy, suppressing the recombination rate of electron-hole pairs, increasing charge separation efficiency. In future there is a need of developing green, scalable, low-cost and highly efficient hierarchically ZnO nanostructures and nanocomposites photocatalyst for remediation of wastewater pollution.

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Cite this chapter as: Malhotra, S.P.K. (2020). ZnO nanostructures and nanocomposites as promising photocatalysts for the remediation of wastewater pollution. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 120-132, https://doi.org/10.26832/aesa-2020-edcrs-09

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-010

CHAPTER
[10]

Remediation of heavy metals using non-conventional adsorbents and biosurfactant-producing bacteria

Swati Rastogi* and Rajesh Kumar

Rhizosphere Biology Laboratory, Department of Microbiology, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar Raebareli Road, Lucknow, India

ABSTRACT

Heavy metal pollution in the ecosystem has attracted worldwide attention due to the persistent non-biodegradable toxic nature that affects not only human beings but also animals and vegetation. Instead of using available conventional techniques, the focus has been shifted to utilize eco-friendly, cost-effective, integrated remediation approaches that are simple, non-conventional with design flexibility and does not harm the prevailing surroundings. The main approaches utilized for remediation of heavy metal contaminated soils are sand capping or land filling, phytoremediation, bioremediation, washing, electro-chemical remediation, stabilization, soil replacement, phytoextraction, phytovoltalization, etc., but again they have their own merits and demerits. Many treatment technologies are employed at industrial scale for HM removal from wastewater effluents such as chemical precipitation, flocculation, coagulation, solvent extraction, adsorption, complexation, electro-kinetics, membrane filtration, etc. Therefore, the present chapter critically highlights the role of non-conventional adsorbents and bacterial surfactants as the best alternative technique for heavy metal remediation from contaminated soil and water systems.

KEYWORDS

Adsorbents, Bio-surfactants, Environmental sustainability, Heavy metals

Swati Rastogi, Email: sswatirrastogi73@gmail.com

Introduction

The industrial processes/discharge and natural weathering are the two main causes of heavy metal (HM) pollution due to which the latter are dispersed into land and water ecosystem leading to environmental pollution. The gradual acclimatisation of these soluble metal ions above their permissible limits and their accumulation in the food web exerts adverse toxic and malignant effects on the living forms (Kumar *et al.*, 2019). These HM ions are persistent and can cause their effect even at very low concentrations. HM toxicity directly affects the normal functioning of the body. Lead (Pb) and Cadmium (Cd) are considered as one of the two deadliest HM ions whose persistence over a long period of time can affect central nervous system, can cause damage to vital organs such as lung and kidneys. The main sources of Pb and Cd are paint and pigment industries, electroplating and battery industries. Cd is also released into the environment as a by-product during smelting of Pb and Zinc (Zn) (Dinis and Fiuza, 2011). Mercury (Hg) being another toxic HM ion is discharged through minings, volcanic eruptions, pharmaceutical industries, etc. whose high concentration can affect immune system leading to abnormal brain functioning (Rastogi *et al.*, 2019; Mahmud *et al.*, 2016). Table 1 discusses about some of the common heavy metal ions, source of discharge, permissible limits in different ecosystem and their harmful effects.

Many treatment technologies are employed at industrial scale for HM removal from wastewater effluents such as chemical precipitation, flocculation, coagulation, solvent extraction, adsorption, complexation, electro-kinetics, membrane filtration, etc. (Mohammed *et al.*, 2015) but these are conventional approaches and have their own limitations which are discussed in the coming section (Table 2). The main approaches utilized for remediation of heavy metal contaminated soils are sand capping or land filling, phytoremediation, bioremediation, washing, electro-chemical remediation, stabilization, soil replacement, phytoextraction, phytovoltalization, etc. (Koptsik, 2014; Kumar *et al*., 2019) but again they have their own merits and demerits. The focus has been shifted towards assessing non-conventional approaches or materials to remediate such noxious HM ions from the environment.

Conventional approaches and their limitations

The era of wastewater treatment has given birth to many physico-chemical conventional approaches that has been raised to an alarming rate leading to the generation of secondary toxic sludge/by-products, requires large operational cost and expensive chemicals plus can work efficiently at high concentrations only due to which more attention is diverted towards non-conventional approaches or employing conventional approach using non-conventional methods

Table 1. Sources of heavy metals, types, their permissible limits, and harmful effect on living and non-living system.

Heavy metal	Sources	Permissible limit in soils (mg/kg) adapted from Deuel and Holliday (1994)	Permissible limit in drinking water (mg/L) ; WHO standards	Toxic effect	References
Cd	Electroplating, Pigmented products, mining etc.	0.01-0.7	0.005	Damage to liver, kidneys, hypertension, carcinogenic	Pavon *et al*. (2019); Das and Al-Naemi (2019)
Cu	Wood processing industries	2-100	1.0	Dermatitis, chronic asthma, generation of free radicals	Alak *et al*. (2019)
As	Wood processing industries, through herbicides, mining, etc.	1-50	0.05	Visceral cancers, kidney and vascular disease,	Navasumrit *et al*. (2019)
Pb	Paint and pigment industries, batteries, automobiles, etc.	2-200	0.05	Damage to brain, fetus, liver, kidneys, bones,	Chung *et al*. (2019)
Zn	Electrolysis, Galvanization processes, paints, fertilizers, etc.	10-300	5.0	Nervous sytem dysfunction, growth retardation	Poole *et al*. (2019)
Hg	Soil leaching, fossil fuel burning, etc.	0.01-0.3	0.001	Circulatory and nervous system disorders,	Cariccio *et al*. (2019)
Fe	Smelting, fertilizers, mining, etc.	7000-550,000	0.1	Retarted growth, low RBC count	Hino *et al*. (2019)

Table 2. Merits and demerits of common conventional approaches of wastewater treatment.

Technology	Heavy metal	Advantages	Disadvantages	References
Chemical precipitation	Cu(II), Zn(II), Cd (II), Pb(II)	Cheap and Simple method	Sludge generation, costly, can't detect low metal ion concentration	Huang *et al.* (2019); Wu (2019)
Ion exchange	Pb(II), Cu(II), Ni (II)	Regeneration of resins is possible	Expensive, secondary pollutant generation	Nemati *et al.* (2019); Ma *et al.* (2019)
Coagulation/ Flocculation	Pb(II), Cd(II), Cu (II), Cr(III), Ni (II), Co(II), As (III)	Sludge settling characteristics	High chemicals input and maintenance	Bora and Dutta (2019)
Membrane filtration	Zn(II), Cd(II), Pb (II) , Hg(II)	Highly efficient	A complex and costly method	Ye *et al.* (2019); Efome *et al.* (2019)
Floatation	Sr(II), La(III), As (V)	Selectivity, efficiency	High maintenance and operational conditions	Elazzouzi *et al.* (2019); Taseidifar *et al*. (2019)
Electro-chemical treatment	Cd(II), Pb(II), Zn (II)	Fast and controlled process	High operational cost	Giwa *et al*. (2019); Delil *et al*. (2020)
Adsorption	Cr(VI), Zn(II), Pb (II), Cd(II), Cu(II)	Cost effective by using low cost adsorbents, Biosorption-a new vista in adsorption technology	Process efficiency depends on type of adsorbent used	Kyzas *et al*. (2019); Sharma *et al*. (2019)

or materials (Rangabhashiyam *et al*., 2019). However, the advantage and disadvantages of some of the common conventional approaches have been summarized in Table 2.

Sustainable amendments for heavy metal remediation

Adsorption

Among all the conventional approaches available for remediation of heavy metals, adsorption is the most appropriate ancient technology as it is simple to perform, requires less operational cost and has design flexibility. C.W. Scheele in 1773 showed first time the uptake of gases onto charcoal and clays (Bhatnagar and Minocha, 2006) but the term 'Adsorption' was coined by a German physicist Heinrich Kayser in 1881 (Calvert, 1990). It is defined as a surface phenomenon which involves adherence or binding of a chemical species (known as adsorbate) on to the solid or liquid surfaces termed as adsorbent (Crini *et al*., 2019). An adsorbent is selected on the basis of its pore size (surface porosity), high surface area and surface chemistry and the type of pollutant in study (Bhatnagar and Minocha, 2006).

Heavy metal remediation using non-conventional adsorbents

The usage of commercial activated carbons (CACs) or materials that are being converted into ACs are being restricted due to their expensive operational and manufacturing cost and attention has been shifted towards application of cost effective non-conventional adsorbents (NCAbs). These NCAbs could be of biological origin or from natural materials and can be applied directly in their raw or treated form (Crini *et al*., 2019). Their application has been increased at an alarming rate in the past few years as they are abundant in nature, are economical ready to use (or can be modified) but their usage is still restricted to pilot scale and needs to be explored more in large field applications (Sangeetha *et al*., 2017).

Agricultural solid wastes as adsorbents/ nonconventional green adsorbents: In recent years, agricultural solid waste (ASW) has been explored at various levels in their natural or modified form using physico-chemical methods for pollutant removal as former mainly composed of lignin, hemicellulose, lipids, hydrocarbons, carbohydrates, proteins, water that contain various functional groups on their surfaces (Gisi *et al*., 2016). These functional groups present on their surfaces have charges that can facilitate binding of a particular pollutant by varying pH levels (Rastogi *et al.,* 2019). Rosales *et al*. (2019) investigated the role of untreated lime peel and pineapple core wastes in the removal of Cr (VI) from aqueous solutions with adsorption capacities of 9.20 and 4.99 mg/g respectively at pH 2.01. In an another recent study conducted using peels of *Artocarpus nobilis* for the removal of Ni(II) showed enhanced metal removal efficiency from 50 to 71 to 93% through optimization processes having 12,048 mg/kg as maximum adsorption capacity via static and dynamic conditions with Freundlich model as the best fitted adsorption model where regression coefficient has 0.994 value (Priyantha and Kotabewatta, 2019). An efficient adsorption process includes optimization of various factors that can affect an adsorption study such as pH, adsorbent dose, reaction contact time, initial metal concentration, temperature, revolutions per minute (rpm), pressure, etc. which are needed to be identified for the large scale application of adsorption process (Guyo *et al.,* 2017). Biswas *et al.* (2019) employed central composite design (CCD) for adsorption factors optimization using a novel biochar aliginate composite adsorbent in the removal of Zn(II) ions. They reported the initial Zn(II) concentration (43.18 ppm) and adsorbent dose (0.062 g) as most effective factors on account of high f-value which explained maximum adsorption capacity of 120 mg/g giving 85% removal efficiency. Though the conversion of agricultural waste residue at nano-scale level provides high surface area but also leads to difficulty in their separation from the study system, therefore, focus has been shifted to utilise them in the dual form where an adsorbent is merged with a suitable membrane (Zeng *et al.*, 2016). Hubadillah *et al.* (2016) explored the efficiency of green ceramic hollow fibre membrane (CHFM) synthesised from rice husk ash (RHA) in removal of Ni(II), Zn(II) and Pb(II) ions giving 99% removal rate. The modified CHFM/RHA based dual function material and others might serve as a promising low-cost adsorbent + filtration unit for the removal of noxious heavy metal ions from the aqueous systems.

Industrial by-products as low-cost adsorbents: The processing of substances at industrial level generates huge amount of secondary wastes whose disposal is another problem but these can be utilised as adsorbents in their raw or modified form. For instance, the iron industry during smelting of iron in blast furnace produces slag waste whereas coal industry generates fly ash wastes that can be optimized for heavy metal removal from waste streams. Nguyen and his team assessed the removal efficiency of slag and fly ash wastes in the removal of five metals (Pb, Cu, Cd, Cr and Zn) and found the maximum adsorption capacity for Pb and Cd, when used in multiple metal system at an optimum pH 6.5 (Nguyen *et al.*, 2018). Another mixed metal system study conducted by Ma *et al.*, (2018) reported the maximum adsorption capacities to be 420.17, 680.93, 251.89, and 235.29 mg/g for Ni(II), Cu(II), Zn(II) and Co(II) respectively using a novel waste product 'calcium silicate powder' as adsorbent obtained during alumina production in coal ash industry. Liu *et al.* (2017) employed fly ash based granular adsorbent containing zero valent iron (ZVI-GAM) for the removal of Pb(II) and Cr(VI) from the aqueous system with 78.13 and 15.70 mg/g maximum adsorption capacities respectively. Red mud is another waste by-product that is being exploited as an efficient adsorbent. Hydrazine sulphate mixed red mud when incorporated in calcium alginate beads utilised as an excellent adsorbent for Pb(II) ions removal having 138.6 mg/g adsorption capacity (Babu *et al.*, 2017). Tsamo *et al.* (2018) explored the efficiency of low cost raw and hydrocholoric acid treated red mud in the removal of Cr(VI), Cu(II) and Pb(II). They reported that acid treated red mud had only little affect in removal of Cr(VI) and Cu(II) but had increased removal percentage for Pb(II) (79.365 from 52.083 μmol/g adsorption capacity). Ahsaine *et al.* (2017) reported the use of sulphuric acid modified sewage sludge for the removal of Cd(II) ions from aqueous system with adsorption capacity of 56.2 mg/g. A similar study explored the role of thermally (physical activation) modified sewage sludge in the removal of Cu(II) giving about 73% removal rate from the synthetic wastewater (Abdel-Aziz *et al.*, 2017). In the recent years, many researchers have worked with industrial wastes as suitable adsorbents for the heavy metal removal.

For instance, iron ore slime (a mining waste) for Pb(II) and Hg(II) removal (Sarkar *et al.*, 2017); carboxymethyl-chitosan treated solid sludge biochar for Pb(II) and Hg(II) ions (Ifthikar *et al.*, 2018); coal fly ash for Hg(II) removal (Attari *et al.*, 2017); magnetic 4A-zeolite from red mud for Al (III), Fe(II), and other metals (Xie *et al.*, 2018). Recently, hollow porous granules (PS-HPGs) were synthesised from industrial wastes of polysulphone hollow fibre membranes when incorporated with nano-range polydopamine (PD) served as efficient adsorbent for the 80% removal of Cu(II) ions and for Zn(II) and Ni(II) ions after certain modifications (Posati *et al*., 2019).

Natural materials: It is usually advocated that mesoporous adsorbents derived from natural materials are good candidates for the heavy metal removal study as these provide large surface activity due to large surface area and uniform large pore size. Mesoporous silica materials (MSMs) derived from MCM41 type was investigatd in the removal of Cu(II), Cd(II) and Pb(II) with adsorption capacities around 36.3,32.3 and 58.5 mg/g in the pH range 5-7 (Zhu *et al*., 2017). Vojoudi *et al.* (2017) evaluated the efficiency of magnetic mesoporous silica as nanoadsorbent for the removal of Pb(II) and Hg(II) ions in batch study leading to 303.03 and 256.41 mg/g adsorption capacities respectively.

Microbial bioadsorbents: The utilization of microorganisms in the eradication of toxic pollutants from contaminated environment is known as bioremediation. Their inbuilt biosorptive or bioaccumulative mechanistic ability (Javanbakht *et al*., 2014) helps them to tolerate heavy metal toxicity that can be employed in many ways such as absorption, adsorption, oxidation, etc. in pollutant removal or in restoration of original environment (Rajendran *et al*., 2003). Also, these microorganisms either bacteria, fungi or alga are being exploited in their live as well as dead form that makes them as potential biosorbing agents for the sequestration of heavy metal ions from the aqueous environments (Ayangbenro and Babalola, 2017). Jaiswal *et al.* (2018) used alginate beads immobilized with fungal biomass as biosorbing material in the removal of As at pH 6 and found the adsorption capacity of about 59.5 mg/g. The potential of dried *Gelidium amansii* (marine alga) biomass in free and immobilized form was assessed for the removal of Pb(II) leading to 100% removal percentage at pH 4.5 (El-Naggar *et al*., 2018). Jin *et al.* (2017) investigated the potential of bacterial cellulose pellicles modified with polyethyleneimine in the removal of Cu(II) and Pb(II) ions with maximum adsorption capacities to be 148 and 141 mg/g respectively. Microorganisms are being used not only as whole in live or dead form as adsorbents but their secretions are also explored as suitable adsorbents for the removal of toxic metal ions from waste streams. Castro *et al.* (2018) explored the efficiency of biogenic (bacterial) iron compounds mainly siderite and magnetite as adsorbent in the removal of Cu, Zn, As, and Cr and reported higher removal percentage for As in single and bimetal system (As-Cu). Li and Zhou (2018) used heavy metal resistant immobilized *Brevibacterium* as bioadsorbent for the removal of Pb and Cd having 114.36 and 82.12 mg/g maximum adsorption capacity. A brief overview of various non-conventional adsorbents has been summarized in Table 3.

Nanoadsorbents/nanocomposites: The applicability of adsorbents that are carbon-based or metal oxide and metal organic frameworks (MOFs), zeolites in the nano-range has been increased in the recent years due to their large surface area and high surface chemistry (Nasir *et al*., 2019). Zanin *et al*. (2016) assessed the role of natural clinoptilolite zeolite (CL) as adsorbent in the

Table 3. Explains various examples of non-conventional adsorbents, target heavy metal ion(s) and their adsorption efficiency.

Non-conventional adsorbent type	Example	Target heavy metal ion(s)	pH	Adsorption capacity (mg/g)	References
Nanocomposites/ Biocomposites	Chitosan-boehmite desiccant composite	Pb(II), Cd (II), Hg(II)	6-7 (Pb(II), Cd (II) & 10 (Hg (II)	98.84, 99.54, 74.98	Rajamani *et al.* (2019)
Nanocomposites/ Biocomposites	Cellulose biocomposite sponge	Hg(II)	5.5	495	Zhang *et al.* (2019)
Nanocomposites/ Biocomposites	Fe3O4@BHPS	Pb(II), Cd (II)	5.5, 7.1	186.2, 125	Alqadami *et al.* (2019)
Nanocomposites/ Biocomposites	SiO2@chitosan composite	As(V), Hg (II)	6-7	198.6, 204.1	Liu *et al.* (2019)
Agro-Industrial wastes	Zeolite from JIS type II fly ash	Hg(II), Pb (II)	5	30.8, 40.5	Kobayashi *et al.* (2020)
Agro-Industrial wastes	Carboxymethylated softwood kraft pulp cellulose fibers	Cu(II), Ni (II)	6	16.90, 11.63	Wang *et al.* (2019)
Agro-Industrial wastes	Lemon peel	Cu(II)	3	13.2	Meseldzija *et al.* (2019)
Agro-Industrial wastes	Acid modified Biochar from rice husk	Cr(VI)	2	4536µg/g	Sarkar *et al.* (2019)
Microbe based/ Microbial bioadsorbent	Bacterial cellulose/ attapulgite magnetic composites	Cu(II), Cr (VI), Pb (II)	5.5	70.5, 91.0, 67.8	Chen *et al.* (2020)
Microbe based/ Microbial bioadsorbent	Graphene oxide based bacterial cellulose	Cu(II), Cd (II), Pb(II)	5-5.5	91.32, 148.37, 160.0	Luo *et al.* (2020)
Microbe based/ Microbial bioadsorbent	*Pseudomonas* sp. strain 375 (live and dead form)	Cd(II)	7	92.59, 63.29	Xu *et al.* (2020)
Microbe based/ Microbial bioadsorbent	*Penicillium* sp.	Pb(II)	5.5	0.16	Rastogi *et al.* (2019)
Microbe based/ Microbial bioadsorbent	*Pseudomonas* sp. strain DC-B3	Cu(II), Cd (II)	6	12.6, 26.5	Liang *et al.* (2019)
Industrial byproducts	Graphene oxide based newspaper wastes	Pb(II), Ni (II), Cd(II)		75.41, 29.04, 31.35	Chen *et al.* (2020)
Industrial byproducts	Incinerated sewage sludge ash	Pb(II)	6	62.42	Wang *et al.* (2019)
Natural materials	Magnetic Fe_3O_4-chitosan@bentonite	Cr(VI)	2	62.1	Feng *et al.* (2019)
Natural materials	Clay minerals (bentonite, volcanic ash soil, red soil)	Ni(II), Cu (II), Zn(II)	-	99.9, 99.9, 89.2	Esmaeili *et al.* (2019)

removal of heavy metals from graphic industry with removal efficiency up to 95.4, 96.0 and 85.1% for Fe, Cu and Cr respectively. But these nanocomposites tend to agglomerate that results in reduction of surface area, also gives rise to recyclability and environmental issues due to which these are utilized in hybrid composite forms (Bajpai *et al*., 2019). Shahat *et al.* (2015) explored the role of an organic nano-ligand N, N'-di (3-carboxysalicylidene)-3, 4-diamino-5-hydroxypyrazole that was anchored using building block approach on mesoporous silica and termed as facial adsorbent for the removal of Co(II) ions from their aqueous solutions and reported maximum adsorption capacity of 157.73 mg/g at higher pH values. In an another similar study conducted by Vafaeifard *et al*. (2019) analysed the potential of nanostructured flowerlike $Mg(OH)_2$ that was assembled on granular polyurethane as nanoadsorbent for the removal of Cu (II), Cd (II) and Pb (II) with astonishing 472, 1050 and 1293 mg/g adsorption capacities respectively in batch processes and up to 184 mg/g adsorption capacity for Cu(II) in a continuous-flow column study. Bio-nanocomposites are advantageous as they impart biodegradability, biocompatibility and antimicrobial activity (Bajpai *et al.*, 2019). Souza *et al*. (2018) investigated the potential of *Malpighia emarginata D.C.* seed fibers microparticles (Me-SFMp) as bioadsorbent and found metal removal efficiencies up to 81, 84.2, 86.8, and 95.1% for Ni, Cu, Pb and Cr respectively while 100% for both Zn and Cd. An efficiency of a novel chitosan-iron (oxyhydr) oxide composite known as chitosan goethite bionanocomposite (CGB) in the form of beads was explored and found to remove As(V) more than As(III) from aqueous solutions through diffusion-adsorption mechanism (He *et al*., 2016). Ahmad and Mirza (2015) evaluated the role of methionine modified bentonite/alginate (Meth-bent/Alg) in the removal of Pb(II) and Cd(II) at pH 5 and 4 respectively with 30.86 and 217.39 mg/g adsorption capacities at 303 K respectively.

Polymer-layered silicate nanocomposites (PLSNs) and polymer-functionalized nanocomposites (PFNCs) are emerging as superior nonconventional nanocomposites as these provide stability, better reinforcement rate at less than 10%, resistance against many solvents, temperature, ions and have mechanical strength, diverse functional groups on their surfaces leading to strong specific bindings to metal ions or any other pollutant (Ucankus *et al.*, 2018; Bajpai *et al.*, 2019).

Bacterial bio-surfactants

The unfavourable environment triggers a stress response in microorganisms such as bacteria and fungi to produce various secondary metabolites to cope up with those antagonistic conditions. Bacterial bio-surfactants are one such compound that has proved their existence fruitful for the bioremediation of inorganic contaminants particularly heavy metals (Akbari *et al.*, 2018). Table 4 explains about different class of biosurfactant and their types along with latest metal remediation potential. Some of the common properties that make a bio-surfactant molecule to be preferred over chemical surfactants are surface and interfacial tension reduction ability, highly tolerant to

Table 4. Bio-surfactant class/type producing microorganism and their action on metal ion type with removal method (adapted from Sarubbo *et al*., 2015)

Bio-surfactant class	**Bio-surfactant type**	**Microorganism**	**Target heavy met al**	**Remediation method**	**References**
Glycolipids	Rhamnolipids	*Psuedomonas* sp., *Shewanella* sp.BS4, *Marinobacter* sp.	Cd(II), Ni(II), Cu(II)	Washing	Shen *et al.* (2019); Lee and Kim (2019)
	Sophorolipids	*Candida* sp. AH62, *C. bombicola* ATCC 22214	Cu(II), Zn(II)	Washing	Da Rocha Junior *et al.* (2019)
	Trehalolipids	*Rhodococcus* sp.	Co(II)	Washing	Narimannejad *et al*. (2019)
	Mannosylerythritol lipids	*Ustilago* sp., *Moesziomyces antarcticus*	-	-	Bakur *et al*. (2019)
Lipopeptides and Lipoproteins	Lichenysin	*Bacillus* sp.	Cu(II), Pb(II)	Washing	Saleem *et al.* (2019)
	Surfactin	*Bacillus subtilis, paenibacillus* sp. D9	Pb(II), Cu(II), Zn(II), Fe(II), Ca(II), Ni(II), Cr(VI), Cd(II)	Washing	Jimoh and Lin (2020); Hisham *et al*. (2019)
	Carbohydrate-lipid-protein	*P. fluorescens*	Cr(VI)	Washing	Kalaimurugan *et al*. (2019)
	Mannan-lipid-protein	*C. tropicalis*	Cu(II), Zn(II), Pb(II), Cd(II)	Biosorption	Mbachu *et al*. (2019)
Particulate surfactants	Vesicles	*Pseudomonas marginalis*	Cd(II)	Plant growth promoting phytoremediation	Shahid *et al*. (2019)
	Whole microbial cells	*Cyanobacteria*	Cd(II), Cu(II), Pb(II)	Biosorption	Delneuville *et al*. (2019)

pH, salinity, temperature moderations, biodegradability and biocompatibility, less toxic, specificity and emulsification capacity (Usman *et al*., 2016). There has been done much work in the recent years that has proved the role of bio-surfactant producing bacteria in the bioremediation of heavy metal contaminated soils. Chen *et al*. (2017) assessed the potential of bio-surfactant rhamnolipid in washing of heavy metal ions from river sediment. A dose of 0.8% rhamnolipid removed Cu (80.21%), Cd (86.87%), Pb (63.54%) and Cr (47.85%) after 12 h at pH 7.0. They emphasised that the efficiency of washing depended on initial heavy metal ion speciation, rhamnolipid concentration, washing time, liquid/solid ratio and pH. In an another experimental setup, researchers modified the conventional electro-kinetic treatment with biodegradable rhamnolipid and complexing agent Tetrasodium of N, N-bis (carboxymethyl) glutamic acid (GLDA) in heavy metal removal from sewage sludge and showed significantly higher removal percentages of 70.6 ± 3.41%, 82.2 ± 5.21%, 89.0 ± 3.34%, 60.0 ± 4.67%, 88.4 ± 4.43% and 70.0 ± 3.51% for Cu, Zn, Cr, Pb, Ni and Mn respectively (Tang *et al*., 2017). Similar studies performed by Yang *et al*. (2018) proposed an efficient bioleaching technique using bio-surfactants from *Burkholderia* sp. Z-90 in combination with flocculation by poly aluminium chloride (PAC) as a cost effective, environment-friendly remediation model for severely heavy metal contaminated soils. Their results showed removal efficieny of Zn, Pb, Mn, Cd, Cu and As upto 44.0, 32.5, 52.2, 37.7, 24.1 and 31.6% respectively at 1:20 (w/v) soil liquid ratio for 5 days which were found to be more efficient than that by 0.1% of rhamnolipid. The bioremediation potential of bacterial bio-surfactants pertains to their high biodegradable nature, low toxicity, multi-functionality, environmental compatibility and economical production which make them an excellent alternative over various synthetic surfactants that are available in the market (Akbari *et al*., 2018).

Bio-surfactant mediated methods for the management of heavy metal contaminated soils

There are various methods available for remediation of heavy metal contaminated soils. The different in-situ approaches include surface capping, encapsulation, electro-kinetic extraction, soil flushing, chemical immobilization, bioremediation and phytoremediation and ex-situ methods are landfilling, solidification, soil washing and vitrification (Liu *et al*., 2018; Kumar *et al*., 2019) but bio-surfactant producing bacteria manages this high density metal pollution through soil washing and soil flushing methods (Ayangbenro and Babalola, 2018).

Soil flushing: This is an in-situ approach where a small quantity of biopolymer is injected in the contaminated soil in a cement mixer that has drain pipes or trenches for the introduction and collection of biopolymer solution into or out of the soil. This surfactant based flushing technique was first demonstrated by Pankow and Cherry (1996). The complex thus formed due to the strong bonding between anionic bio-surfactants and cationic heavy metal ions is flushed out of the mixer as it easily separates out from soil matrix and soil gets deposited back into it. The metal

-biopolymer complex precipitates out the biopolymer leaving behind the metal ion (Mulligan *et al.*, 2001; Ayangbenro and Babalola, 2018). Wang and Mulligan (2009) did column experiments to assess the potential of rhamnolipid JBR425 and found enhanced removal of As(V), Cu, Zn and Pb using 0.1% rhamnolipid with 70 pore-volumes flushing operation under alkaline conditions. The desorption of adsorbed metal ions from the adsorbent matrix can be enhanced by flushing the matrix with bio-surfactant-foam solution as demonstrated by Haryanto and Chang (2015) in removal of adsorbed Cu(II) ions from sand-packed columns.

Soil washing: This ex-situ remediation technology eliminates obnoxious heavy metal ions from the soil through washing and scrubbing of the soil with bio-surfactant solution (Sarubbo *et al.*, 2015). Diaz *et al*., (2015) assessed Fe and Zn removal from contaminated soil using alternate cycles of bioleaching with oxidising bacteria (*Acidithiobacillus thiooxidans* and *Acidithiobacillus ferrooxidans)* and washing with rhamnolipid solution and found the combined strategy to enhance removal percentage up to 36% for Fe and 63 % to 70% for Zn than alone treatments. The high percentage of toxic contaminants in the soil and sludge may obstruct nutrient recycling and land usage. The washing of soil sediments with bio-surfactant solution could provide a suitable bioremediation alternative that can enhance mineral availability and land application. Tang *et al*. (2019) showed increased metal mobility, binding ability and removal efficiency of Cu, Zn, Cr, Ni and Mn up to 62 %, 74 %, 60 %, 68 % and 64 % respectively than Pb (only 15 %) using rhamnolipids and saponins in multiple washing steps.

Mechanism of heavy metal removal by bio-surfactants

The working strategy for BS mediated HM remediation is based on Le Chatelier's principle either through precipitation or adsorption. BSs are capable of forming complexes with free metal ions present in the solution leading to desorption of metal ions (Wu *et al.*, 2017) from the solution phase. Qi *et al*. (2018) assessed the removal of Pb(II) and Cd(II) from soil by utilising sophorolipids of *Starmerella bombicola* CGMCC 1576 and reported about 95 and 52% of Cd and Pb removal percentage respectively by complexation mechanism in soil washing system. Secondly, as BSs can reduce the surface and interfacial tension of the medium, these get accumulated in the form of micelles on the solid/solution interface and bind the metal ions on themselves (Ayangbenro and Babalola, 2018). According to Tortora *et al.* (2016) the metal-BS complex or metal-micelle complex can be taken out from the system using micellar enhanced microfiltration (MEMF) or micellar enhanced ultrafiltration (MEUF). The efficiency of BSs depends on their size, class type, charge and structure that facilitates or determines their interaction with the sorbed metal on the soil (solid) surfaces (Wan *et al.*, 2017), also their translocation through soil pores on to the sorbed metal ions. Alternatively, the type of soil, its structure, contamination level and duration, pH, cation exchange capacity (CEC) and soil particle pore size also affects BS ability to remove metal ion from their surfaces or depth (Xue *et al.*, 2018; Pourfadakari *et al.*, 2019).

Surfactant/bio-surfactant modified low cost adsorbents (LCAs)

Chemically originated or biologically secreted surfactants are amphillic molecules having both hydrophilic and hydrophobic ends and are widely used in the HM remediation process where biological surfactants are preferred over chemically synthesised surfactants as the former have low toxicity, specificity, biodegradable nature, etc (Hailu *et al*., 2018). The natural materials such as zeolites and clays are known to be used as adsorbents in the HM removal process whose efficiency can be intensified by using acids or alkalies (Jimenez-Castaneda and Medina, 2017). In recent years, many studies have been conducted where these amphillic molecules when incorporated on such zeolites or clay materials, has increased the efficiency of the latter in the remediation process through ion exchange mechanism (Jimenez-Castaneda and medina, 2017; Li *et al*., 2007). Tran *et al.* (2018) explored the efficiency of cationic surfactant 'hexa-decyl-tri-methyl-ammonium' (HDTMA) modified organo-zeolite (Na-H-zeolite) in the removal of Pb, Cu, Ni and other organic pollutants. In a similar study, cationic surfactant 'hexa-decyl-tri-methyl-ammonium -bromide' C16 and zwitterionic surfactant 'hexa-decyl-di-methyl(3-sulphonatopropyl) ammonium' Z16 were applied on organo-montmorillonites for the removal of Cu(II) ions from the aqueous system (Ma *et al*., 2016).

Conclusion and recommendations

The application of non-conventional adsorbents and bacterial surfactants for the removal of heavy metal is gaining attention, owing to their easy availability, biodegradable nature and low toxicity. The agro-industrial wastes can be applied directly or in modified form for the treatment process and also can be used as substrates for the production of bio-surfactants making the remediation process more economical. The present chapter furnishes that this integrated approach can open up a novel aspect for remediation of heavy metal ions from the environment. Henceforth, more research is needed to be carried out to find new materials and novel bio-surfactants for environmental sustainability.

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Cite this chapter as: Rastogi, S. and Kumar, R. (2020). Remediation of heavy metals using non-conventional adsorbents and biosurfactant-producing bacteria. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 133-153, https://doi.org/10.26832/aesa-2020-edcrs-010

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-011

CHAPTER
[11]

Management and sustainable energy production using flower waste generated from temples

Vinod Kumar, Sonika Kumari* and Pankaj Kumar

Agro-ecology and Pollution Research Laboratory, Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), India

ABSTRACT

Temples are considered as the house of deities. As being a part of their culture, people of Hindu religion pay visits to the temple before starting any auspicious occasion to get blessings of their Gods. Out of them, those who are immense believers of God are the daily visitors of temples. As a part of worship, flowers are essentially used. As a result, a huge amount of flower waste is generated from temples worldwide. The majorly offered flowers in temples include rose, marigold, jasmine, *Hibiscus*, etc. The flower waste generated from such activities causes harmful effects to many life forms, therefore, its management has become an emerging issue. As flower waste contains enough nutrient and lignocellulosic material, it can be used for a variety of purposes like bioenergy and biofuel production, compost preparation, conditioner for lawn dressing, eco-friendly incense sticks, soaps, rose water and other food products, etc. To achieve sustainable energy demands, low-cost bioenergy can be generated from floral waste. Energy from flower waste either might be in the form of biogas, biohydrogen, bioethanol, biocharcoal, or direct burning to get heat energy. This book chapter deals with a possible consequence that may arise as a result of improper flower waste disposal along with its possible utilization for low-cost bioenergy production and how waste flowers can be used as potential bioenergy material.

KEYWORDS Bioenergy, Flower waste, Sustainable energy production, Temple waste

Sonika Kumari, Email: sonikakumari02gkv@gmail.com

Introduction

The varied climate of India allows the natural growth of a variety of floral species which are widely used in worshipping places for decoration on various occasions. Various religious rituals are performed in temples in which a variety of items including sweets, leaves, garlands, edible and non-edible fruits, flowers, etc. are offered to Gods (Samadhiya *et al*., 2017). The waste collected from the temple includes biodegradable and non-biodegradable materials out of which flower waste is segregated due to its biodegradable nature. A huge amount of flower waste is generated at religious places like temples, churches, dargahs because flowers are offered to Gods in almost all religions due to the religious beliefs which afterward are discarded (Yadav *et al*., 2015). As compared to kitchen waste management, floral waste lacks proper handling strategies (Jadhav *et al*., 2013). Improper disposal of floral waste in open landfills may result in various health hazards. After a few days of disposal, microorganisms act upon flower waste to degrade it thereby releasing harmful gases. These gases include methane (CH_4), carbon dioxide (CO_2), ammonia (NH_3) and others which create the foul smell and significant contribution to greenhouse emissions (Singh *et al*., 2017). Dumping of flower waste in water bodies results in a threat to aquatic environments. The aquatic organisms including fishes, diatoms, protozoans, molluscans plankton diversity are significantly affected by such waste disposal practices (Mahindrakar, 2018). On the other hand, pesticides and chemical fertilizers being used for flower cultivation alter the pH of water bodies resulting in health loss of aquatic bodies. Rotting flowers trigger algal growth in water bodies resulting in eutrophication on a large scale. Increased organic load of the water body by flower waste disposal may tend to grow harmful weeds and microbes which eventually depleting its oxygen levels (Makhania and Upadhyay, 2015). Besides this, nearby drains and water canals connected to such rivers may also get obstructed by flower waste disposal (Maity and Kumar, 2016). With the increase of the human population, the number of visitors is also increasing which consequentially contributing to the enormous amount of flower waste generated (Samadhiya *et al*., 2017).

To date, most of the holy cities of India including Haridwar, Kedarnath, Katra, Shirdi, Tirupati, Bhubaneswar, Patna, Gaya, Varanasi, etc. have insufficient flower waste disposal policy. Therefore, the management of flower wastes generated in Indian temples has become a cause of environmental pollution (Echavarria-Alvarez and Hormaza-Anaguano, 2014). It is estimated that nearly 40% of flowers from total production remain unsold and wasted in India and Srilanka. Dumping of flower waste on roadsides and open places gives filthy look to an area and distorts the image of an area especially the places that are regarded as important tourist destinations (Waghmode *et al*., 2018). As flower waste may have a significant content of lignocellulose, it may act as a good material to produce bioenergy like biogas, biohydrogen, bioethanol, biocharcoal, or direct burning to get heat energy. There is a strong need to explore the potential of generated flower wastes from temples and their potential utilization as a feedstock of energy production. Therefore, this book chapter deals with a consequence that may arise as a result of improper flower waste disposal along with its possible utilization for low-cost bioenergy production while addressing how waste flowers can be converted into wealth.

Generation of flower waste in religious places of India

India is a country of festivals with so many festivals celebrated throughout the year. In all religious places, the flowers are offered to devotees which afterward are discarded and becomes waste (Yadav *et al*., 2015). Most of the festivals involve worshipping to God including Navratri (celebrated twice in a year) in which nine different forms of the Goddess (Durga) are worshipped. Temples are decorated with flowers of different kinds as well as flowers are offered to Goddess Durga at the time of puja (Yadav *et al*., 2018). As offered flowers to God are considered as sacrosanct so they are not thrown with other waste generated in hotels, markets, etc. as it hurts the religious sentiments, therefore, are disposed in water bodies or left in open places (Barad and Upadhyay, 2016). The quality and quantity of flower waste generated vary from temple to temple. Gods are worshiped with their favorite flowers as mentioned in Vedas. Besides this, the number of flowers offered also varies from days to days. For example, in temples of Lord Shiva, the amount of flower waste generated is more on Monday and Saturday than other days of the week, Shivratri being Hindu festival generates quite a high amount of flower waste as compared to normal weekdays (Dwivedi *et al*., 2019). Table 1 shows the status of flowers offered in some selected temples of Chennai as reported by (Perumal *et al*., 2012). There are nearly 2 million temples in India out of which major temples are in most recognized holy cities including, Haridwar, Kedarnath, Katra, Shirdi, Tirupati, Bhubaneswar, Patna, Gaya, Varanasi, etc. (Ramachandara, 2012). Figure 1 shows some famous temples in India.

Composition of flower wastes

The composition of flower waste generated vary from place to place like in Dargahs the flower waste mostly consists of jasmine flowers, in Gurudwaras mainly marigold flowers are used and in case of temples marigold, lotus, rose, etc. (Elango and Govindasamy, 2018). Flower wastes are composed of high lignocellulose, cellulose, crude proteins, crude fibers, essential oils, nitrogen-bearing compounds, etc. Such components of flower waste can be utilized as a stock for bioenergy resources. *Chrysanthemum* flowers are a natural source of flavonoids, volatiles, myricetin and quercitrin (Wu *et al*., 2010). Jasmine flowers contain essential oils, flavonoids,

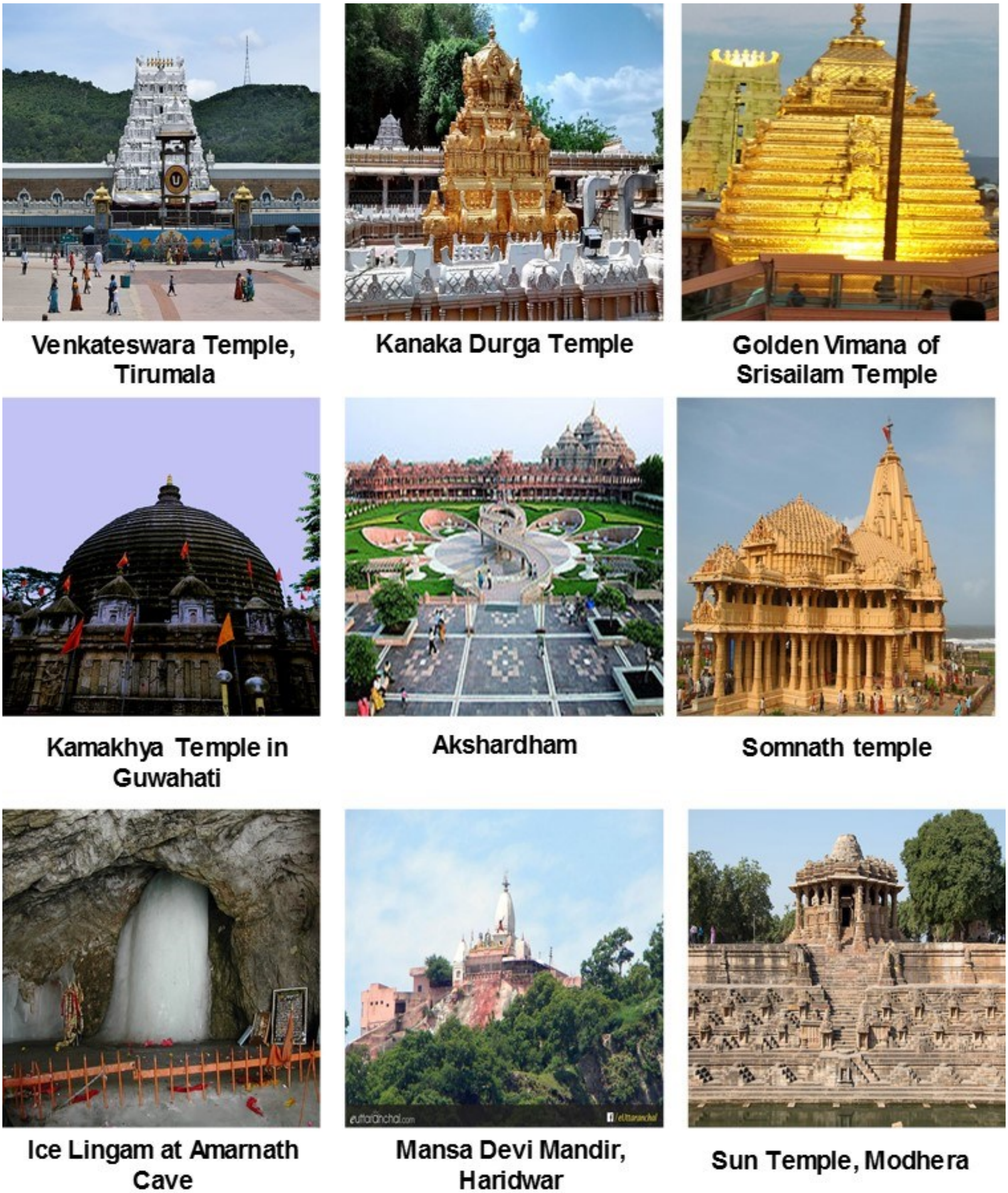

Figure 1. Some famous temples of India.

Table 1. Status of flowers offered in the selected temples of Chennai (Source: Perumal *et al.*, 2012).

Temple	Flowers	Quantity of wasted flowers (kg per day)	Quantity of flowers wasted (kg per day)
Ashtalakshmi, Besantnagar	Jasmine, marigold, rose	1000	200
Marudeeshwar, Thiruvanmiyu	Jasmine, rose, chrysanthemum	950	125
Kabaleeshwar, Mylapore	Rose, marigold, chrysanthemum	2500	800
Murugan, Vadapalani	Jasmine, marigold, rose	1500	400
Sri Parthasarathy, Light House	Rose, marigold, chrysanthemum	1200	400

phenolics, saponins, and steroids (Kunhachan *et al.*, 2012). Rose flowers are rich in riboflavin, sugars, tannins, pectin, mineral salts, salt of tartaric acid (Thakare *et al.*, 2017). *Hibiscus rosa-sinensis* contains essential oils, flavonoids, tannins, quinines, phenols, alkaloids, cardiac, protein, carbohydrates, reducing sugars and steroids (Al-Snafi, 2018). Thiophenes, flavonoids, carotenoids, phenolic compounds, and terpenoids are reported in most of the *Tagetes* species (Gupta and Vasudeva, 2012). Several alkaloids, flavonoids, and non-flavonoid compounds are found in lotus flower (Paudel and Panth, 2015).

Issues in management of flower waste

Management and handling of flower waste become difficult as compared to the kitchen and other municipal waste because religious sentiments of people are attached with the flowers that are offered to God which afterward becomes part of temple waste (Samadhiya *et al.*, 2017). Because of this, few religious places do not allow to even separate flower waste from temple waste and convert into useful products like making compost, etc. (Jadhav *et al.*, 2013). Mostly flower waste is disposed of in water bodies which result in their deterioration. Due to the decomposition of flower waste dissolved oxygen is depleted from water bodies hence, the death of fishes and other aquatic organisms (Mahindrakar, 2018). Besides this, dumping of flower waste causes landfill problems resulting in surface and groundwater contamination. Due to the biodegradable nature of flower waste, it creates a wrong assumption among people that flower waste degrades fast if it is dumped anywhere despite fast decomposition flower waste decomposes very slowly as compared to kitchen waste (Jadhav *et al.*, 2013).

Flower waste and bioenergy

Flower waste can be utilized in several ways to produce bioenergy (Figure 2).

Bioethanol

Bioethanol produced from flower waste can be blended with other fuels which increase its energy efficiency providing an eco-friendly approach of reduced carbon footprint (Waghmode *et al*., 2018). Through, saccharification of the reducing sugars obtained from the flower waste may give a promising yield of bioethanol and methanol. However, the pretreatment of flower waste should be optimized as per the composition of waste generated.

Biogas

Flower waste can also be used as raw material to produce biogas by using anaerobic digestion technology (Lakshmi and Vijayalakshmi, 2017). Methane is a potent greenhouse gas (Singh and Bajpai, 2011), by using flower waste for biogas production, it will help to solve three problems firstly reduced emission of methane in the atmosphere and secondly fulfillment of energy needs and lastly reduced soil pollution from decomposition of flower waste (Rashed and Torii, 2015). The biogas produced from flower waste can be used as a source of heat for cooking purposes or can be used in electricity production (Kulkarni and Ghanegaonkar, 2019). A recent report by Ranjitha *et al*. (2014) showed that flower waste has enormous potential to produce biogas. The amount of produced biogas per kg of the substrate from flower wastes in Kenya as reported by them is given in Table 2. Whereas the composition of biogas produced from flower waste is given in Table 3.

Other uses of flower waste

Other strategies for flower waste management are given below (Figure 2):

Vermicomposting: Being rich in organic matter flower waste can be converted into organic manure by using certain species of earthworm as an alternative to chemical fertilizer. Such ver-

Table 2. Amount of biogas (per kg substrate) produced from flower wastes in Kenya (Source: Ranjitha *et al*., 2014).

Substrate	Biogas (per kg of substrate)
African wattle	10.92
Roselle	5.18
Nile tulip flower	5.38
Silk tree mimosa	23.73
Sunset flower	2.73
Jasmine	6.07

Table 3. Analysis of biogas generation (volume) from flower waste (Source: Singh and Bajpai, 2011).

Months (year)	Methane (%)	Carbon dioxide (%)	Other gases (%)
December (2009)	43	50	7
January (2010)	44	50	6
February (2010)	50	44	6
March (2010)	50	43	7
April (2010)	52	42	6
May (2010)	54	40	6

Table 4. Physico-chemical characteristics of floral waste vermicompost (Source: Jain, 2016).

Parameters	Control (Soil)	Vermicompost (50:50)
Color	Dark Brown	Black
Odor	Odorless	Odorless
Moisture	20.50	22.80
Bulk Density(g/cm3)	0.88	0.89
pH	7.9	7.0
Conductivity (ms cm-1)	3.50	3.35
Organic Carbon	16.5	19.4
Total Nitrogen	0.90	2.0
C/N ratio	20.0	21.55
Total Phosphorus (P_2O_5)	2.57	2.0
Potassium (K_2O)	0.4	0.9
Calcium	4.4	5.9
Magnesium	0.2	0.3
Sulphur	0.40	0.50

micompost may be helpful to provide nutrient-conditioning to the soil (Sharma and Yadav, 2017). Due to the presence of a higher value of nitrogen-phosphorus-potassium in flower degradation material, it can also be used as NPK fertilizer. The microbial consortium can be prepared from flower waste in order to avoid the problems of flower waste generated (Jadhav *et al*., 2013). Table 4 provides characteristics of flower waste vermicompost as analyzed by in study of Jain (2016).

Food products: Edible waste flowers such as roses and marigolds are rich in nutrient, therefore, can be used for making syrups, cakes, ice creams, cookies, jellies, jams, sweets, beverages, etc. by food industries (Waghmode *et al*., 2018).

Biochar: The woody part of flower waste can be converted into biochar through the process of slow pyrolysis (Bogale, 2017). Biochar can be further used as a material for absorption or adsorption of heavy metals and other harmful substances resulting in purification of wastewater (Waghmode *et al*., 2018).

Table 5. Composition of essential oil of Rosa damascene obtained from GC-MS analysis (Source: Perumal *et al.*, 2012).

Peak area (%)	Components	Retention time (sec)
0.07	Benzaldehyde	3.189
27.19	Phenyl ethyl alcohol	4.775
0.15	Tetradecanol	5.394
1.44	Propanamide	5.452
0.01	Phenyl ethyl ester	5.703
3.12	Thiophene carboxylic ester	6.457
0.23	methyl 4-pentanyl acetyl ester	7.733
0.19	Hexadecanol	8.11
0.29	Ethyl amino 1- butyl cyclohexa benzene	9.091
0.08	Bromo propionate	9.097
0.55	2-2-dimethyl phenyl ethyl ester	10.595
0.19	Tricosene	11.243
0.36	Heptyle 2-phenyl ethyl ester	12.316
0.27	Isohexyl ester	12.452
0.10	8-methyl heptacosane	13.099
0.21	Eicosane	14.801
0.14	Pentatriacontene	16.068
3.17	Nonadecene	16.209
7.76	Hexadecane	16.744
0.72	Benzene propaonic ester	17.402
0.09	Eicosene	18.098
1.11	Phenyl Dodecanoic ester	18.562
0.17	Di phenyl ethyl ester	19.703
0.20	Octadecyl tri chloro ethyl ester	19.887
0.35	Heneicosanol	20.167
0.21	Chloropropronic ester	20.235
10.49	Heneicosane	20.316
0.11	Hexadecyleste	21.995
0.27	2Propyl tridecyl ester	22.682
0.54	Dodecanoic ester	23.29
1.15	Tricosane	23.629
1.89	Tetratetracontene	23.764
0.48	Cyclobutyl pentadecyl ester	25.379
0.21	Pentadecyl 2-phenyle ethyle tridecyle ester	26.655
3.03	Pentatriacontene	26.752
2.73	Chloropropionic ester	26.848
0.15	Benzene dicarboxylic ester	26.955
3.45	Tetra methyl trisilocendecanol	27.602

Table 5. continued...

0.23	Dimethyle benzaldehyde thiocarbamoyl hydrazon	27.718
0.70	Pthalic diphenyl ester	28.037
0.31	Hexacosane	28.124
0.19	Dibromoecosane	28.18
0.48	Octadecyle ester	28.88
0.39	Cyclotrisiloxane	29.495
0.22	Benzamine	29.536
0.39	Methoxyethyl ester	29.594
0.84	Hexadecane-l-ol acetate	29.72
0.61	Cyclobutane	30.068
0.44	Nonacosane	30.909
0.70	Cyclohexadiene	30.977
0.32	Trimethyl silyl ester	31.073
5.77	Phenyl ethyl tetradecyl ester	31.275
0.52	Thiophene	31.85
0.32	Hexadecyl 2-phenylethyl ester	32.6

Essential oil extraction: In India, around 300,000 metric tons of flowers are being utilized for various purposes like making garlands, decorations, pigments extraction, insecticides, and perfume ingredients. The flowers offered to deities are available as temple flower waste among which rose was found to be 50% so can be used for extraction of essential oils (Perumal *et al.*, 2012). About 300 compounds are present in rose oil. Perumal *et al*. (2012) studied the composition of essential oil in *Rosa damascene* (Table 5).

Dye extraction: Colored pigments present in flowers give them characteristic color which attracts the eyes of the viewer. The pigments from colored flowers are extracted to further used in a variety of purposes like:

- For dyeing fabrics in the textile industry.
- Making colored candles.
- Food industry for making eggs, vegetables, etc. colored.
- Making colors in powdered form by using solar drier for drying flowers which can be used as Holi and Rangoli colors, being purely organic is safe to use (Kumar *et al.*, 2016).

Medicinal uses: Some flowers from temple flower waste such as marigold, *Hibiscus rosa sinensis* have medicinal properties so can be utilized for the medicinal purpose that is mostly taken in the form of decoction (Voon *et al.*, 2011).

***Essence*:** Essence can be extracted from flowers. These are kind of infusions made from flowers by boiling them, there is no physical part of the flower. Flower essence has wide utility it can be used in beauty products, shampoos, lotions, aromatherapy, etc. (Ali *et al.*, 2015).

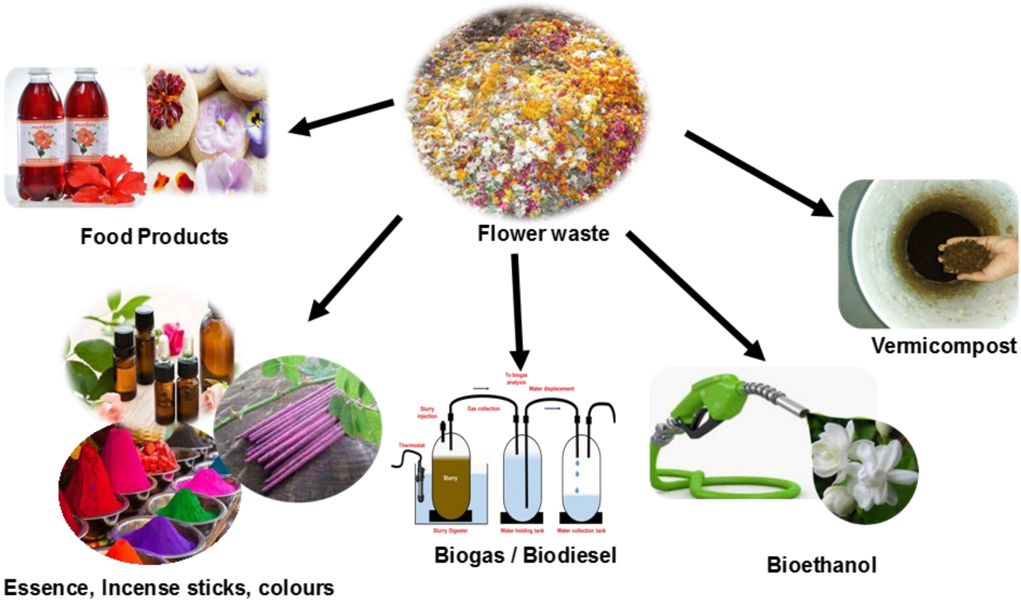

Figure 2. Use of flower waste feedstock as a resource for production of bioenergy and other useful materials.

Miscellaneous uses: Incense stick making and handmade paper production are being carried out by using waste flowers moreover dry flowers can be used for various art and craft activities. Some flowers can also be used as veterinary feed. Nowadays activated carbon is being prepared from temple flower waste which has a wide range of utility due to its adsorption properties (Elango and Govindasamy, 2018).

Conclusion and recommendations

This chapter deals with the problems of flower waste generated at religious places. Improper handling and disposal of flower waste cause serious problems affecting the soil, water and air quality of the nearby environment. However, flower waste is a good source of lignocellulose and organic matter, therefore, it can be used as a potential resource for bioenergy production and other useful products. By using flower waste, a significant amount of bioenergy can be produced, which may serve a dual purpose by helping in reducing the environmental problems and giving us eco-friendly energy at a low cost. Besides bioenergy production, many other compounds can also be extracted from flower waste which has great demand by industrial sectors. Thus, this book chapter emphasized on the utilization of flower waste generated from temples as a potential resource for bioenergy production to meet future goals of sustainable energy production.

Acknowledgments

This work was academically supported by the Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar, India. The Corresponding author (S.K) is grateful to her lab mates for their support and guidance at each step.

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Cite this chapter as: Kumar, V., Kumari, S. and Kumar, P. (2020). Management and sustainable energy production using flower waste generated from temples. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 154-165, https://doi.org/10.26832/aesa-2020-edcrs-011

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-012

CHAPTER
[12]

Solid waste management and its role in mitigating environmental degradation with special reference to recycling of wood wastes

Ettammal Sreenivasan

Technical Manager & Head, R&D, The Western India Plywoods Ltd, Mill Road, Baliapatam P.O, Kannur, Kerala – 670010, India

ABSTRACT

Due to rapid industrialization, urbanization and population growth in India, solid waste generation has been increased to a large extent. In recent years, disposal of solid wastes has caused serious environmental hazards and economic problems. India generates 1.45MT of wastes per day at present. Annual increase in overall quantity of solid waste is assessed at about 5% and nearly three-fourths of the waste is generated in urban areas. Municipal Solid Wastes (MSW) amount is expected to increase significantly in the near future as the country strives to attain an industrialized nation status by the year 2020. When solid waste is disposed off on open lands or in low-lying landfill areas, it causes an adverse impact on the environment, such as ground water contamination, generation of inflammable gases, acidity to surrounding soil, release of green house gases, etc. Huge quantity of wood wastes generated through forestry and agricultural practices, paper pulp industries, wood-based industries, and many agro-industries also pose an environmental pollution problem. Sadly, much of the lignocellulose waste is often disposed by biomass burning, which is not restricted to developing countries alone, but is considered a global phenomenon. This chapter discusses the environmental impacts of improper solid waste management, structure and sources of waste generation and regulations and also deals with the details of waste processing techniques with special reference to the low-cost methods of converting wood wastes and residues from plywood and other wood-based units into useful products.

KEYWORDS Environmental management, Recycling, Solid waste, Wood waste

Ettammal Sreenivasan, Email: dr.sreeniettammal@gmail.com

Introduction

Solid wastes are organic and inorganic waste materials produced by various activities of our society, which have lost their value to the first user. This includes household garbage, rubbish, sanitation residues, construction and demolition debris, industrial and biomedical wastes. A society receives raw material and energy as inputs from the environment and gives solid waste as output to the environment. In the long-term perspective, such an input-output imbalance degrades the environment (Ramachandra and Bachamanda, 2007). Due to rapid industrialization, urbanization and the ever-increasing population solid waste generation has been increased to a large extent. In recent years, disposal of solid wastes has caused serious environmental hazards and economic problems. Burning of solid wastes contributes tremendously to environmental pollution thus, leading to polluted air, water and land. Risks to the public health and the environment due to solid waste in large metropolitan areas are becoming intolerable.

India generates 1.45MT of wastes per day at present and is facing a municipal solid waste dilemma, for which all elements of the society are responsible. The explosion in population is changing the nature of solid waste management from mainly a low priority, localized issue to an internationally pervasive social problem. The community sensitization and public awareness is low. There is no system of segregation of organic, inorganic and recyclable wastes at household level.

The management of solid waste is going through a critical phase, due to the unavailability of suitable facilities to treat and dispose of the larger amount of wastes generated daily in metropolitan cities. In some cities, industrial, residential and commercial areas are mixed and thus all waste gets intermingled. Therefore, it becomes necessary that the local bodies along with State Pollution Control Board (SPCB) work out requisite strategy for organizing proper collection and disposal of solid waste.

Improper solid waste management: Its environmental impacts

Improper solid waste management causes all types of pollution: air, soil, and water. Indiscriminate dumping of wastes contaminates surface and ground water supplies. In urban areas, solid waste clogs drains, creating stagnant water for insect breeding and floods during rainy seasons. Uncontrolled burning of wastes and improper incineration contributes significantly to urban air pollution. Greenhouse gases are generated from the decomposition of organic wastes in landfills while untreated leachate pollutes surrounding soil and water bodies. These negative environmental impacts are only a result of solid waste disposal; they do not include the substantial environmental degradation resulting from the extraction and processing of materials at the beginning of the product life cycle. In fact, as much as 95 percent of an item's environmental impact occurs before it is discarded as Municipal Solid Wastes (MSW) (Rajput *et al*, 2009).

Government regulations

Integrated Solid Waste Management (SWM) by applying scientific methods is relatively a new concept in India, although there are reports of attempts by Government of India as early as the 1960s when the Ministry of Food and Agriculture offered soft loans of Urban Local Bodies (ULBs) and also financial support given to state governments for setting up of MSW composting units during the fourth five-year plan (1969-74). These initiatives including a modification of this scheme in 1974 to support the major cities were unsuccessful due to a number of reasons.

However, during the recent past, the management of solid waste has received considerable attention from the Central and State Governments and local (municipal) authorities in India and as a result, we have adequate legal framework in India to address SWM. Government has successfully implemented various rules and awareness programmes to ensure proper disposal of solid wastes:

a) The major initiative taken by the Honourable Supreme Court of India in 1998, which resulted in formation of an expert committee to study the status of SWM in Indian cities. This committee identified the deficiencies/gaps in the existing SWM system in the country and prepared the Interim Report in 1999 on SWM Practices for few cities.

b) As a second initiative, in conformance with Sections 3, 6 and 25 of the Environment Protection Act of 1986, and on the basis on the recommendations by the Committee, the Ministry of Environment and Forests (MoEF) of the Government of India, developed and issued Municipal Solid Waste (Management and Handling) Rules (MoUD, 2000). These rules aim at standardization and enforcement of SWM practices in urban areas. The Manual on Municipal Solid Waste (Management and Handling Rules) 2000 groups SWM activities into six functional elements i.e., a) waste generation, b) waste handling, c) collection, d) sorting, processing and transformation, e) transfer and transport and f) disposal. It also lays emphasis on seeking participation of citizens in waste segregation, prohibiting littering of garbage, proper storage of waste and efficient transportation of waste for its processing and final disposal.

c) RCRA- Nation's primary laws governing disposal of solid and hazardous waste. Passed on Oct 21,1976 and later amended in 1984.

d) The Hazardous Waste (Management and handling Rules) of 1989 is an effective mechanism to regulate the generation, collection, storage, transport, treatment and disposal of hazardous wastes both indigenously generated and imported.

e) Adopted and notified Bio-medical Waste (Management and Handling Rules) in 1998 with the objective to stop the indiscriminate disposal of hospital waste and ensure that such waste is handled without any adverse effect on human health and environment.

f) Notified in 1999, Recycled Plastics Manufacture and Usage Rules with an amendment in 2003 to ensure proper collection, segregation, transportation and disposal of plastic waste (Rajput *et al.*, 2009).

Industrial wood wastes

Lignocellulose is the major structural component of woody plants and non-woody plants such as grass and it represents a major source of renewable organic matter. Lignocellulose consists of lignin, hemi-cellulose and cellulose. The chemical properties of the components of lignocellulosics make them a substrate of enormous biotechnological value. Large amounts of lignocellulosic "waste" are generated through forestry and agricultural practices, paper pulp industries, timber industries, and many agro-industries. But, they pose an environmental pollution problem. Sadly, much of the lignocellulose waste is often disposed by biomass burning, which is not restricted to developing countries alone, but is considered a global phenomenon. Wood-based industries in India produce large volumes of residues which must be utilized, marketed or properly disposed of. Heaps of wood residues are common features in wood industries throughout the year. Wood waste is generated in various sectors of the wood industry during processing. This includes wood waste generated from sawmills, furniture industries and plywood industries as they are directly involved with the usage and conversion of timber into its derived products for consumer use. In the sawmill industry, the wood has to be converted into various sizes to maximize profit and also satisfy the demands of the people. Table 1 lists the different types of wood wastes and residues from the various wood processing units. Sawmill and plywood units generate a lot of wood wastes due to the intensity of wood processing. Saw dusts, wood off cuts, wood backs, plain shavings, wood rejects are all wastes generated during wood processing in sawmill.

Table 1. Analysis of residues generated in wood processing units.

Source	Type of wood wastes and residues
Sawmill unit	Bark, sawdust, trimmings, split wood, planer shavings and sander dust
Block board /Flush door/ Ply-wood unit	Bark, sawdust, veneer clippings and waste, panel trim, sander dust and boiler ash
Fibreboards units (Hardboard, Softboard, Pre-compressed Board)	Effluent sludge, Chip wash residue, trimming waste, sander dust and boiler ash
Furniture unit	Sander dust, cutting dust, wood shavings and wood cuts

Wastes such as off-cuts, sander dusts, wood shavings and wood chips are produced in the furniture unit. The plywood factory mainly generate wood waste from bark, peeler cores, veneer wastes and panel trims while the quantity of wastes from blockboard and flush door units is very negligible but comes from chip wastes from panel trimmings and dust from sanding machines (Figure 1). Press effluent sludge, chip wash residue and boiler ash are some of the major residues produced in the fibreboard factories.

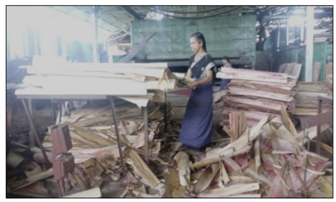

Wood shavings


Saw dust


Bark residues


Peeling waste (core)


Wood cuts


Clipping waste


Veneer edging wastes


Planer shavings


Cross cutting wastes (Timber cuts)


Cross cutting wastes

Figure 1. Selected wood wastes from plywood and other wood-based units.

Wood waste utilization

Waste generated in wood industries usually become pollutants which pollute the environment either due to burning or improper disposal. Over the years more advanced and improved methods of wood waste utilization have evolved. Saw dusts are used as animal beddings for poultry, in particular board making, as fuel for cooking and as charcoal briquettes. Wood industries utilize waste wood, using it in firing furnaces to raise steam and hot water. Heat generated from this plant can be used domestically and industrially. Bark is sold sometimes to traditional healers or given away free of charge while slabs are disposed by selling them as firewood in local markets. At present, there are a number of methods being used to dispose of solid wastes including the wood wastes and it requires the selection of the correct method focusing on efficient and environmentally safe disposal. New technologies are also being added to assist the organic solid waste treatment, conforming to strict environmental regulations.

Wood waste processing techniques

Sanitary Land filling

Sanitary landfill is a solid waste operation that is little better than an open dump. Actually, the term refers to an installation where a satisfactory, nuisance-free waste disposal operation is being carried out in accordance with recognized standard procedures. It is a fully engineered disposal option, which avoids harmful effects of uncontrolled dumping by spreading, compacting and covering the wasteland that has been carefully engineered before use. It also isolates the refuse, minimizing the amount of surface water entering into and gas escaping from the waste, it appears that landfilling would continue to be the most widely adopted practice in India in the coming few years, during which certain improvements will have to be made to ensure the sanitary landfilling (Kansal, 2002).

Incineration

In incineration, combustible waste is burned at temperatures high enough (900-1000°C) to consume all combustible material, leaving only ash and non-combustible to dispose off in a landfill. Under ideal conditions, incineration may reduce the volume of waste by 75% to 95%. In Indian cities, incineration is generally limited to hospital and other biological wastes. This may be due to the high organic material (40-60%), high moisture content (40-60%) and low calorific value content (800-1100 Kcal/Kg) in solid waste. In modern incineration facilities, smokestacks are fitted with special devices to trap pollutants, but the process of pollutant abatement is expensive (Botkin and Keller, 2000).

Pyrolysis

Pyrolysis is defined as the thermal decomposition of organic derivatives under inert condition in oxygen-deficient environment. In this process, the chemical constituents and chemical energy of some organic wastes is recovered by destructive distillation. It is a form of incineration that chemically decomposes organic materials at high temperature in the absence of oxygen. Pyrolysis of organic materials produces three phases of matter: a) gaseous products including carbon monoxide and hydrogen (industrially known as syn-gas), methane, short hydrocarbon chain gases, and carbon dioxide, b) small quantities of liquid (known industrially and economically as bio-oil and tars) and c) a solid residue containing carbon and ash (Rajput *et al*., 2009).

Composting

Composting is defined as the biological oxidative decomposition of organic constituents in wastes under controlled conditions which allows development of aerobic microorganisms that convert biodegradable organic matter into a final product sufficiently stable for storage and application without adverse environmental effects (Adhikari *et al.*, 2008). It is the process of controlled biological maturity under aerobic conditions, where organic matter of animal or vegetal origin is decomposed to materials with shorter molecular chains, more stable, hygienic, humus rich, and finally beneficial for the agricultural crops and for recycling of soil organic matter.The process is mediated by different microorganisms actuating in aerobic environment: bacteria, fungi, actinomycetes, algae, and protozoa, which participate naturally in the organic biomass or are added artificially (Tuomela *et al*., 2000). The process can be described by this simple equation:

$$\text{Organic matter} + O_2 \rightarrow \text{Compost} + CO_2 + H_2O + NO_3^{-} + SO_4^{2-} + \text{heat}$$

Composting method is gaining special consideration these days as an environmentally sound approach to manage organic wastes especially in countries like India, where more than 50% of solid waste comprises of organic/green waste. Many large-scale compost plants with capacities of ranging from 150 to 300 tonnes /day were set up in the cities of Bangalore, Baroda, Mumbai, Calcutta, Delhi, Jaipur and Kanpur (Sharholy *et al*., 2008). Now, about 9% of solid waste is treated by composting (Srivastava *et al*., 2005; Gupta *et al*., 2007). Compost, the main product of this transformation is rich in humus and plant nutrients such as nitrogen and phosphorous and the foremost by-products from the process are carbon dioxide, water, ammonia and heat. This potential biological fertilizer would play key role in productivity and sustainability of soil and also protect the environment as eco-friendly and cost effective inputs for the farmers (Oluchukwu *et al*., 2018)

a) ***Composting by effective microorganisms:*** The technology of EM was originally developed by T. Higa during the1970s at the University of Ryukus, Okinawa, Japan (Higa and Chinen, 1998). EMs have a number of applications including agriculture, livestock, gardening and landscaping, composting, bioremediation, cleaning septic tanks, algal control and household uses. It is a mixture of groups of organisms that has a reviving action on humans, animals and the natural environment and has also been described as a multi-culture of coexisting anaerobic and aerobic beneficial microorganisms. The major microbes contained in EM include: lactic acid bacteria - *Lactobacillus plantarum, L. casei* , *Streptococcus lactis*, photosynthetic bacteria – *Rhodopseudomonas palustrus, Rhodobacter spaeroides*, yeasts - *Saccharomyces cerevisiae, Candida utilis*, actinomycetes - *Streptomyces albur, S.griseus* and fermenting fungi – *Aspergillus oryzae, Mucor hiemalis*. They contain various organic acids due to the presence of lactic acid bacteria, which is a strong sterilizing compound and suppresses harmful microorganisms and enhances decomposition of organic matter. Also they have the ability to suppress disease inducing microorganisms such as *Fusarium*, which occur in continuous cropping programs. The wood wastes, wood residues and other biowastes and the quantity required for the microbial composting process using commercially available EM in dormant state activated by the addition of water and jaggery (pure cane sugar) are shown in Table 2. These residues provided a suitable environment for the effective microorganisms (EM) to grow and multiply and produced a higher quality of compost (Sreenivasan, 2013a). Some of the important observations during this composting period are summarized below: i) The nitrogen content increased during the process of composting and Organic carbon content of the wastes decreased during composting indicating a higher mineralization of organic matter. ii) The C:N ratio of the wastes was higher before composting than after. Enhanced organic matter decomposition in the presence of effective microorganisms results in lowering the C:N ratio. iii) EM controls the foul smell and the process is free of odours. iv) A shift in pH from the initial condition toward an acidic condition. The occurrence of acidic conditions may be attributed to the bioconversion of the organic material into various intermediate types of organic acid and higher mineralization of the nitrogen and phosphorous into nitrites/nitrates and orthophosphate respectively.

Table 2. Wood wastes and other biowastes used for EM composting.

Item	Quantity (in Kg)
Chip wash residue	450
Press effluent sludge	200
Saw dust	250
Boiler ash	150
Coir pith	250
Cow dung slurry	100

b) ***Vermicomposting:*** One of the most economically viable processes for the conversion of lignocellulosic wastes into useful products is the use of earthworms. This process by which earthworms are used to convert organic materials (usually wastes) is known as vermicomposting. Vermicomposting is a biotechnological mesophilic process of composting, in which certain species of earthworms such as *Eudrilus euginae, Eisenia fetida* are used to enhance the waste conversion to produce a better useful end product. Organic wastes can be ingested by earthworms and egested as a peat-like material termed "vermicompost" (Nagavallemma *et al*., 2004) The goal is to process the material as quickly and efficiently as possible. For vermicomposting different bedding materials are used such as semi-composted solid manure, shredded or mulched paper (non-coloured), cardboard, shredded fall leaves, chopped up straw, sawdust etc. Sawdust is a useful medium mixed with cow dung to produce high quality compost. Large amounts of other lignocellulosic wastes generated through forestry and agricultural practices, paper-pulp industries, timber industries and many agro-industries which generally impose a threat to the environment can be effectively converted to organic manures using this technology. During vermicomposting, the important plant nutrients such as N, P, K, and Ca, present in the organic waste are released and converted into forms that are more soluble and available to plants. Vermicompost also contains biologically active substances such as plant growth regulators. With years of research works, WIP has established a pilot scale unit to convert the chip wash residue, a lignocellulosic waste generated in huge quantity from its wood fibre-based hardboard manufacturing plants into vermicompost, using an epigeic earthworm, African Night Crawlers (*Eudrilus eugeniae*). (Sreenivasan, 2013b) (Figure 2). Investigations to assess the impact of vermicompost produced from this wood waste on growth enhancement and productivity of vegetable crops like tomato, chilli and brinjal grown under field conditions were also carried out in WIP during 2013- 2014(Sreenivasan *et al*., 2017).

Figure 2. A view of a vermicomposting unit.

Briquetting

Biomass from agricultural or forest-based activities and wood-based industries is generally difficult to handle because of its bulky and scattered nature, legal and administrative problems, low thermal efficiency and copious liberation of smoke. In order to achieve maximum and efficient exploitation of waste resources locally available, it is essential to compress them into manageable and compact pieces which have a high thermal value. The process is called briquetting. This process has acquired considerable significance in the recent past, due to its increased fuel efficiency, reduction in bulk, and having high calorific value of the briquettes. Briquettes are made by compacting loose wood waste into a dense material through the application of high temperature (300-350°C) and moderate pressure. Sawdust, wood chips and bark are suited for making briquetting over which sawdust is the more preferred material. This densification process can produce briquettes with uniform shape and sizes that can be more easily handled using existing handling and storage equipment and thereby reduce cost associated with transportation, handling, and storage (Karunanithy *et al.*, 2012).

Briquetting of sawdust produces renewable environment friendly sources of energy. It is an alternative for cooking fuel. The briquettes are generally burnt as a cleaner and more consistent and alternative to firewood logs, offering a higher energy density and steady combustion. The use of briquettes has considerably reduced the demand for firewood for fuel in industrial boilers. Saw dust briquettes also avoid contaminating environment with lower SO_2 (zero percent) and CO_2 (15.29 percent) emissions but ash content (1.3 percent) and volatile matter (23.41 percent) is high when compared to fire wood and charcoal. The usage of briquettes as an alternative source of solid fuel for several applications in boilers and industrial use is having increased attention. The briquettes are often used as an energy source for cooking purpose and in some small scale industries like bricks, tea and bakery. Briquetting is also being promoted recently by Government agencies as an excellent method for managing the solid and liquid wastes from plywood factories including the wood wastes and the effluent water from glue spreader washings, preventing these wastes from entering the nearby water bodies and soil.

Biomass briquettes are usually cylindrical-shaped with a diameter between 25-100 mm. and length varies between 100-400 mm. Briquetting of biomass to increase its bulk density consists of applying pressure to a mass of particles with or without a binder and converting it into a compact aggregate.

Techniques for briquetting

The briquettes are produced by densification of waste biomass using various processes. It has been observed that density, durability and combustion efficiency of briquettes increases with decrease in the size and increase in pressure during preparation. Three versions of compaction/ briquetting machines based on the use of different forms of energy, manually operated, bullock operated, and power-operated, have been designed, fabricated and tested by different agencies in the country. The technologies available for the production of direct compaction briquettes are given below:

a) ***Binderless technology***: To compact the biomass, binding materials are not used here and this process involves either the application of high pressure (at the range of 1200-1400 kg/cm^2) under which condition the residue gets heated to about 182°C, and the lignin begins to flow and act as a binder or extracting the diversified material around the room temperature. Here there is no need to add external agent like glue or binder. The existing units are using imported briquetting machines of 400 kg/cm^2 capacity. The manufacture of indigenous briquetting machines has been taken up. These machines are available in the capacity range of 100-3000 kg/h operating on electric power.

b) ***Using binder*:** The briquetting machines operate at lower pressures (500- 1000 kg/cm^2) and are powered by electricity. Briquettes produced by this technology requires binders like molasses, ligno-sulphonates etc. Briquettes produced by this process are suitable neither for household use nor for hotels, canteens, etc. because they release a great deal of smoke while burning. These briquettes however, find use as industrial fuel in boilers in isolated pockets of the country.

A large number of machines (presses) are designed and developed to suit commercial as well as for rural areas in cottage industries.

Briquetting presses

Briquetting presses are of two types: screw or piston type. In screw type, the biomass is screwed forward under high pressure through a nozzle (funnel shaped) in which case, the briquette gets its cylindrical shape. In the second case, the same forward pressure is effected with a piston. There are two methods to retain their cylindrical form. One of them operates with binding agent and the other without binding agent. Briquetting without binding agent requires a raw material with a maximum moisture content of 15 percent and a briquetting press which can generate a pressure of at least 1000 kg/cm^2. The minimum pressure can vary depending upon the nature of raw material pressed. Briquetting with binding material does not require the same low moisture content which varies depending upon the raw material. The four chief parameters of the briquetting process are: moisture, particle size, binding agent, and level of pressure.

Figure 3 shows one of the two piston presses installed in 2009 and 2011 by The Western India Plywoods Ltd (WIP), Kerala as part of its solid waste management programme to utilize the huge quantity of the wood wastes generated from the manufacturing units and started the production of biomass briquettes with a total capacity of 20 tonnes per day. The briquettes are manufactured by means of one or any combination of the following operations: drying, size reduction,

Figure 3. A Biomass briquetting unit.

densification, cooling and dust removal, using a blend of wood wastes obtained from the factories engaged in the manufacturing of a wide range of wood-based panel products like Plywood, Softboard, Hardboard, Densified wood, Pre-compressed press board, etc. This feedstock consists mainly of lignocellulosic wastes like saw dust, wood shavings, peeling waste or bark waste Initially, the product was utilized as boiler fuel for in-house energy requirements. Later due to the increased production, the company started its marketing in Kerala and the neighbouring states. The increasing demand of the product is an indication of its wide acceptability considering its fuel efficiency. The biomass fuel briquettes are obtained with features like: 19.8 percent MJ/kg, 10 percent humidity, 1.3 percent of ashes, 15.29 percent fixed carbon and 83.41 percent of volatile matter. Some of the major features of this product are given in Table 3.

i) Briquette is a boiler fuel for conversion to energy. It is chosen over coal and other non-renewable fuel that are hard to obtain and generate.

Table 3. Properties of wood waste fuel briquettes.

Property	Unit	Result
Diameter	cm	9
Length, range	cm	20 - 35
Moisture content	%	1.33
Ash content	%	2.87
Density, range	g/cc	1.04 – 1.17
Weight, range	kg	1.30 – 2.40
Gross calorific value, range	K.cals/kg	4200 - 4600

ii) They are easy to store, pack and easy to transport and hygienic to handle
iii) Briquettes have consistent quality, high burning efficiency and are ideally sized for complete combustion.
iv) Briquettes have high practical thermal value and low ash content.

Biomethanation

It is a waste-to-energy process which uses thermo-chemical conversion similar to composting process. It basically taps the methane gas generated from the biochemical reaction in wastes dumped in aerobic digesters (Kumar *et al*., 2018).

Cement composite bricks

Development of cement composites mixed with wood wastes and residues to produce low-cost, environmental friendly construction materials, is the latest addition to the list of recycling methods of wood-based industries (Figure 4). In 2017, C. Surabhi and her team investigated the feasibility of producing cement composite bricks using saw dust and boiler ash and focused on the strength and durability of the products (Surabhi *et al*., 2017)

Manufacturing: Prior to brick formation, particles were soaked in water for 24 hours to reduce the amount of water soluble sugars and tannins and were finally air dried up to 5 percent moisture content for a better combination. Then the materials were mixed appropriately in predetermined ratios and were filled inside a wooden mould of prescribed dimensions for a standard brick size (190 mm X 90 mm X 90 mm). Bricks of sawdust: boiler ash: cement (1:1:1 and 1:1:2) combination was found to be better in strength than the other two samples of composite bricks made of saw-dust: cement (1:3 and 1:2) and boiler ash: cement (1:3 and 1:2).

Figure 4. A cement composite brick.

Future outlook

Wood wastes are generated daily due to a high demand for engineered wood products for various uses. These wood residues have various consequences on our environment due to improper disposal. The large quantities of wood residues entering the environment can be better utilized to help reduce the impact on our forests and the environment. Unlike small-scale wood-based units, there are well-established integrated wood waste management practices (Figure 5) in large wood-based panel industries like The Western India Plywoods Ltd including the use of bark and peeling wastes as a boiler fuel to generate heat for the facility's process needs.

Wood bark is an important component of hog fuel and is made from wood residues (bark, wood chunks, sawdust, etc.), then processed through a chipper or mill. The end products are coarse chips and clumps which are used as fuel. All other wood wastes from its saw mill, furniture, fibreboard and plywood units are disposed off in a proper manner as detailed above, which in most other cases is either by burning or dumping in open areas which pose environmental hazards. Other wood waste utilization and disposal options under various stages of implementation or consideration by Indian firms include:

i) Use of bark-free wood chips and other wood waste as a raw material input for the fibreboard making industries.
ii) Particleboard manufacturing using sawdust and wood chips along with low-cost, non-conventional wastes like shredded currency wastes and paper mill wastes
iii) Use of wood and bark chips as coloured mulch for gardens, highway verges, and agriculture.
iv) Use of Sawdust and wood shavings for animal bedding.

Conclusion

The problem of managing the solid wastes has acquired alarming dimensions especially over the last two decades. In the early days, waste management was hardly considered as an issue of concern as the waste could be easily disposed off in a safe manner within the premises where it is generated. With time, due to changes in our lifestyle coupled with urbanization and industrialization, the quantity and the characteristics of the wastes have changed dramatically leading to the present situation and it plays a major role in the increased threats to the environment. Environmental degradation is one of the most urgent environmental issues which require our careful attention. Some environments may not recover at all depending upon the extent of damage. The plants and animals that inhabited these places will be lost forever. We must consider the long-term effects of our developmental activities, so as to considerably reduce any future impacts on the environment. Since there is no single solution, the proposed recycling

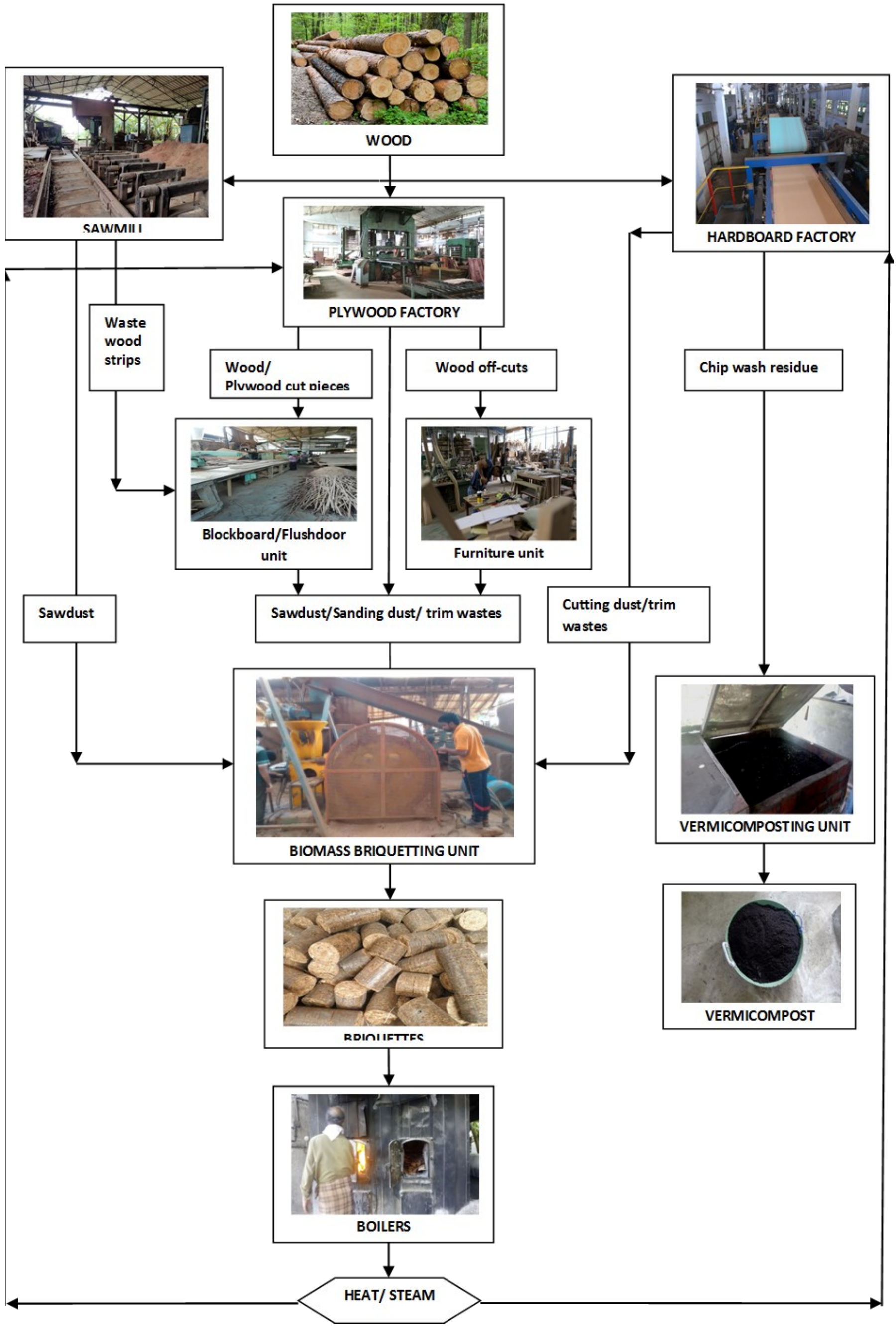


Figure 5. Material flow of wood and wood wastes in a large wood-based industrial complex.

methods can be used to adopt an integrated solid waste management system based on our local needs and socioeconomic settings in order to ensure the acceptability of the system and the environmental sustainability. In addition to sound planning, public awareness and community participation, there is an urgent need to support the industries in adopting latest technologies for managing the huge quantity of wastes generated from their processing units in order to prevent the contributions from the sector to the environmental degradations in the future.

Acknowledgement

The author wishes to express his sincere thanks to Shri. P.K. Mayan Mohamed, Managing Director of The Western India Plywoods Ltd, Kannur, Kerala for his support and constant encouragement in carrying out the wood waste management related projects and also for his permission to publish this article.

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Cite this chapter as: Sreenivasan, E. (2020). Solid waste management and its role in mitigating environmental degradation with special reference to recycling of wood wastes. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 166-182, https://doi.org/10.26832/aesa-2020-edcrs-012

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-013

CHAPTER
[13]

Biodiversity of entomofauna with reference to habitat degradation at Pancheshwar dam site on the River Mahakali, Central Himalaya

Aman Verma* **and Manoj Kumar Arya**

Insect Biodiversity Laboratory, Department of Zoology, D.S.B. Campus,
Kumaun University, Nainital – 263002, Uttarakhand, India

ABSTRACT

Conservation of insect biodiversity is essential as insects play numerous crucial roles in ecosystem functioning and the global economy. The Pancheshwar Multipurpose Project is the largest hydropower project in South Asia envisaged to built at the confluence of the River Sarju with the River Mahakali, forming international boundary of India with the North-West of Nepal. Despite its nature to threaten the existence of biological diversity at large scale, the serious efforts to quantify regional diversity have been entirely overlooked in the current project. Keeping this in view, a study was conducted during 2017-2018 aimed to inventorize diversity and richness of entomofauna with reference to the adverse impacts of pre-dam construction activities and degradation of forests at the Pancheshwar dam site located in the district Champawat of the state Uttarakhand, Central Himalaya. A total of 5908 individuals and 140 species under seven insect orders were reported of which the Lepidoptera was the most species rich (67.85%) and abundant (47.61%) group of insects with 10 species of butterflies protected under the Indian law. The present records indicated the existence of rich insect diversity in the dam site which is expected to meet the needs of understanding the importance of biodiversity conservation in such critical areas which are continuously being affected from the large-scale developmental projects, eroding and threatening flora and fauna.

KEYWORDS

Butterflies, Disturbance, Insects, Pre-dam construction, Rare species

Aman Verma, Email: amanzoology187@gmail.com

Introduction

Class Insecta, constituting more than 58% of the known global biodiversity is the most specious group that consists 66% (10, 20,007 species under 39 orders) of all animals on the Earth (Zhang, 2011). Besides the provisioning of vital ecosystem services, insects are of utmost importance because of their direct or indirect influence on agriculture, human health and global economy (Berenhaum, 1995; Adetundan *et al*., 2005; Premalatha *et al*., 2011). Insect diversity and abundance is critical for the functioning and stability of terrestrial and freshwater ecosystems (Godfray, 2002). They affect the nutrient and energy flow of ecosystems and are essential in diverse ecological processes such as pollination, seed dispersal, nutrient cycling and decomposition, bio-turbation, maintenance of wildlife species (Losey and Vaughan, 2006; Nichols *et al*., 2008), and they serve as predators of pests and prey for valued vertebrates (Engelmann, 1961; van Straalen, 1998). Insects act as ecosystem engineers since they are the major modifiers and controllers of the physical state of abiotic and biotic materials (Samways, 2005). Insects have been employed extensively in the landmark studies in biomechanics, climate change, developmental biology, ecology, evolution, genetics, palaeolimnology, and physiology. Moreover, insects that act as predators of economically damaging insects provide effective means for biological pest management of the crops (Dempster, 1968).

The insect distribution is mainly influenced by the ecological, climatic and edaphic factors, such as the vegetation, rainfall and temperature. Habitat structure influences insect diversity and abundance (Spitzer *et al*., 2008). The occurrence and abundance of insects may directly reflect environmental changes (Wahizatul *et al*., 2011). They have short generation times and respond quickly to minor ecological changes in the environment (Work *et al*., 2002). Because of their conspicuousness and susceptibility to environmental factors many insect taxa can be used as ecological indicators of ecosystem integrity (Pyle, 1976; Heath, 1981; Kremen, 1994; King *et al*., 1998; Tscharntke *et al*., 1998; Kati *et al*., 2004; Choi, 2006; Langor and Spence, 2006; Maleque *et al*., 2009).

The Pancheshwar Multipurpose Project is the largest hydropower project in South Asia. It is a bi-national scheme between the Governments of India and Nepal signed under the Mahakali Treaty on February 12, 1996. The construction of 315 m tall, 20 m wide and 814 m long high rock fill dam spreading over an area of 116 sq km has been envisaged across 2.5 km downstream near Pancheshwar temple of the village of Pancheshwar at the confluence of the Sarju River with the River Mahakali. A re-regulating dam is also proposed downstream of the main dam at the Rupaligad to mitigate hydrological impacts generated from the main dam powerhouses (Everard and Kataria, 2010). The region covered by the entire project structure located between 29°25′0″ to 29°47′30″ N latitude and 79°55′0″ to 80°35′0″ E longitude, lies in Champawat, Pithoragarh, Bageshwar and Almora districts of the Kumaon Division, Uttarakhand, India and in Baitadi and Dharchula districts of the Far Western Development Region in the Nepal. The affected area by the project that extends nearly from 400 m to 2100 m contains tropical to temperate type of vegetation. The lower elevational zones are dominated by sal trees which gradually merge into pine and oak mixed forests in the upper ridges (PDA, 2015). The entire area of 14,000 ha of which 9,100 ha lying in India and rest in Nepal will be acquired for construction of the both dams. In order to construct main reservoir at the Pancheshwar, 51.6% of the total land of the region (2415.1 ha), covered with forests (1456.8 ha), shrubs (584.6 ha) and grasslands (373.7 ha) will be acquired for clearance to harness power potential of both rivers (PDA, 2017).

IUCN, UNEP and WCD recommendations on dams and biodiversity highlight the avoidance of areas rich in species which needed to be given high priority in selection criteria. Accelerating rates of biodiversity loss lead to the signing of international agreements, such as the convention on biological diversity and agenda 21, have called for the world biodiversity to be inventoried and monitored (Stork and Samways, 1995). Lack of knowledge on biodiversity, ecology and geographic distributions of species due to poor surveys and expeditions from such areas may have serious impediments (McAllister *et al*., 2001). The assessment of environmental impact of large dams on lower groups of organisms such as insects remained poorly understood for the loss of wildlife in India (Mishra, 2009).

Environment Impact Assessment of the proposed project by the Pancheshwar Development Authority revealed the presence of 47 species of butterflies which is severely under reported information on insect fauna of the region (PDA, 2017). Despite the importance of common and largest insect orders *viz*. Coleoptera, Lepidoptera, Hymenoptera and Diptera as herbivores, pollinators, parasitoids and predators (Steffan-Dewenter and Tscharntke, 2002), they have been entirely neglected in the preliminary assessment of environment by the authorities. In order to mitigate massive habitat loss and decline of the ecologically important group of insects, monitoring and quantification of insect diversity and abundance is the pre-requisite in systematic conservation planning and sustainable development.

In the light of the aforesaid statements, the purpose of the present study was to assess diversity and abundance of common insect orders, their seasonality and also aimed to evaluate the species of conservation concerns that may decline potentially in reaction to changes in the microclimatic conditions. Besides providing insight into the diversity and richness of insects, the present study is very critical for their future conservation and management purposes as insects are extremely important biological resource, essential in ecological functioning and sustainability of the region.

Study site

The present study was conducted at the proposed Pancheshwar dam site (29°26.84′ N Latitude and 80°13.70′ E Longitude) and within 10 km periphery of the submergence area. The glacial and snow-fed River Mahakali forming international boundary of India with west of Nepal flows in a narrow V- shaped gorge, flanked by 45 degrees slopes rising more than 1000 m above the river bed. The River Mahakali is not only rich in ichthyofauna but also harbors several threatened, game and migratory species of fish (Saund *et al*., 2012). The study area is located on a mountain with elevation ranging from 440 m to more than 1000 m above msl in the district Champawat of the state Uttarakhand, India (Figure 1). The region is well connected with 40 km long road that starts at an altitude of 1600 m from the main town of Lohaghat and goes down to the low-lying valley, reverent for its sacred deity Lord Shiva temple in the study area. The terrain is undulating with mountains and ridges intersected by deep ravines and rivulets in low-lying areas and covers grasslands on hilltops (PDA, 2017). The forest of the study area is classified as 3C/C2a Moist Siwalik Sal Forest and 5B/C2 Northern Tropical Dry Mixed Deciduous forest mainly at low-lying areas which merge with 9C1/b Upper Himalayan Chir Pine Forest at upper altitudinal zones (Champion and Seth, 1968).

Some part of the land nearby the Sarju River is cultivated for agricultural practices and some fruit bearing trees like mango, papaya, pear, banana, guava, walnut, tamarind, cinnamon, grapes, jackfruit and several citrus fruits are also grown by local villagers. The yearly precipitation is

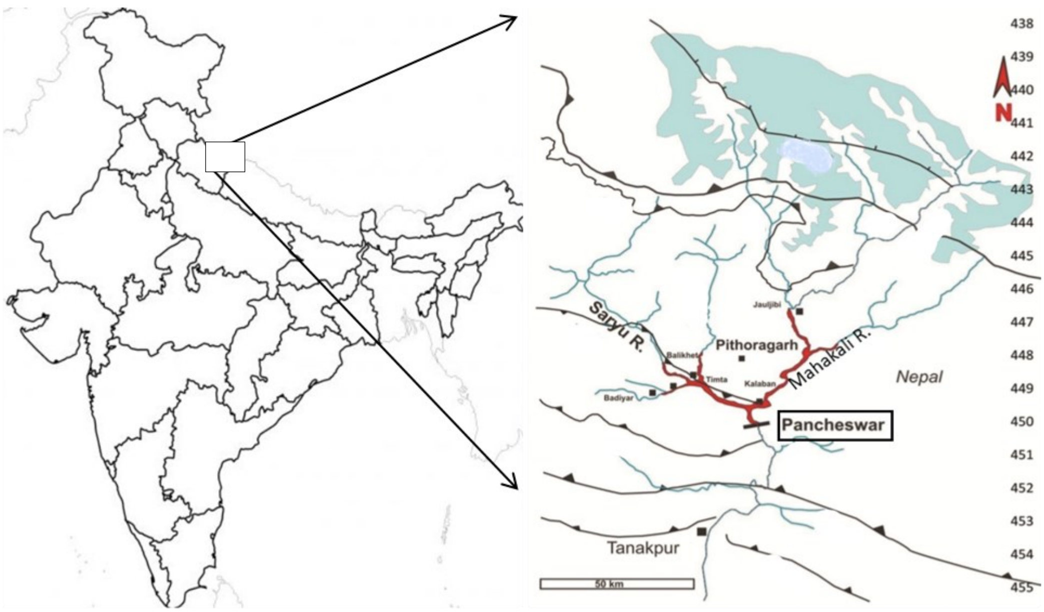

Figure 1. Map showing the location of the Pancheshwar dam site on the River Mahakali (Modified: Sati et al., 2019).

roughly less than 1000 mm with variable climate of tropical to sub-tropical type, characterized by hot summer season (March-June), moist and wet rainy season (July-October) and cold winter season (November-February). The relative humidity was high i.e., 93% during July while least during December i.e., 45.5%. During the present study monthly temperature varied with an average from 22°C to 29°C during hot summers and from 14.5°C to 20°C in dry cold winters. For the purpose of the present study, five permanent transects each of length one km were chosen to cover a range of micro-habitats with varied degree of anthropogenic pressures within 10 km periphery of the submergence area, given as under:

- Transect 1- Upstream of the confluence area i.e., right bank of Sarju River
- Transect 2- Upstream of the confluence area i.e., left bank of Sarju River
- Transect 3- Downstream of confluence area between Sarju River and River Mahakali
- Transect 4- Concrete road merging with un-metalled track towards dam construction site
- Transect 5- Uphill road along forest edges near village Khaikot Talla

The lower elevation was selected in village Pancheshwar containing transects 1 to 3 which is characterized by riparian zone with diverse array of micro-habitats. The higher elevation site comprised transects 3 and 4 that link village Khaikot Talla located 10 km uphill from the main dam site characterized by degraded forest land with high level of disturbance (Figure 2a-e). It is also that an area of 83 ha has been selected nearby village Khaikot in the proposed project for carrying out mechanized construction activities.

Sampling and identification of insects

The insect survey in the selected transects of the study area was conducted on three consecutive days in a month during a period of one year from August 2017 to July 2018. Both transect walk and quadrant methods were employed for the sampling of different insect orders. Observations took place between 08.00-16.00 h of the day mainly during suitable weather conditions i.e., on clear sunny days with low wind velocity. The record of population trends of adult Lepidoptera was made by using Pollard Walk Method counting individuals seen around an imaginary 5 m radius of the observer while walking with constant pace in each transect on the same sampling day at different timings (Pollard, 1979; Pollard and Yates, 1993). Species were identified following butterfly identification guides (Haribal, 1992; Kumar, 2008; Kehimkar, 2014; Singh, 2017; Sondhi and Kunte, 2018). In case if identification is difficult, butterflies in question were captured using the butterfly net, identified with field identification guides and were released at their point of capture to avert biodiversity loss.

Two quadrates each having dimensions of 10 m × 10 m in the each selected transects lines were laid at random for the sampling of insects belonging to orders other than the Lepidoptera. The methods such as baited pitfall traps, aerial net, manual collection and sweep net were employed

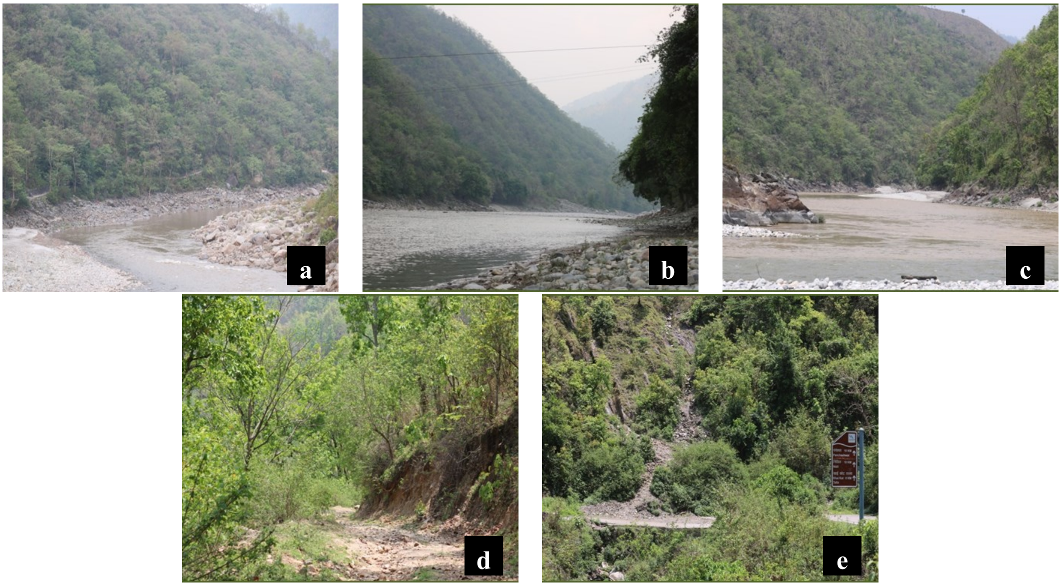

Figure 2. View of the selected transects (a) right bank of the Sarju River, (b) left bank of the Sarju River, (c) downstream of confluence area between the Sarju River and the River Mahakali, (d) Pancheshwar dam construction site and (e) uphill road along forest edges near the village Khaikot Talla.

(Gadagakar *et al*., 1990). After the collection, insect specimens were curated, preserved and got identified at the Insect Biodiversity Laboratory of Department of Zoology, DSB Campus, Kumaun University, Nainital, Uttarakhand. The specimens of plants were collected from each transect and got identified after preparing the herbarium on scientific guidelines.

Data analysis

Based on the number of sightings, the relative abundance of each species was calculated. In order to assess diversity and seasonality of different insect orders across the seasons *viz*. pre-monsoon (March-May), monsoon (June-August), post-monsoon (September-November) and winter (December-February), measures of diversity indices such as Shannon (H_s for insect diversity), Margalef (H_m for species richness) and Evenness (E for even distribution of species) were calculated using the program PAST version 3.4. Data for the number of species and individuals recorded during the study period was pooled to obtain individual based rarefaction curve at 95% confidence level to determine the sampling effort using the same program.

Floristic composition of the study site

Appendix I (Available as supplementary information in e-version of this chapter) provide the information on vegetational composition of the Pancheshwar dam site which was recorded during the study period. Floral studies of the region resulted in a total of 187 species of plants comprising 46 species of trees, 38 species of shrubs, 63 species of herbs, 29 species of grasses and 11 species of climbers (Figure 3). The common plant species in the tree layer include *Shorea robusta, Mallotus philippinensis, Adina cordifolia, Holoptelea integrifolia, Syzygium cumini, Terminalia tomentosa, Acacia catechu, Sapium insigne, Kydia calycina, Bombax ceiba, Boehmeria rugulosa, Ougeinia oojeinensis, Trema politora, Toona ciliata, Mangifera indica, Aegle marmelos, Pinus roxburghii* and several species of *Ficus*. The common shrubs and floor vegetation included *Vitex negundo, Callicarpa macrophylla, Justicia adhatoda, Woodfordia fruticosa, Ricinus communis, Persea odoratissima, Eupatorium odoratum, Lantana camara, Murraya koenigii, Cassia mimosoides, Indigofera heterantha, Rubus ellipticus, Calotropis procera, Zizyphus mauritiana, Bidens pilosa, Cannabis sativa, Circium walichii, Conyza japonica* and *Sida acuta*.

Taxonomic composition and diversity of entomofauna

During the one year of study period, a total of 5,908 individuals under 140 species that belonged to 29 different families and seven orders of the class Insecta were reported from the Pancheshwar

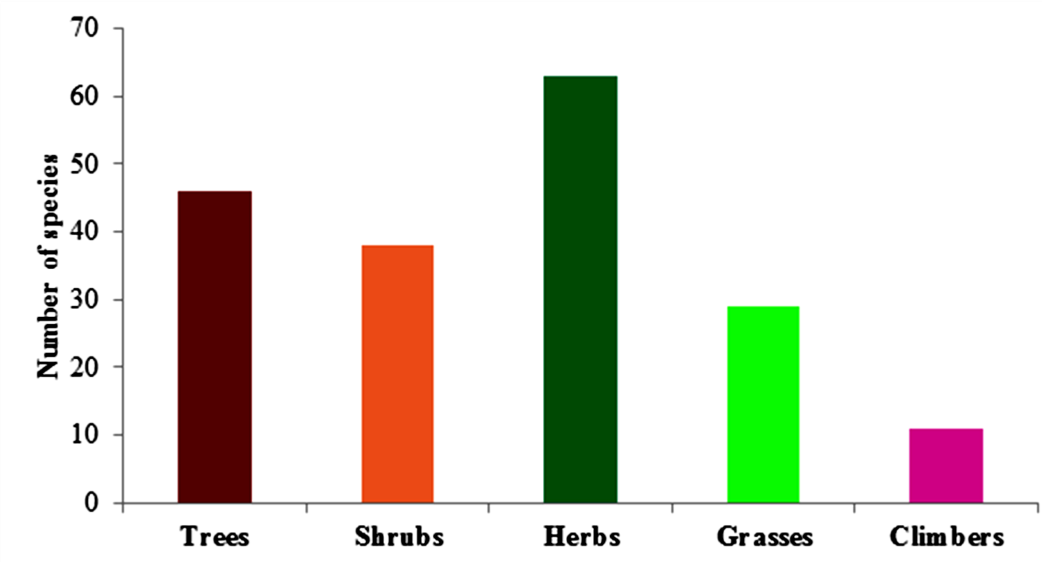

Figure 3. Diversity of the plants recorded from the Pancheshwar dam site.

dam site located in the Kumaon Mountains of the Central Himalaya (Appendix II; Available as supplementary information in e-version of this chapter). Figure 4 depicts that among the recorded entomofauna, Lepidoptera outnumbered the other insect orders in terms of species richness (N = 95; 67.85% of the total species) and abundance (2,813 individuals; 47.61% of the total individuals). Odonata was the second most specious (N = 11; 7.85% of the total species) and abundant order (15.53% of the total individuals). Coleoptera and Orthoptera were similar in terms of species richness (N = 9 each; 6.42% of the total species), wherein the former group consisted 13.32% of the total individuals while the latter comprised 8.12% of the total individuals. Hymenoptera was represented by 5.71% of the total recorded species (N = 8) and 8.56% of the total individuals (506 individuals). Diptera and Hemiptera were found to be least diverse in terms of species richness (N = 4 each; 2.85% of the total species) and abundance (4.23% and 2.60% of the total individuals, respectively). Sample based individual rarefaction was asymptotic and the steeper curve was observed for the insect communities, signifying sufficient sampling efforts (Figure 5). This also point towards the potential of the region in sustaining more insect diversity and further samplings might result in addition of more species from the study area.

The values for various measures of diversity indices varied significantly among the recorded insect orders (Table 1). Order Lepidoptera exhibited maximum value for species diversity (H_s = 4.20) and species richness (H_m = 11.84), followed by Odonata (H_s = 2.22 and H_m = 1.46). Hymenoptera showed higher species diversity (H_s = 1.99) as compared to the Orthoptera (H_s = 1.88) and the Coleoptera (H_s = 1.80), however it showed slightly lower species richness (H_m = 1.12) than Orthoptera (H_m = 1.29) and Coleoptera (H_m = 1.20). Minimum diversity and species richness was calculated for the orders Diptera (H_s = 1.35 and H_m = 0.54) and Hemiptera (H_s = 1.24 and H_m = 0.59). The maximum value of evenness as recorded for the order Diptera (E = 0.972) revealed that members of this order are more evenly distributed than the others while the members of Coleoptera (E = 0.677) and Lepidoptera (E = 0.706) were less evenly distributed during the study period.

Table 1. Diversity indices calculated for the different insect orders during the study period.

Order	**Shannon (H_s)**	**Margalef (H_m)**	**Evenness (E)**
Lepidoptera	4.20	11.84	0.706
Hymenoptera	1.99	1.12	0.916
Coleoptera	1.80	1.20	0.677
Diptera	1.35	0.54	0.972
Hemiptera	1.24	0.59	0.867
Orthoptera	1.88	1.29	0.727
Odonata	2.22	1.46	0.836
Total	4.55	16.01	0.680

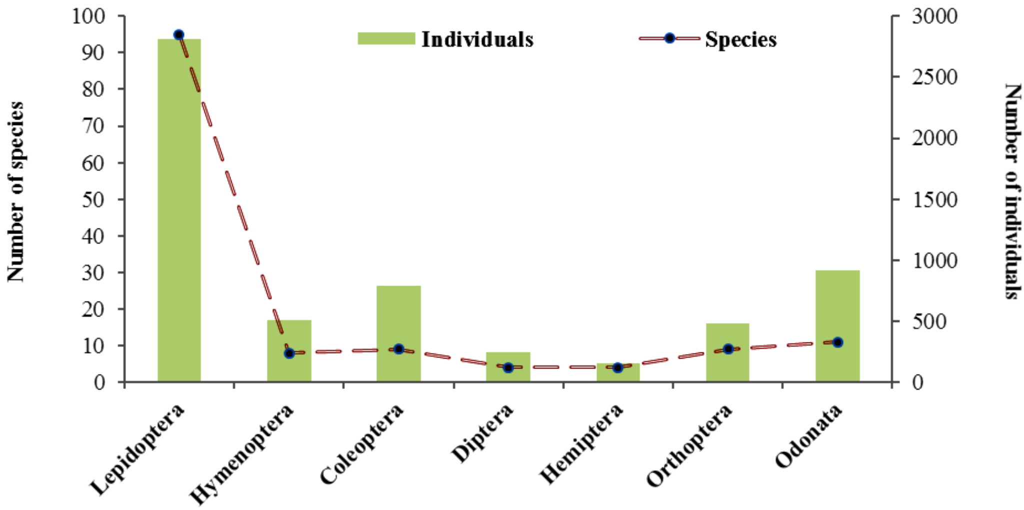

Figure 4. Species richness and abundance of different insect orders as recorded during the study period.

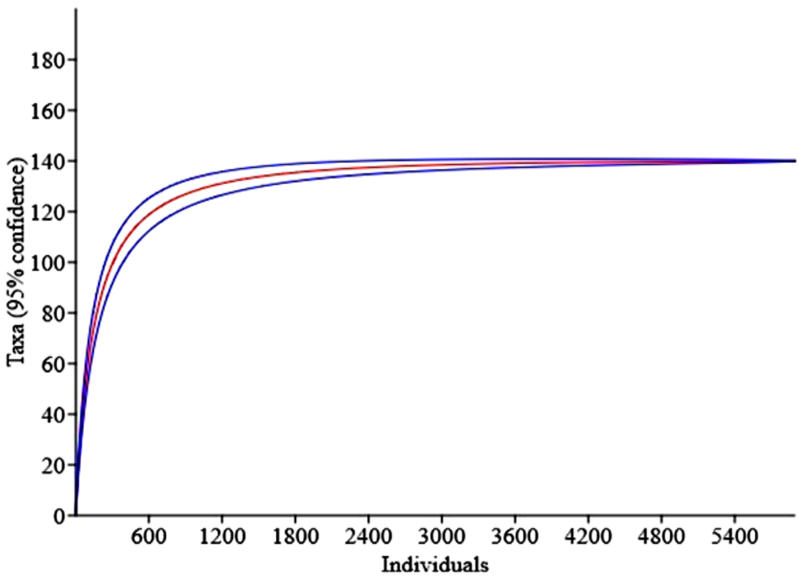

Figure 5. Sample based individual rarefaction curve with 95% confidence interval (blue lines) in the Pancheshwar dam site (August 2017 to July 2018).

The family-wise collection of number of species and individuals of the different insect orders has been presented graphically in the Figure 6. Order Lepidoptera comprised six families of butterflies namely, Nymphalidae (45 species and 1,241 individuals), Lycaenidae (16 species and 335 individuals), Pieridae (12 species and 689 individuals), Hesperiidae (11 species and 159 individuals), Papilionidae (7 species and 263 individuals) and Riodinidae (3 species and 72 individuals). The moths were represented by single species with 54 individuals under the family Sphingidae. Species such as *Eurema laeta*, *Eurema hecabe*, *Pieris brassicae*, *Euploea core*, *Junonia iphita* and *Papilio polytes* were the most abundant butterflies which altogether constituted 10.32% of the total insect individuals. On the other hand, *Horaga onyx*, *Moduza procris*, *Belenois aurota*, *Curetis bulis*, *Castalius rosimon*, *Hestina nama*, *Udaspes folus* and *Pseudocoladenia fatih* were the least abundant species of butterflies. Order Hymenoptera was represented by five families, of which Apidae was the most specious and dominant family consisting three species and 3.63% of the total insect individuals. *Apis dorsata* was the most abundant bee species of this family. The species of wasp namely, *Vespa basalis* of the family Vespidae was the most dominant species of the order Hymenoptera.

Order Coleoptera was comprised of four families namely, Scarabaeidae (4 species and 333 individuals), Chrysomelidae (3 species and 155 individuals), Coccinelidae (single species with 266 individuals) and Meloidae (single species with 33 individuals). *Coccinella septumpunctata L. var. divaridata* was the most dominant species of this order followed by *Anomala dimidiata* and *Altica*

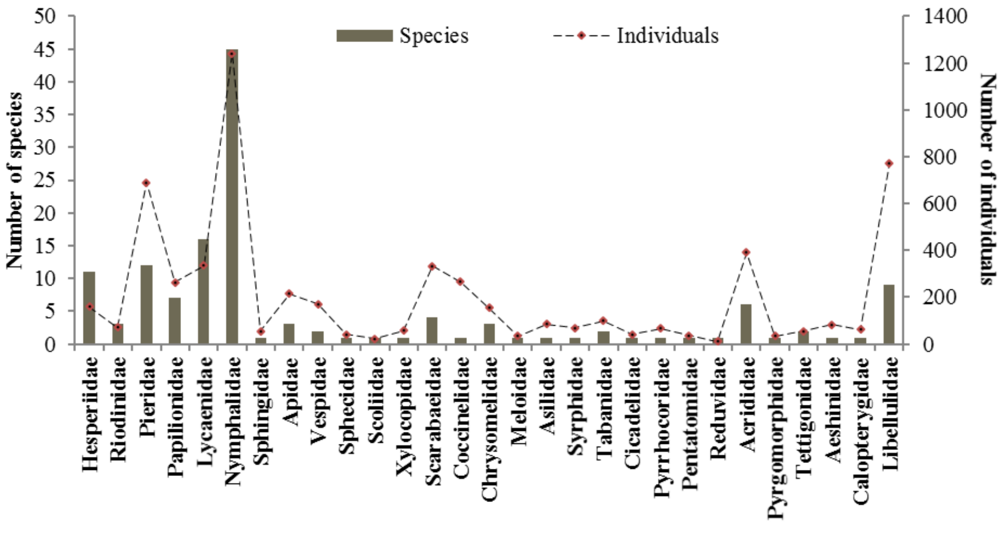

Figure 6. Family-wise collection of species richness and abundance of different insect orders.

himensis while *Protaetia neglecta* was the least abundant species of the beetles. Order Hemiptera was represented by four families with single species in each family, Pyrrhocoridae was the most dominant among them and *Physopelta gulta* as the dominant species of this family. Among the order Orthoptera which consists of three families, Acrididae was the most dominant family consisting six species and the species such as *Acrida exaltata* and *Trilophidia annulata* were the dominant. Diptera was represented by three families namely, Tabanidae (2 species and 98 individuals), Asilidae (single species with 84 individuals) and Syrphidae (single species with 68 individuals). Among three families under the order Odonata, Libellulidae was the most dominant represented by nine species and 13.08% of the total insect individuals. Dragonflies such as *Orthetrum taeniolatum*, *Orthetrum triangulare*, *Orthetrum pruinosum* and *Orthetrum glaucum* were the most abundant species of this order.

Seasonal diversity of insects

Figures 7 and 8 represent the relative number of species and individuals recorded among the different orders of insects across the four major seasons *viz*. pre-monsoon, monsoon, post-monsoon and winter, respectively. It is evident that different seasons exerted marked impact on the species richness of the Lepidoptera, wherein the species richness peaked twice i.e., during the pre-monsoon (N = 90; 64.28% of the total species) and post-monsoon seasons (N = 86; 61.42% of the total species). No such major difference in the trend of species richness across the different seasons was observed for the other orders. The individual abundance for most of the orders was reported to be maximum during the monsoon season while the species richness and individual abundance was least during the cold winters. The calculated values of diversity (H_s), species richness (H_m) and evenness (E) across the major seasons for the different insect orders has been presented in the Figure 9. The species diversity and the species richness of the order Lepidoptera was maximum during the pre-monsoon season (H_s = 4.21 and H_m = 13.22) and the post-monsoon season (H_s = 4.20 and H_m = 12.65). The species diversity of the orders Hymenoptera (H_s = 2.03), Coleoptera (H_s = 1.89), Diptera (H_s = 1.37), Hemiptera (H_s = 1.29) and Odonata (H_s = 2.24) was maximum during the post-monsoon season while the Orthoptera showed high species diversity during the monsoons (H_s = 1.93). The species richness was fairly high during the post-monsoon season among the orders Hymenoptera (H_m = 1.42), Coleoptera (H_m = 1.48), Hemiptera (H_m = 0.78) and Orthoptera (H_m = 1.60) while the orders Diptera (H_m = 0.78) and Odonata (H_m = 1.90) showed maximum species richness during the pre-monsoon season. Similarly, trends in the evenness of species under different orders varied significantly across the different seasons.

Species of conservation priority and economic importance

During the present study a total of ten species of butterflies are legally protected under the different schedules of Indian Wildlife (Protection) Act, 1972 indicating high host plant richness in

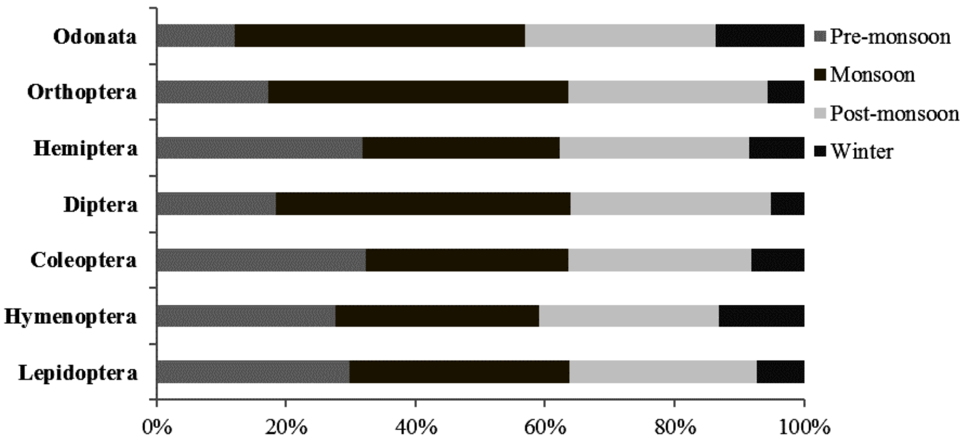

Figure 7. Relative composition of species richness of different insect orders across the seasons.

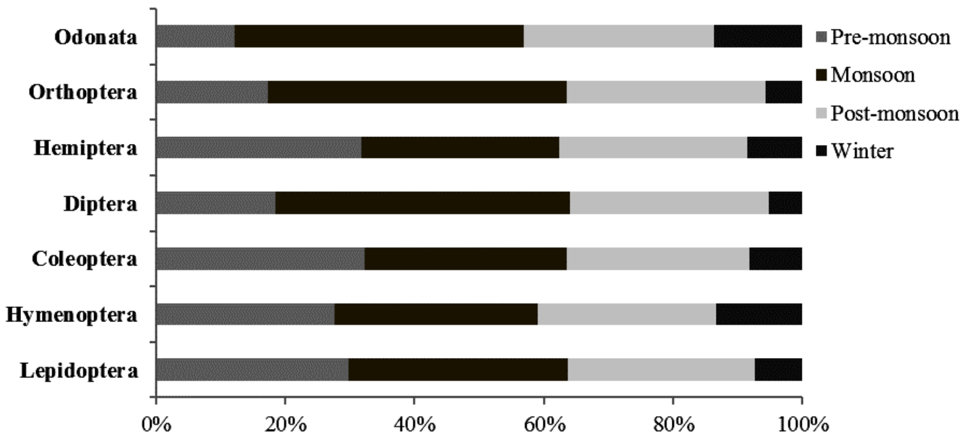

Figure 8. Relative composition of individual abundance of different insect orders across the seasons.

Table 2. List of species of butterflies under different schedules of the Indian Wildlife Protection Act (WPA), 1972 recorded from the Pancheshwar dam site (Anonymous, 2006).

Family	Species	Schedules of WPA	Local status
Papilionidae	*Papilio clytia* Linnaeus	I	Rare
Lycaenidae	*Castalius rosimon* (Fabricius)	I	Rare
	Deudorix epijarbas (Moore)	II	Rare
	Euchrysops cnejus (Fabricius)	II	Uncommon
	Everes argiades (Pallas)	II	Uncommon
	Horaga onyx (Moore)	II	Very Rare
	Lampides boeticus (Linnaeus)	II	Common
	Megisba malaya (Horsfield)	II	Rare
Nymphalidae	*Euploea core* (Cramer)	IV	Very Common
	Euploea mulciber (Cramer)	IV	Uncommon

the Pancheshwar dam site and are thus, these species are important from the standpoint of their conservation in ecological studies (Table 2). Of these, *Horaga onyx* was very rare and *Papilio clytia*, *Castalius rosimon*, *Deudorix epijarbas*, *Megisba malaya* were rare in their distribution range throughout the study period. Thus, there is an urgent need to adapt conservation policies for these species as they are of more conservation priority over rest of the other taxa available in the study area. Five species namely, *Eurema brigitta*, *Euploea core*, *Junonia almana* and *Junonia hierta* present in the study area are listed as least concerned species in the IUCN Red list of threatened species. Besides, butterfly known as 'Common Peacock' (*Papilio bianor*), common in its distribution range in the present study area was declared as the 'State Butterfly' of the Uttarakhand by the State Wildlife Board in November 2016.

Species namely, *Coccinella septumpunctata L. var. divaridata* (Coccinelidae, Coleoptera) and *Altica himensis* (Chrysomelidae, Coleoptera) have strong implications as bio-control agents while the oil extracts of *Mylabris cichorii* (Meloidae, Coleoptera) possess anti-carcinogenic properties. Five species namely, *Anomala dimidiata*, *Anomala lineatopennis* of the family Scarabaeidae under the order Coleoptera, *Pieris brassicae*, *Pieris canidia* of the family Pieridae and *Papilio demoleus* of the family Papilionidae under the order Lepidoptera have been reported earlier as the pestiferous insects. Each insect provide an ecosystem service and contributes to the stability of the ecosystem. Therefore, the direct and indirect benefits of the other insects can never be overlooked. The state of Uttarakhand nestled in the Central Himalaya is endowed with magnificently diverse land-scapes and is bestowed with marvelous range of biodiversity supporting many endemic animal and plant species. The state forms a potential zoo-geographical zone and is home to an

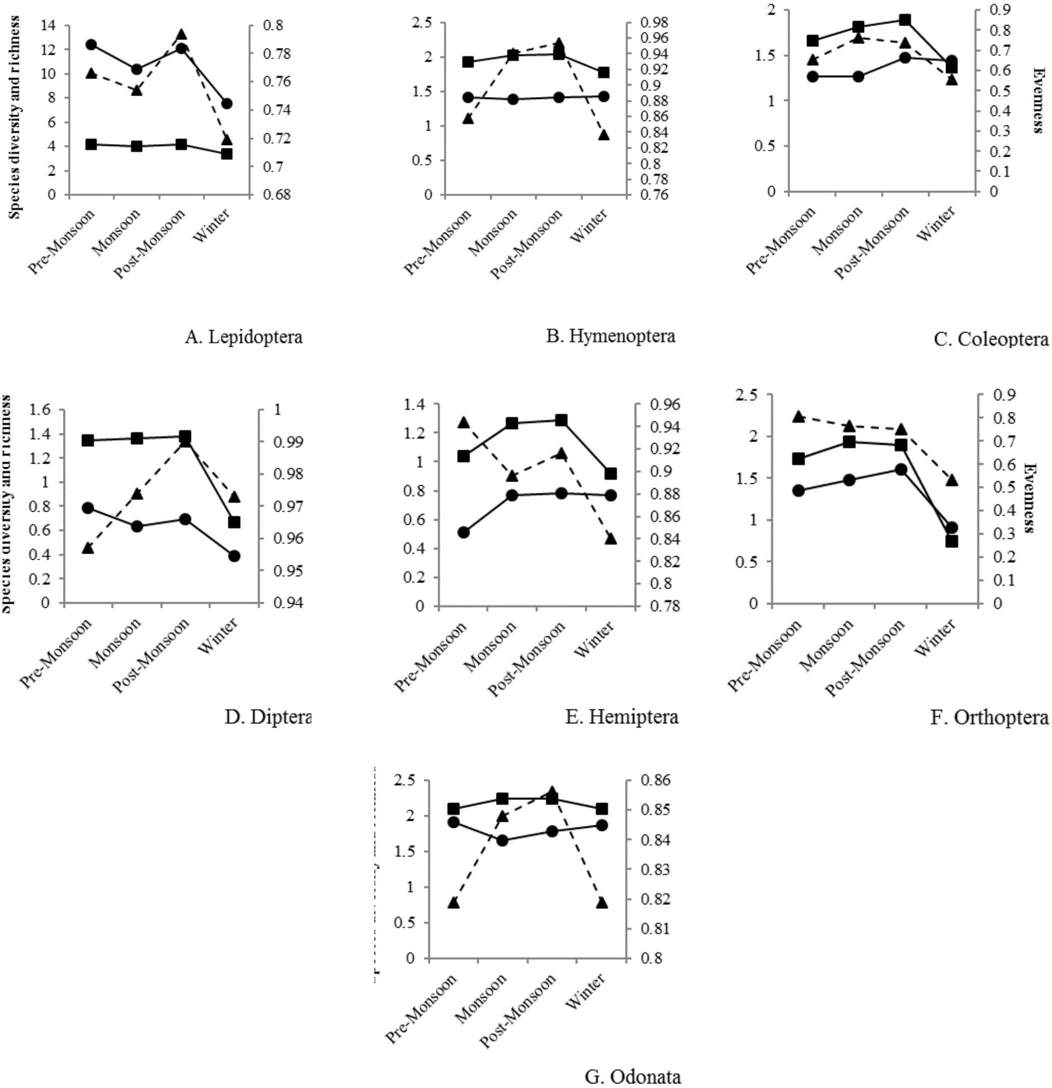

Figure 9. Measures of diversity indices of the recorded insect orders across the different seasons (unbroken lines, ■ Shannon, Hs and ● Margalef, Hm; dashed lines, ▲ Evenness, E).

average of 4,160 species of insect fauna including Lepidoptera (1,523 species), Coleoptera (1,074 species), Diptera (541 species), Hymenoptera (181 species), Orthoptera (144 species), Odonata (122 species) and others (Chandra, 2011). Scientists and academicians have published numerous reports in regard to the distribution and diversity of different insect orders from the Indian Himalayan Region (Mani, 1956; Singh, 1963; Biswas, 1995; Tandon *et al*., 1995; Uniyal *et al*., 2000; Uniyal and Mathur 2000; Kumar *et al*., 2007; Uniyal, 2007; Joshi *et al*., 2008; Chandra *et al*., 2012; Arya and Dayakrishna, 2013; Arya *et al*., 2013; Sanyal *et al*., 2013; Sondhi and Kunte, 2016; Singh and Sondhi, 2016). The attempts made in the present study revealed a rich diversity and richness of insects, especially of butterflies with 94 species from the Pancheshwar dam site, providing better life supporting natural resources for the existence of many rare and economically important insect species. The high diversity and richness of butterflies and dragon flies might be attributed to the diverse vegetational composition and the pre-dominance of riparian habitat in the region.

Seasonality is a conspicuous feature in the life history of many insects (Wolda and Wong, 1988) and occurs for a variety of reasons including macroclimatic and microclimatic changes, and seasonal availability of food resources (Wolda, 1988). Since diversity and its structure are intricately linked to climatic seasonality in tropical forests and for those parts of the tropics where wet and dry seasons alternate (Davis, 1945), any assessment of global biodiversity by extrapolation from local and regional measurements requires that seasonal patterns to be recognized (Plant *et al*., 2017). Insect diversity and abundance tend to vary over time in association with multiple factors that are associated with each season. It include changes in ambient temperature, light intensity, precipitation, host plant quality, vegetation cover, and a differential set of predators and predation risk (Sajjad *et al*., 2012; Shobana *et al*., 2012). Each insect taxa in each season could exhibit different responses, so that the effects of the wet or the dry season could be reflected in numeric responses and herbivorous insects peak in abundance depending upon the time that the resource they exploit is most abundant (Pinheiro, 2002). Moreover, underlying factors such as life span, number of generations per year and fecundity of each insect could be the determinants for the diversity of different insect orders (Sajjad *et al*., 2012), besides the plant diversity (Koricheva *et al*., 2000). In the present study, the measures of diversity indices *viz*. Shannon, Margalef and Evenness calculated across the different seasons followed different patterns among the different insect orders. The peak abundance for most of the orders was reported during the monsoons coincident with leaf flush and flowering (Wolda, 1978).

Knowledge of the host plants is crucial in the development of long term conservation strategies; primarily for the areas facing declining populations of butterflies and other herbivorous insects. The present study area is generally covered with sub-montane broadleaf summer-deciduous forest (Singh and Singh, 1987) and exhibit a diversity of plant species congenial for butterflies. Botanical families such as Rutaceae, Annonaceae, Lauraceae, Aristolochiaceae, Dioscoreaceae constitute larval food plants for the butterflies of Papilionidae, whereas Cruciferae, Fabaceae, Moraceae, Poaceae, Tiliaceae, Rubiaceae, Asteraceae, Euphorbiaceae, Malvaceae, Acanthaceae, Fagaceae, Myrataceae, Lauraceae, Rosaceae, Oxalidaceae and other are most preferred host plants of the butterflies of Pieridae, Nymphalidae, Lycaenidae and Hesperiidae (Robinson *et al*., 2001). The members of these botanical families are of common occurrence in the dam site and have been listed in the present study.

The loss in biodiversity due to habitat degradation and fragmentation is of global concern irrespective of regional and local importance (Baur and Erhardt, 1995). During the years 1970-2000 a net deforestation rate of 0.54% has been recorded in the Indian Himalayan Region due to the ongoing anthropogenic forest conversion aggravated by global climate change. Nevertheless, considerable progress has been made in the protection of forests, gross deforestation rate continues as a focal hindrance (Reddy *et al*., 2013). It is also estimated that if deforestation in the Himalaya continues at the current rate, the dense forest cover (>40% canopy cover) will be restricted to 10% of land area in the Indian Himalayan Region by 2100 (Kumari *et al*., 2019). This may lead to a significant loss of 366 endemic plants and 35 endemic vertebrates (Pandit *et al*., 2007). Insect pollinators are strongly affected by the habitat loss and pollinator limitation due to decreased diversity or abundance lead to reductions in pollination efficiency, fruit and seed set, and gene flow among plant communities (Kunin, 1993; Matthies *et al*., 1995). Forest disturbance affects bee and butterfly species diversity thus impacting key stone ecological process of pollination (Steffan-Dewenter and Tscharntke, 1999). Habitat fragmentation affects particularly the specialist species of higher trophic levels such as monophagous and oligophagous butterflies and insect species with limited dispersal abilities (Steffan-Dewenter and Tscharntke, 2002).

The main dam site and the surrounding area affected both upstream and downstream in the Pancheshwar are of significant ecological, cultural and spiritual as well as of tourism importance (Everard and Kataria, 2010). The construction of the proposed dam would threaten and disturb not only the local wildlife populations but also the ecological balances over a wide geographical scale. On the other hand, it is anticipated as a milestone in the water and energy sector of India as well as Nepal (Everard and Kataria, 2010). The execution of the proposed dam in its current format raises concern regarding the feasibility and geo-environmental implications of the proposed Pancheshwar high dam in the ecologically sensitive and tectonically active terrain of the Himalaya (Sati *et al*., 2019). The Himalayan ecosystem within which the dam is planned for construction is a transitional zone between the western Nepal and the eastern Uttarakhand, thus owing stocks of mostly Palaearctic regions; however, some of the faunal elements below tree line are common between Oriental and Palaearctic regions so it supports a diversity of wildlife, much of which is threatened due to ongoing pre-dam construction activities. Moreover, Askot Wildlife Sanctuary lying in the district Pithoragarh nearly 3 km upstream of the tail end of the submergence is located 50 km away from the project area where main construction activities are likely to take place (PDA, 2017). The surrounding area at the confluence of rivers in the village

Pancheshwar was observed frequent for the activities like camping, rafting and angling, as this specified area is renowned worldwide to abode for 'Golden Mahseer' fish (*Tor putitora*) listed as endangered species in the Red list of IUCN. During this study, pre-dam construction activities such as tunneling, road constructions, soil erosion from constructions and quarrying, river impoundment, un-managed excessive felling of trees and collection of minor and major forest products by locals and labors were easily recognizable constant interferences while natural and human induced landslides are highly prevalent in the study area (Figure 10a-b). These imminent threats are causing a drastic change in the vegetational composition of the area disrupting key plant-pollinator and predator-prey interactions, which in turn affecting primarily to the floristic diversity and ultimately to all sorts of faunistic wildlife through a number of eco-biological interactions of the complex food web.

Conclusion

The present study reported rich diversity of entomofauna with total species diversity of 4.55 (Shannon) and species richness of 16.01 (Margalef) from the Pancheshwar, however the future sustenance of these insects looks uncertain in regard to the current ongoing developmental project executed on macro scale. The composition of the resident butterflies and other insect communities in degraded forests of the present study area will fluctuate with time according to the species that are better adapted for the current level of disturbances. Decline in forest quality is expected to lead to shifts in relative abundance and diversity of insect communities, which can be monitored with regular surveys to study any immediate effect of the type and degree of disturbances in the study area. It is suggested that concerted research efforts are needed for the scientific documentation of other biological resources both on temporal and spatial scales due to unique geography of the area. Successful nature conservation could only be met with adequate foresight and planning. In the current scenario, Compensatory Afforestation Fund Management and Planning Authority (CAMPA) established to promote afforestation and regeneration activities as a way of compensating for forest land diverted to non-forest uses is needed to come on the fore front and should take necessary steps for the plantations of those species important as the host plants for butterflies and other herbivorous insects. Large-scale compensatory afforestation by such authorities would help to mitigate the local extinction of fauna over a wide range. Species that are of common occurrence might require detailed conservation plans and employment of appropriate management practices. Moreover, emphasis should be on stringent legislation to reinforce the regulations regarding the use and access to resources in the present study area. There is an immediate need of understanding and conserving biodiversity at spatio-temporal scales and conservation authorities in collaboration with ecologists should reach

Figure 10. Human induced threat factors for the biodiversity, (a) tunneling and (b) frequent landslides due to current pre-dam construction activities at the Pancheshwar dam site, Central Himalaya.

these goals in order to preserve ecological integrity and sustainability of the region.

Acknowledgements

The authors would like to thank the Divisional Forest Officer, Champawat Forest Division, Forest Department, Uttarakhand for providing us permission and hospitality in the study area to carry out our surveys. We also express our immense thanks to the SSB personnel of India's Central Armed Police forces and all the local people for their kind help and cooperation throughout the field study.

Supplementary information

Supplementary information/document to this book chapter can be found online at https://doi.org/10.26832/aesa-2020-edcrs-0XX.

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Cite this chapter as: Verma, A. and Arya, M.K. (2020). Biodiversity of entomofauna with reference to habitat degradation at Pancheshwar dam site on the River Mahakali, Central Himalaya. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 183-204, https://doi.org/10.26832/aesa-2020-edcrs-013

In: Environmental Degradation: Causes and Remediation Strategies
DOI: 10.26832/aesa-2020-edcrs-014

CHAPTER [14]

Strategies to prevent environmental stresses by silicon fertilization in rice crop

Ardeep Kumar

Department of Agronomy, College of Agriculture,
G.B. Pant University of Agriculture and Technology, Pantnagar - 263153 (Uttarakhand), India

ABSTRACT

Rice is the most important staple food crop for a large part of the world's population, especially in East and South Asia, Middle East, Latin America, and the West Indies. As the population increases rapidly in these regions, the demand for rice will grow to an estimated 2000 million metric tons by 2030. To supply to this increasing demand, the methods of rice production will require significant improvement. Achieving this goal, however, is sure to be a challenge with respect to future climatic changes, which will basically be characterized by current global warming trends. The rise in temperatures and levels of carbon dioxide and uncertain rainfall associated with climate change may have serious adverse effects either directly or indirectly on the growth, development, and yield of rice crops. To cope with the unfavorable growth conditions, plants respond with a series of morphological, biochemical, and molecular adaptations, aiming at safeguarding the basic metabolic activities. All the unfavorable factor which limit crop yield may be consider as a stress. Silicon seems to protect plants from such types of stresses caused by environmental degradation. This can be managed by proper agronomic practices or developing resistance variety. Therefore, in this chapter we showed that how we can manage these stresses to boost rice productivity in changing climatic scenario while using silicon fertilizer as a protective agent.

KEYWORDS Climate change, Environmental stress, Global warming, Rice crop, Productivity

Ardeep Kumar, Email: ardeepkumar4@gmail.com

Introduction

Stress is an external factor that decreases crop yields from yield maximum to a lower level for examples diseases, insects, salinity, and excesses of trace elements. Due to global warming, and potential climate abnormalities associated with it, crops typically encounter an increased number of abiotic and biotic stress combinations, which severely affect their growth and yield (Ramegowda and Kumar, 2015; Kumar *et al*., 2020). Concurrent occurrence of abiotic stresses such as drought and heat has been shown to be more destructive to crop production than these stresses occurring separately at different crop growth stages (Prasad *et al*., 2011). Abiotic stress conditions such as drought, high and low temperature and salinity are known to influence the occurrence and spread of pathogens, insects, and weeds (Peters *et al*., 2014). They can also result in minor pests to become potential threats in future. These stress conditions also directly affect plant–pest interactions by altering plant physiology and defense responses. Additionally, abiotic stress conditions such as drought enhance competitive interactions of weeds on crops as several weeds exhibit enhanced water use efficiency than crops (Valerio *et al*., 2013). Abiotic stresses like salinity, water deficit, chilling, and heavy metals adversely affect the growth and several physiological processes of plants. In general, low temperature mainly results in mechanical constraint, whereas salinity and drought exert their malicious effect by disrupting the ionic and osmotic equilibrium of the cell. The detrimental effects of excess salts are the consequences of water deficit that results from decreased osmotic/water potential of soil solution due to high solute concentration in the soil, as well as ion-specific stresses due to altered Na^+/K^+ ratios and Na^+/Cl^- ratios that are inimical to the plants. The phytohormone abscisic acid (ABA) regulates desiccation tolerance in seeds as well as in vegetative tissue. The endogenous ABA concentration increases in different plant tissues during drought, salinity, or cold induced oxidative stress. To cope with the unfavorable growth conditions, plants respond with a series of morphological, biochemical, and molecular adaptations, aiming at safeguarding the basic metabolic activities. It is now well known that the stress signal is first perceived at the membrane level by the receptors and then transduced into the cell to switch on the stress responsive genes for mediating stress tolerance. Population growth and water scarcity combined mean that there is no alternative but induced by drought, high salinity, and low temperature stresses, and their products are thought to function in stress tolerance and response (Roychoudhury *et al*., 2013).

Environmental factors responsible stress in rice crop

Droughts

Drought is generally avoided in areas where irrigation water is available throughout the season, but it is a consistent feature across much of the 63.5 million hectares of rainfed rice sown annually, most of which is in tropical Asia, Africa and Latin America. It can occur at any stage during the rice cropping season, but it is more devastating when it occurs just prior to flowering than it is during the vegetative stage, with substantial effects on grain yield. About 70% of the rice area in sub- Saharan Africa is rainfed. The spatial and temporal variability of rainfall in this region expose rice plants to frequent drought spells. Regardless of the total rainfall and distribution, the poor physical properties of highly weathered, coarse-textured soils in some parts of sub-Saharan Africa induce low water-holding capacity and establish water deficit as a major constraint to rainfed crop yields in sub-Saharan Africa. This is particularly true for upland rice, which makes up 32% of rice-growing areas in sub-Saharan Africa. Analysis of farmer perceptions in 18 countries in sub-Saharan Africa across rice environments provided evidence that in 2008 an estimated 10% of rice farmers experienced drought affecting 37% of their rice area, causing 29% of rice yield loss. The diversity of affected production systems, variability of drought in terms of timing and severity, and the multiple traits involved in drought tolerance require strategic research to prioritize and define environment-specific approaches for developing drought-tolerant rice cultivars.

Submergence and water logging

Rice plants require water for growth but excess water that occurs during submergence or water logging is harmful or even lethal. A submerged plant is defined as "a plant standing in water with at least part of the terminal above the water or completely covered with water" (Catling, 1992). Submergence subjects plants to the stresses of low light, limited gas diffusion, effusion of soil nutrients, mechanical damage, and increased susceptibility to pests and diseases (Ram *et al.*, 1999). Basically, flooding (i.e., submergence) can be classified into "flash flooding" and "deepwater flooding" in accordance with the duration of flooding and the water depth. Flash flooding, which generally lasts less than a few weeks, is caused by heavy rain but the depth is not very deep. On the other hand, deepwater flooding, which lasts for several months, occurs during the rainy season, and the water depth reaches several meters (Hattori *et al.*, 2011). Water logging is defined as a condition of the soil in which excess water limits gas diffusion (Setter and Waters, 2003). Oxygen diffusivity in water is approximately 10,000 times slower than in air, and the flux of O_2 into soils is approximately 320,000 times less when the soil pores are filled with water than when they are filled with gas (Colmer and Flowers, 2008). The principal cause of damage to plants grown in waterlogged soil is inadequate supply of oxygen to the submerged tissues as a result of slow diffusion of gases in water and rapid consumption of O_2 by soil microorganisms. Oxygen deficiency in waterlogged soil occurs within a few hours under some conditions. In addition to the O_2 deficiency, production of toxic substances such as Fe^{2+}, Mn^{2+}, and H_2S by reduction of redox potential causes severe damage to plants under waterlogged conditions (Setter *et al*. 2009).

Soil salinity

Irrigation has the potential to ensure high rice yields and is a good strategy to offset recurrent droughts. Unfortunately, soils of most irrigated areas have continued to be degraded as a result of poor irrigation practices and the absence of efficient drainage. These have led to a rapid rise in the water table and an increase in soil sodium/alkalinity and salinity (Bertrand *et al*., 1993). In the Office du Niger (Mali), 50% of the water table is now saline and occasionally very saline despite low mineral content of the irrigation water (Bertrand *et al*., 1993). In the Senegal River delta, marine-derived soil salinity is an inherent problem and sodicity is increasing in irrigated flood plains in inland areas due to high evaporation, rising groundwater tables and poor drainage (Matlon *et al*., 1998). Miézan and Dingkuhn (2001) observed that waters of the Niger and Senegal rivers carry substantial alkalinity, and the salt content of water sometimes increases markedly between the main rivers and the actual irrigation site. However, van Asten *et al*. (2003) show that salt accumulation in the soils of Sahelian countries has more to do with the underlying bedrock than with the irrigation system. Examining soils in the irrigated areas of Foum Gleita (Mauritania) they found that the geographical distribution of salt was not related to the presence of irrigation or drainage canals. Also the alkaline salts present in the upper soil layers in Foum Gleita did not come from irrigation water, but from the underlying bedrock. Additional to the salt stress itself, the high pH resulting from the sodification/ alkalinization reduces the availability of plant nutrients such as zinc and increases nitrogen losses through volatilization (Miézan and Dingkuhn, 2001). However, salinity tolerance at these two stages is only weakly associated (Moradi *et al*., 2003). Discovering and combining suitable tolerance traits for both stages is essential for developing resilient salt-tolerant varieties. Moreover, the salt-tolerance level of cultivars depends on environmental conditions (Asch *et al*., 1997). Generally, salinity effects on rice are more severe in arid climates than in humid ones. For example, salinity levels at an electric conductivity (EC) of 9.5 mS/ cm were reported to cause a 50% yield loss in the humid tropics (Flowers and Yeo, 1981), whereas under the arid conditions of the Sahelian dry season an equivalent yield loss was observed at an EC of only 3.5 mS/cm (Dingkuhn *et al*., 1993).

Role of silicon in enhancing the resistance to environmental stresses

Silicon and rice blast disease

The suppressive effect of Si on rice blast was reported as early as 1917 by Onodera (1917). Rice blast, caused by *Magnaporthe grisea*, is the most destructive fungal disease of rice, particularly in temperate, irrigated rice and tropical upland rice. The pathogen can infect all the above-ground parts of the rice plant, but occurs most commonly on leaves causing leaf blast during the vegetative stage of growth or on neck nodes and panicle branches during the reproductive stage, causing neck blast (Bonman *et al.*, 1989). Silicon reduces the epidemics of both leaf and panicle blast at different growth stages. In Florida, where soil is deficient in Si, application of silicate fertilizer is as effective as fungicide application in controlling rice blast (Datnoff *et al.*, 1997). Rice seedling blast is significantly suppressed by the application of Si fertilizers in the nursery (Maekawa *et al.*, 2001).

Silicon and powdery mildew disease

Silicon has been reported to prevent the incidence of powdery mildew disease, which is caused by *Sphaerotheca juliginea*, in a number of plant species. Miyake and Takahashi (1983) reported that by increasing the Si concentration in the culture solution, the Si content in the cucumber shoot increased, resulting in a reduced incidence of powdery mildew disease. In strawberry, when the Si content of leaves increased proportionally to the increase of the Si concentration in the culture solution, the incidence of powdery mildew decreased (Kanto, 2002). Silicon deficiency in barley and wheat leads to a poor growth habit and increased powdery mildew susceptibility (Zeyen, 2002). Menzies *et al.* (1991) found that infection efficiency, colony size, and germination of conidia were reduced when cucumbers were grown in nutrient solutions with high concentrations of Si. Foliar application of Si has been reported to be effective in inhibiting powdery mildew development on cucumber, muskmelon, and grape leaves (Bowen *et al.*, 1992). Si applied to leaves may deposit on the surface of leaves and playa similar role to that of Si taken up from the roots.

Silicon and other diseases

In addition to blast and powdery mildew, the occurrence of brown spot, stem rot, sheath brown rot on rice, fusarium wilt, and corynespora leaf spot on cucumber decreased by increasing the Si supply. In turfgrass, several diseases were also suppressed by Si application (Datnoff *et al.*, 2002). Rice bacterial blight caused by *Xanthomonas oryzae* pv. oryzae (Xoo) is a serious disease worldwide. Chang *et al.* (2002) reported that in the cultivar TNI which is susceptible to this disease the Si content in leaves was lower than that of the resistant breeding line, TSWY7 under the nutrient cultural system adopted. The degree of resistance to this disease increased in parallel with the increased amount of applied silicon. Si-induced decrease of soluble sugar content in the leaves seems to contribute to the field resistance of the disease. Silicon is also effective in increasing the resistance to the fungal diseases caused by *Pythium ultimum* and *Paphani dermatum* in cucumber roots (Cherif *et al.*, 1994).

Silicon and pests

Silicon suppresses insect pests such as stem borer, brown plant hopper, rice green leaf hopper, and white backed plant hopper, and non insect pests such as leaf spider and mites (Savant *et al.*, 1997). Stems attacked by the rice stem borer were found to contain a lower amount of Si (Sasamoto, 1961). In a field study, a positive relationship between the Si content of rice and resistance to the brown plan thopper has been observed (Sujatha *et al.*, 1987).

Possible mechanisms involved

Two hypotheses for the Si-enhanced resistance to diseases and pests have been proposed. One is that Si deposited on the tissue surface acts as a physical barrier. It prevents physical penetration and / or makes the plant cells less susceptible to enzymatic degradation by fungal pathogens. This mechanism is supported by the positive correlation between the Si content and the degree of suppression of diseases and pests. The other one is that Si functions as a signal to induce the production of phytoalexin (Cherif *et al.*, 1994). Si application to cucumber resulted in the stimulation of the chitinase activity and rapid activation of peroxidases and polyphenol oxidases after infection with Pythium spp. Glycosidically bound phenolics extracted from Si-treated plants when subjected to acid or B-glucosidase hydrolysis displayed a strong fungistatic activity. However, in oat attacked by *Blumeria graminis*, Si deficiency promoted the synthesis of phenolic compounds (Carver *et al.*, 1998).

The phenylalanine ammonia-lyase activity was enhanced by Si deficiency. The reason why Si deficiency exerts opposite effects on the synthesis of phenolic compounds, as a disease response in different plant species, has not been elucidated. Recently, Kauss *et al.* (2003) have reported that during the induction of systemic all acquired resistance (SAR) in cucumber, the expression of a gene encoding a novel proline-rich protein was enhanced. This protein has C-terminal repetitive sequences containing an unusually high amount of lysine and arginine. The synthetic peptide derived from the repetitive sequences was able to polymerize orthosilicic acid to insoluble silica, which is known to be involved in cell wall reinforcement, at the site of the attempted penetration of fungi into epidermal cells.

Silicon and radiation damage

Silicon seems to protect plants from radiation injury. When rice seedlings (30-days old) were irradiated with different doses of γ-rays, the decrease in the dry weight was less appreciable in the Si-supplied plants than in the Si plants that had not been treated with Si, suggesting that Si increases the resistance of rice to radiation stress (Takahashi, 1966). Furthermore, when the plant was supplied with Si after radiation treatment, the growth recovery was faster compared to that of the plants without Si supply.

Silicon and water stress

Water deficiency (drought stress) leads to the closure of stomata and subsequent decrease in the photosynthetic rate. Silicon can alleviate water stress by decreasing transpiration. Transpiration from the leaves occurs mainly through the stomata and partly through the cuticle. As Si is deposited beneath the cuticle of the leaves forming a Si-cuticle double layer, the transpiration through the cuticle may decrease by Si deposition. Silicon can reduce the transpiration rate by 30% in rice, which has a thin cuticle (Ma *et al.*, 200l). Under water-stressed conditions (low humidity), the effect of Si on rice growth was more pronounced than on rice that cultivated under non-stressed conditions (high humidity) (Ma *et al.*, 2001). When rice leaves were exposed to a solution containing polyethylene glycol (PEG), electrolyte leakage (EL) (an indicator of membrane lesion) from the leaf tissues decreased with the increase in the level of Si in the leaves (Agarie *et al.*, 1998). The level of polysaccharides in the cell wall was higher in the leaves containing Si than in those lacking Si. These results suggest that Si in rice leaves is involved in the water relations of cells, such as mechanical properties and water permeability. Among the yield components, the percentage of ripened grains is most affected by Si in both rice and barley (Ma and Takahashi, 2002). This function of Si may be attributed to the alleviative effect of Si on water stress. One important factor for the normal development of the spikelets is to keep a high moisture condition within the hull (Seo and Ohta, 1982). The Si content in the hull of the rice grain becomes as high as 7% Si and that of the barley grain is 1.5%. Silicon in the hull is also deposited between the epidermal cell wall and the cuticle, forming a cuticle-Si double layer as in the leaf blades. However, in contrast to the leaves, transpiration occurs only through the cuticle because the hull does not have a stoma. Silicon is effective in decreasing the transpiration from the hull. The rate of water loss from Si free spikelet's was about 20% higher than that from spikelet's containing Si (7% Si) at both the milky and maturity stages (Ma *et al.*, 2001). Therefore, Si plays an important role in keeping a high moisture condition within the hull by decreasing the transpiration rate from the hull. This is especially important under water deficiency stress and stress associated with climatic conditions.

Silicon and stress associated with climatic conditions

Silicon application in rice is effective in alleviating the damage caused by climatic stress such as typhoons, low temperature and insufficient sunshine during the summer season (Ma and Takahashi, 2000). A typhoon attack usually causes lodging and sterility in rice, resulting in a considerable reduction of the rice yield. Deposition of Si in rice enhances the strength of the stem by increasing the thickness of the culm wall and the size of the vascular bundles (Shimoyama, 1958), thereby preventing lodging. Strong winds also cause excess water loss from the spikelets, resulting in sterility. Silicon deposited on the hull is effective in preventing excess water loss.

In addition, the effect of Si on the rice yield is also obvious under stress due to low temperatures and insufficient sunshine (Ma and Takahashi, 2002).

Silicon and heat stress

Silicon also increases the tolerance to heat stress in rice plants. Agarie *et al.* (1998) observed that electrolyte leakage caused by high temperature (42 °C) was less pronounced in the leaves grown with Si than in those grown without Si. These results suggest that Si may be involved in the thermal stability of lipids in cell membranes although the mechanism has not been elucidated.

Conclusion

Si enhanced resistance to diseases and pests. Si deposited on the tissue surface acts as a physical barrier. It prevents physical penetration and / or makes the plant cells less susceptible to enzymatic degradation by fungal pathogens. It provides strength to the stem by increasing the thickness of the culm wall and the size of the vascular bundles. Si is deposited beneath the cuticle of the leaves forming a Si-cuticle double layer which act as barrier for insect and pest attack it also reduces the transpiration losses. Thus it can be concluded that Si has the capacity to provide resistance against environmental stress for the better growth and development of rice plant.

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Cite this chapter as: Kumar, A. (2020). Strategies to prevent environmental stresses by silicon fertilization in rice crop. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 205-214, https://doi.org/10.26832/aesa-2020-edcrs-014

AUTHOR INDEX

Environmental Degradation

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The compliance of this book is helpful for academicians, researchers, students, as well as other people seeking the relevant material in current trends of studies on the topic of environmental degradation. The book starts with an introductory chapter providing background information on the topic covering the necessity of the mitigation measures to be taken in order to ensure the conservation of our mother earth. The second chapter discussed the role of disasters leading to the degradation of environmental composition. The role of pesticides in the degradation of agricultural quality is discussed in the third chapter. Special attention is given to the degradation of river systems with reference to exhausting its resources. The book compliance includes many chapters focusing on environmental degradation by wastewater disposal practices. Certain mitigative measures are provided focusing on sustainable utilization of wastewater for agricultural and horticultural applications. The second half of the book includes sustainable utilization of various solid wastes such as spent mushroom compost, flower wastes, wood wastes, non-conventional plant residues, etc. which may cause deterioration of our environment. The last section of the book provides information regarding the impacts of environmental degradation on biodiversity as well as human economics including agriculture.

ISBN (Print)
978-81-942017-1-7

ISBN (Online)
978-81-942017-2-4

Price for print version
₹ 1550.00 (Inside India)
$ 100.00 (Outside India)

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AEM
AGRO ENVIRON MEDIA

Published by
Agro Environ Media, Publication Cell
Agriculture and Environmental Science Academy
Haridwar (Uttarakhand), India

ISBN 9788194201717
9 788194 201717