ECO-RESTORATION OF THE POLLUTED ENVIRONMENT

A Biological Perspective

Edited by Sandip V. Rathod

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Eco-Restoration of the Polluted Environment

The book *Eco-Restoration of the Polluted Environment: A Biological Perspective* explores recent advances in biological strategies for the remediation of polluted environments, including soil, water, and air. It covers bioremediation of heavy metals, radioactive waste, and waste gases, which are believed to be bottleneck problems for researchers working in this field. The book provides deep insight into biotechnological advances in eco-restoration of the polluted environment, with separate chapters on genetic engineering technology for enhancement of the bioremediation potential of bioresources and the role of biosurfactants, enzymes, and exo-polysaccharides for bioremediation of polluted environments, along with basic aspects of eco-restoration by microorganisms. The book summarizes the significant developments of many years of research in bioremediation technology and discusses them critically by presenting selected examples, while also considering future research directions in the area.

Features:

- Deep insight into the modes of action of various bioremediation strategies, as well as the status and progress of bioremediation technology for sustainable developmental practices.
- A research overview of bioremediation strategies using engineered biological resources for remediation of contaminants. The book will also accelerate the application of suitable engineered microbes and plants for field applications.
- A survey of interdisciplinary findings and insights on the impact of pollution on the ecosystem and human health, climate, and other global changes, with individual solutions to the pollution issue.
- Comprehensive information for relevant stakeholders such as global leaders, agriculturists, investors, innovators, farmers, policymakers, extension workers, agro-industrialists, environmentalists, and the education and health sectors, as well as students and researchers in the field.

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Contents

Foreword

The ecosystem is the base of life, composed of three basic building blocks of life, soil, water, and air, that sustain all living beings. Pollution of the environment through various anthropogenic activities is a serious crisis faced by both developed and developing economies. Compromised environmental health leads to an imbalanced ecosystem, which in turn makes life on Earth unsustainable. Irreversible damage to the ecosystem is indicated by global warming, melting of ice, unrestricted floods, land erosion, eutrophication, polluted water and air, irregular rainfall, crop failures, lack of clean drinking water, frequent epidemics, and compromised human immunity.

Global climate change has made a number of threats to arable land and food security worse, including extreme drought conditions, extremely high and low temperatures, extended periods of flooding and submergence, lavish use of agrochemicals (fertilizers and pesticides), compaction and salinization of the soil, deteriorated soil and rhizospheric microbial health, and a declining water table. The health of the ecosystem is a key factor in achieving optimal crop output. Therefore, in order to guarantee soil quality, crop development, and production in a sustainable way, it becomes essential to look for ways to improve the health of the soil and water. The current environmental catastrophe is the result of harm done to the global ecology, which requires rapid attention and correction. Various solutions for environmental cleanup have been developed, but they are both costly and energy intensive. Exploring nature's potential of widely distributed biological resources for eco-restoration of damaged ecosystems provides an *in situ*, low-cost, eco-friendly, broadly accepted, and easily applicable large-scale remediation technique.

The book *Eco-Restoration of the Polluted Environment: A Biological Perspective*, edited by Sandip V. Rathod, is an attempt to bring out a comprehensive review of knowledge- and experience-based efforts of scientists from various national and international institutes of repute, working hard to devise technologies for bioremediation of emerging environmental pollutants, in a single source. The book will be a great resource for students, teachers, and scientists working in the area of environmental restoration through eco-friendly strategies and would be useful to realize the vital role of this promising science in combating the threat posed to humanity by environmental pollution.

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Preface

Environmental pollution has become a major global problem as a result of the rapid rise of industrialization, urbanization, enhanced agricultural output, and electricity generation. These have also resulted in the indiscriminate exploitation of natural resources in order to suit human interests and demands, ultimately contributing to the disruption of the ecological stability on which the quality of our environment depends. Advanced technologies for sustaining global population produce toxic pollutants that are beyond the self-cleaning potential of nature. One of the most serious issues confronting the developing world today is the contamination of water, soil, and air with hazardous and destructive chemicals. Environmental pollution will pose a serious threat to all lives on earth, and to cope with this issue, scientific communities and legislative authorities are working intensively to find sustainable solutions for pollution without affecting the current economical growth. A large number of strategies have been kept at the forefront for restoration of polluted environments, among which exploring biological resources, including plants and microbes, was found to be promising technology for eco-restoration. Bioremediation strategies focus on the natural potential of plants and microorganisms to treat the polluted environment at the site of contamination. The evolution of plants and microbes at the contaminated site provides them the benefit of diverse metabolic pathways due to short- and long-term relationships with pollutants, enabling them to efficiently transform or degrade the pollutants.

This book examines the many versions and combinations of diverse procedures that will enhance knowledge about biological remediation strategies, taking into account the impact of pollution on various habitats. Contributors to this book include experts in soil science, agronomy, microbiology, edaphology, agriculture, biotechnology, and environment science. The contributors to the book belong to a variety of institutions, universities, and government laboratories, with backgrounds in basic, applied, and industrial science. This book brings together a diverse variety of topics, making it a valuable resource for undergraduate and post-graduate students studying soil science, agricultural science, environmental sciences, biotechnology, microbiology, biochemistry, and environment engineering. I hope that the information, including its basic and practical parts, will be useful to students; scientists; and engineers in academia, industry, and government.

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Biography

Mr. Sandip V. Rathod (Assistant Research Scientist, Soil Science Division) has eight years of teaching and research experience. His research interests include the mitigation of greenhouse gas emissions from agroecosystems, the use of effluent water for agricultural purposes, remediation of heavy metal–contaminated soil and nano fertilizers, and its impact on soil properties. He has handled research projects on the reuse of wastewater and nanofertilizers. He is actively involved in the dissemination of agricultural technologies to farmers through the organization of various training programs and through TV and radio talks. He acted as co-coordinator for a training program on soil and water testing for agriculture. His publication profile includes 15 research papers, 1 book chapter, 2 books, 2 teaching manuals, and 15 popular articles.

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1 Environmental Pollution
Threats and Challenges for Management

Sandip V. Rathod, Piyushkumar Saras, and Shradhdha M. Gondaliya

1.1 INTRODUCTION

An unfavorable change in the physical, chemical, and biological properties of the air, water, and soil that has an impact on human life, the lives of other beneficial living plants and animals, industrial development, living conditions, and cultural assets can be referred to as environmental pollution. A pollutant is something that negatively affects people's health, comfort, property, or environment. The majority of pollutants, in general, enter the environment through waste, sewage, or unintentional discharge or as byproducts or residues from the manufacture of anything valuable. As a result, the land, water, air, and biosphere are becoming polluted. Environmental pollution is generally higher in poor countries than in developed ones, because of poverty, inadequate legislation, and a lack of awareness of pollution forms. It could be that humans come into contact with pollution on every single day without noticing it or that in our hectic daily lives, we have become immune to it (Muralikrishna and Manickam, 2017). Pollution-related illness was estimated to account for 9 million premature deaths in 2015, which is more than three times the number of deaths from tuberculosis, AIDS, and malaria combined (Landrigan *et al.*, 2017).

Deforestation, bush burning, waste from domestic and agricultural sectors in bodies of water, use of pesticides in aquatic animal harvesting, and inappropriate disposal of electronic waste, for example, all are involved in air, land, and water pollution. Furthermore, harmful materials such as air pollutants, heavy and carcinogenic metals, and particulate matter are introduced into the biosphere; sewage and sludge, industrial waste substances, agricultural pollutants, and electronic waste are introduced into water bodies; and activities such as removal of forest areas, poor management of waste from domestic landfills, mining, and intensive farming cause soil pollution. Furthermore, when human populations rise, so do human activities, with a corresponding increase in environmental effects. The effects affect not only people but also other aquatic animal and ocean creatures, including microbes, which, due to their quantity and diversity, maintain the biogeochemical functions required for ecosystem survival.

The contaminants that are discharged into the environment as a byproduct of cultivating and raising food crops and livestock are known as agricultural pollutants. These pollutants are biotic and abiotic byproducts of farming methods (fertilizers, pesticides, and livestock dung) that cause degradation or pollution of the environment and ecosystem, causing harm to humans and their economic interests.

Emerging contaminants can develop in the environment from both natural products and those created by biochemical processes from manufactured substances. When manure, fertilizers, biosolids, or other solid waste items are applied to the soil, emerging agricultural contaminants are either released into the environment or indirectly make a channel to spread into the soil. They may be carried to water bodies by leaching, runoff, and drainage processes after they penetrate the soil. Land used for agricultural production is lost as a result of subsequent degradation such as erosion,

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landslides, soil mineral leakage, and crop and soil contamination by pathogens from humans or animals, salt, or pesticides (Lindgren *et al.*, 2011). Flooding or drought-related declines in crops and cattle are examples of direct repercussions, as is damage to infrastructure that may have an impact on food production. After extreme weather events, a number of infectious illnesses that harm livestock, including anthrax and blackleg, may appear (Bezirtzoglou *et al.*, 2011).

It may be necessary to employ phosphate fertilizers to boost or maintain food production, but doing so results in rising soil cadmium levels, which primarily pose a threat to food safety. Additionally, tainted water is used for agriculture in nations with a shortage of freshwater. Thus, there is a significant likelihood that agricultural land in the USA, Mexico, Japan, and Canada will become more chemically contaminated. A type B nation will probably experience an even bigger expansion of its metal and chemical sectors, along with an increase in the hazards that go along with it. In developing nations like China, there are places with high amounts of chemical pollution. Again, the use of cadmium-contaminated fertilizers poses the biggest hazard to food safety. Due to their past and continuing release into the environment, organic pollutants and metals can be found in a type C nation (such as those in Asia and Europe) in various amounts, but neither the ongoing leakage of toxic chemicals nor serious accidents are anticipated to have a significant impact on agricultural output. Nuclear incidents in type C countries should be evaluated similarly to those in type B nations.

Previous studies have mainly focused on one direction or stage in the pathways connecting environment, food, and health, for example, focusing on the impact of environmental change on crop production or the effects of various diets on health. The effects of climate change on staple crops have received the majority of the attention in research on the effects of environmental change on food production (Porter *et al.*, 2014; Challinor *et al.*, 2014), while the effects on other foods and of other environmental stressors have received less attention. A few studies (Myers *et al.*, 2017; Springmann *et al.*, 2016a) that focus primarily on significant staple crops and/or meat have combined environmental alteration, health, agriculture, nutrition, and markets.

According to recent research, eating more fruits and vegetables still lowers the risk of cancer, cardiovascular disease, and all-cause mortality even after exceeding the WHO limit of 400 grams of fruit and vegetables combined per day (Aune *et al.*, 2017). According to research, socioeconomic status predicted the amount of fruits and vegetables consumed per person.

According to Miller *et al.* (2016a), people in low-income countries consume less per person than high-income ones, and within countries, consumption has been found to be lower in underprivileged areas compared to wealthy ones (Pessoa *et al.*, 2015; Dubowitz *et al.*, 2008). Many fruit and vegetable crops, however, have been shown to be relatively susceptible to environmental pollution (Backlund *et al.*, 2008), increasing the risk of a diminished fruit and vegetable supply in the future, with attendant public health implications.

The world population will continue to face environmental changes that will offer greater challenges to our food systems, health, and well-being in the coming decades. Climate change, increased carbon dioxide fertilization, ground-level ozone, deforestation, soil degradation, changes in water availability, and intensive use of land are all examples of changes that can have a direct and significant impact on agricultural production. Furthermore, variations in the abundance and spread of diseases, pests, and pollinators, which are all linked to environmental change, may have an indirect impact on agriculture.

Since 1950, the earth's temperature has been rising above the average. Climate change is another term for this. Climate change refers to a rise in the global average temperature and changes in the climate that are observed statistically, such as mean surface temperature, and can last from one year to millions of years. Global warming is defined as an average increase in global temperature and is one of the aspects of climate change. Plants' DNA, RNA, proteins, and membranes have been reported to be damaged by UV-B radiation, which hinders photosynthesis (Caldwell *et al.*, 2007). The majority of vegetables, such as beans, tomatoes, spinach, radishes, carrots, cucumbers, and gourds, as well as many fruits, like strawberries and sea-buckthorn, showed a more significant reduction in production due to UV-B exposure than woody plants, according to a meta-analysis of the effect of increases in UV-B on yields (Li *et al*., 2010).

Numerous environmental, behavioral, and economic variables will influence how much environmental change will affect food systems and health. First, the level and trends of various environmental stressors as well as the mitigation measures adopted by both individual nations and the global community as a whole will determine how much of an environmental shift there will be. Second, the mechanisms for adaptation that are created and used will determine the effects of environmental change. Third, marketplaces are essential for moving food between areas of production and consumption. Food systems in regions that are heavily reliant on local markets may be more susceptible to environmental change than agricultural systems that are globally integrated and may be better equipped to adapt to changes in the environmental situation for food production. Fourth, the consumption of particular foods is substantially more susceptible to price fluctuations than the consumption of other foods. Finally, due to variations in pre-existing dietary patterns and price responsiveness, the impact of varying food availability on diet and health is expected to vary between nations and demographic groups.

Understanding the causes and threat of environmental contamination is crucial, yet taking action has a high price. Different physical, chemical, and biological methods have been applied to reduce soil, water, and air pollution, but most chemical and physical methods are costly and contribute to new environmental issues. Microbial bioremediation is one of the methods that have drawn attention from all around the world, presumably because it is an effective and environmentally beneficial way to restore the environment. Biological methods remain sustainable to reduce and control pollution.

1.2 MAJOR TYPES OF POLLUTION

Pollution in the environment is a hot topic these days. Air, water, and soil are all polluted.

1.2.1 Air Pollution

Air pollution refers to a chemical compound, metals, or any other substance that leads to reduced air quality and thereafter the atmosphere. Carbon monoxide (CO), nitrogen oxides (particularly NO and NO_2), sulfur oxides (especially SO_2), and volatile organic compounds are common gaseous pollutants. The health of people all around the world is seriously threatened by air pollution.

Researchers and decision-makers are interested in how air pollution negatively affects agriculture. Realizing that air pollution is a concern on a global scale, and that sustainable food and agricultural growth is a global objective, it is vital to investigate the influence of air pollution on agriculture using global data. Meanwhile, agricultural performance must be measured more thoroughly. Initially, numerous studies used biochemical and field tests to evaluate the processes and toxicology that explain how air pollution affects particular types of livestock and agricultural crops. Nitrogen dioxide, ammonia, sulfur dioxide, particulate matter, and ozone are some of the pollutants that have been discovered to have an effect (Das *et al*., 2021; Sillmann *et al*., 2021).

Producing animal manure aids in the large release of methane into the environment, creating difficult circumstances, while intensive farming helps to deal with the world's food shortages. Additionally, a fungi and algae bloom amplifies the emission of methane into the environment, which has a negative impact on greenhouse gases. There are variations in the global warming potential (GWP) and atmospheric lifespan of greenhouse gases. The warming potential of other gases is based on and represented in relation to the CO_2 GWP, which has been given 1 GWP (Paustian *et al*., 2006). For instance, the Intergovernmental Panel for Climate Change (IPCC) estimates that over 100- and 20-year periods, respectively, 1 ton of CH_4 has a warming effect of around 25 and 72 tons of CO_2. According to studies, CH_4 is more potent than CO_2; hence reducing CH_4 emissions will have a greater immediate and significant impact on mitigating climate change than reducing CO_2 emissions (Moore and MacCracken, 2009). N_2O is another significant greenhouse gas, remaining in the atmosphere for 114 years (Solomon *et al*., 2007) and being 298 times as potent as CO_2 over 100 years (Forster *et al*., 2007). As greenhouse gas emissions such as those of CH_4, CO_2, N_2O, and other gases, have an adverse effect on the environment and cause global warming, which in turn causes changes in the climate and environmental degradation, there has been an increase in concern (Patra and Saxena, 2010). Nitrous oxide (N_2O) is the main greenhouse gas (GHG) released by agriculture, making up 38% of all global emissions. It is produced through the processes of nitrification and denitrification from human activities (such as the use of nitrogen fertilizer, the growth of crops and forage that fix nitrogen, the retention of crop residues, and the application of livestock manure), either through direct additions or through indirect additions. Enteric fermentation, a term used to describe the natural digestive processes in ruminants, is the primary source of methane production in the livestock sector, making it the second-greatest contributor of total agricultural emissions globally, after rice agriculture, which accounts for 11% of emissions. The level of emissions of greenhouse gases has been rising due to both natural and human sources, which is causing global warming and promoting climate change.

A warming globe causes climate change, which has a larger number of negative effects on the weather. It is anticipated that increased floods, storms, droughts, heat waves, and other extreme weather events may result from climate change. Therefore, as the climate changes, severe weather patterns pose serious risks to human civilization. Sea surface temperature, land temperature, snow cover on hills, land temperature, and humidity are all signs of global warming. First, air pollution impairs the biological mechanisms that support animal growth and development. Agriculture is impacted by air pollution in a number of ways, directly as well as indirectly. According to the literature, there are three main ways by which air pollution affects agricultural productivity.

1. As an aggressive oxidant, ozone, for instance, reduces photosynthesis, modifies carbon fixation, directs synthesis toward chemical defenses, decreases water intake, and hastens senescence (Ainsworth, 2017). According to Wang *et al*.'s (2021) estimate, ozone caused a 10% yield loss in winter wheat in the Henan province of China between 2010 and 2012. According to Mills *et al*. (2018), the mean ozone level in 2010 and 2012 decreased annual global yields of maize, rice, wheat, and soybeans by 6.1%, 4.4%, 7.1%, and 12.4%, respectively.
2. Air pollution leads to deterioration of the quality of water and soil. For instance, metals and acidic precipitation from air pollution will end up in the soil and water. Therefore, soil and water's chemical compositions are altered (Aragón and Rud, 2016). Acidification of the soil and water, greater loss of plant nutrients, slower degradation of organic matter, metal pollution, and other impacts are possible outcomes (Vázquez-Arias *et al*., 2023; Luo *et al*., 2019). Through ozone layer loss and global warming, air pollution also has a negative impact on how people live on Earth.
3. Air pollution impairs the health of agricultural workers, which reduces their productivity. One of the biggest dangers to the health of the world's population is air pollution. Medical research has shown that air pollution increases the risk of a wide range of disorders, including heart disease, lung disease, cancer, insomnia, and depressive disorders, among many others. (Dominski *et al*., 2021; Almetwally *et al*., 2020). It makes sense to assume that air pollution lowers farmers' labor productivity and performance (Shah *et al*., 2022).

1.2.2 Water Pollution

Water pollution is a global issue that has gotten worse in both rich and emerging nations, threatening both the physical and environmental health of billions of people as well as economic progress.

According to FAO *et al*. (2012), human settlements, industries, and agriculture are the main causes of water pollution. Millions of tons of toxic sludge, solvents, heavy metals, and other wastes are dumped into water bodies each year by industry, and 80% of municipal wastewater released into water bodies worldwide is untreated (WWAP, 2017). Significant quantities of untreated wastewater from municipalities and industries are a major concern in low-income nations and growing economies. Pesticides, pollutants coming from livestock management, VOCs, food processing waste, chemical waste, medical waste, and heavy metals from various inputs are examples of human-made sources of contamination. Chemicals like pesticides residue; hydrocarbon compounds; POPs; or heavy metals like cadmium, lead, and arsenic can cause cancer, hormone imbalances, reproductive problems, and severe liver and kidney damage, among other harmful health impacts.

Additionally, according to Ewuzie *et al.* (2020), the chemical structure of the water system is significantly impacted by the geological structural formations of various areas. As a result, this could be the reason for the elevated concentrations of the specific compound or structure that is causing water pollution.

However, agricultural pollution is also becoming a problem, made worse by increased sediment outflow and groundwater salinization. Agriculture is the primary cause of contamination in streams and rivers, the secondary source in wetlands, and the third primary source in lakes in the United States (USEPA, 2016). Thirty-eight percent of the water bodies in the European Union are seriously impacted by agricultural pollution (WWAP, 2015). Water pollution is largely caused by agriculture, which uses 70% of the world's water resources. Large amounts of organic matter, agrochemicals, drug remnants, saline drainage, and sediments are released into water bodies by farms. As a result, there are clear threats to human health, aquatic ecosystems, and economic activity (UNEP, 2016). By 2050, 9.8 billion people are expected to inhabit the planet (UNDESA, 2017). Production of more (and more varied) food is necessary due to population expansion, shifting dietary preferences, and changes in consumption habits. This in turn is bringing about new negative environmental impacts, including effects on water quality, and encouraging agricultural development and intensification.

Global crop output has increased mostly because of the extensive usage of additives such as pesticides and artificial fertilizers. The growth of agricultural land has exacerbated the trend, with irrigated playing a crucial role in enhancing production and livelihoods in rural areas while also transmitting agricultural pollution to aquatic bodies. In response to the growing demand for food, agricultural systems have grown and intensified. In absolute terms, clearing of land and expanding agriculture have led to increasing pollution loads in water, but it is likely that some unsustainable trends in agricultural intensification have had the greatest influence.

Irrigation is a critical component in agricultural intensification. Large projects for irrigation have been critical in enhancing global food security, particularly in underdeveloped countries. Nonetheless, the facilities of irrigation have frequently been linked to water system degradation caused by salt, pesticide, and fertilizer drainage and leaching. In the recent era, irrigation area has more than quadrupled (from 139 million hectares [Mha] in 1961 to 320 Mha in 2012; FAO, 2014), while livestock population has increased by over threefold (from 7.3 billion units in 1970 to 24.2 billion units in 2011; FAO, 2016a). Chemical fertilizers like urea and DAP have been used to add to natural sources of nutrients and cycling to raise crops and animals since the 19th century, but their use has risen dramatically in recent decades. The world now consumes ten times as much mineral fertilizer as it consumed in the 1960s (FAO, 2016a). According to Rockstrom *et al.* (2009), nutrient mobilization may already have exceeded limits that will cause drastic changes in the environment in continental- to planetary-scale systems. Nutrients, pesticides, metals, organic carbon, sediments, salts, microbes, and medication residues are the main agricultural contributors to water pollution (and the main objectives for water pollution treatment). The significance of various types of agricultural pollution varies depending on the specific circumstances, and harmful effects like eutrophication result from a confluence of stressors. When fertilizers are used in crop production at a rate higher than they are fixed by soil particles or exported from the soil profile, fertilizer-related water pollution develops. Extra phosphates and nitrogen can seep into the groundwater or enter streams through surface runoff. Since phosphate is less soluble than nitrate and ammonia, it often binds to soil particles and seeps into water sources through soil erosion.

Lakes, reservoirs, ponds, and coastal waterways may become eutrophic due to high nitrogen loads, which can result in algal blooms that crowd out other aquatic life. Despite data shortages, 415 coastal regions throughout the world have been identified as being affected by eutrophication in some way, 169 of which are hypoxic (WRI, 2008). The most frequent chemical contamination in the world's groundwater aquifers is nitrate from agriculture (WWAP, 2013). Agriculture-related water pollution has a direct negative impact on human health, as seen by the well-known blue-baby syndrome, in which excessive levels of nitrates in water cause methemoglobinemia—a potentially fatal condition—in infants.

Manure is typically collected to be utilized as organic fertilizer, but if too much of it is used, it can cause diffuse water contamination. Significant water contaminants include organic matter from animal waste, uneaten animal feed, the animal-processing industry, and improperly managed crop residues. Manure is frequently not stored in secure locations, and after heavy rainstorms, it may enter watercourses via runoff from the ground. As organic matter breaks down, it uses up the dissolved oxygen in the water, significantly causing hypoxia in aquatic environments. Biological oxygen demand (BOD) is the greatest for wastes related to livestock. In contrast to the normal BOD of home sewage, which ranges from 200 to 500 milligrams per liter, pig slurry, for instance, has a BOD of between 30,000 and 80,000 milligrams per liter (FAO, 2006). Aquaculture can have a significant role in the localization of organic burdens in water. Bangladesh's shrimp farming produces 600 tons of garbage per day (SACEP, 2014). The likelihood of eutrophication and blooms of algal organism in lakes, reservoirs, and coastal areas is further increased by the release of organic materials.

Pesticide management in developing nations is extremely difficult due to factors such as the rapid increase in pesticide use, reliance on broad-spectrum pesticides, lax institutional frameworks, lax enforcement of laws, and little knowledge and awareness among farmers regarding the use of dangerous chemicals. Some broad-spectrum and persistent pesticides (like many organophosphates and DDT) were widely banned as a result of the accumulation of pesticides in water and the food chain, which had been shown to have harmful effects on humans. However, some of these pesticides continue to be applied in poorer countries, where they have acute and likely long-term health effects. Countries have increasingly embraced a pest management strategy based on the use of synthetic pesticides as land usage intensifies. The global market for pesticides is now a multi-billion dollar sector, valued at more than USD 35 billion annually (FAO, 2016a). Numerous countries use insecticides, herbicides, and fungicides heavily in agriculture (Schreinemachers and Tipraqsa, 2012). The largest pesticide use intensities worldwide are found in Costa Rica, Colombia, Japan, and Mexico (Schreinemachers and Tipraqsa, 2012). According to Zhang *et al.* (2011), the share of herbicides in the world's pesticide usage climbed quickly, while the percentage of fungicides and insecticides decreased.

Nevertheless, agriculture uses millions of tons of active pesticide components (FAO, 2016a). Globally, acute pesticide poisoning significantly increases morbidity and mortality in humans, particularly in underdeveloped nations where subsistence farmers frequently use extremely dangerous pesticide formulations. They can contaminate water supplies with carcinogens and other poisonous materials that can harm humans if improperly chosen and managed. By destroying plants and insects and having detrimental effects up the food chain, pesticides can also have an adverse impact on biodiversity.

Agricultural pollution also has an impact on aquatic ecosystems; for instance, eutrophication brought on by the buildup of nutrients in lakes and coastal waterways affects fisheries and biodiversity. Aquaculture relies heavily on carnivorous species, which demand enormous quantities of fishmeal and other pelleted food. Numerous non-fed aquaculture practices, like mussel farming, can clean and filter water, but others, like intense caged crab culture, may disturb natural nutrient cycles and worsen water quality. Since the 1980s, aquaculture has increased more than 20-fold, primarily in Asia and inland fed aquaculture (FAO, 2016b). According to FAO (2016b), 167 million tons of aquatic animals were produced globally in 2014, of which 146 million tons were reportedly directly consumed by people. Nearly 90% of the world's aquacultural production is in Asia, with China leading the way with 45.5 million tons produced annually (FAO, 2016b). From the last few decades, the demand for fish and shellfish has increased tremendously, more than that for any other agricultural product. The greater production intensity and concentrations of one species are being caused by market forces and differentiation. Because of these changes, people are using more medications (such as antibiotics, fungicides, and anti-fouling agents), which leads to contamination further down the food chain.

1.2.3 Soil Pollution

Soil pollution is described as the accumulation of persistent toxic substances, chemicals, salts, radioactive elements, or disease-causing agents in soils, which has a negative impact on plant development and animal health (Okrent D., 1999). Soil is the foundation of agriculture. All crops for human consumption and animal feed rely on it. To some extent, we are depleting this crucial natural resource due to increasing erosion. Furthermore, massive amounts of human-made garbage, sludge, and other products from new waste management plants, as well as polluted water, are creating or contributing to soil pollution. Pollutants may likewise enter the food chain through plant absorption. There are numerous methods for soil to become contaminated, including seepage from a garbage dump; releasing industrial trash into the ground; allowing contaminated water to seep into the ground; underground storage tank rupture; excessive pesticide, herbicide, or fertilizer use; and seepage of solid waste

Heavy metals, organic and inorganic solvents, fossil fuels from petrochemical plants, oil refineries, hydrocarbons, and power plants are some examples of soil pollutants. The main causes of soil pollution are inadequate landfills, open-air disposal, and waste burning. Soil pollution is frequently a byproduct of petroleum discovery, refinement, and distribution via vehicle transport. Petroleum hydrocarbons, pesticides, heavy metals, and solvents are the most frequent chemical pollutants of soil. It is difficult work with many related issues to evaluate the ecological hazards of contaminated soil, application of chemically formulated pesticides, sewage and sludge amendment, and other anthropogenic activities that expose the environment to poisonous compounds. Terrestrial assessment of ecological risk is not only a young scientific topic that has advanced quickly just since the middle of the 1980s, but it is also made difficult by the fact that, unlike most aquatic habitats, soil is frequently on small, marginal, and medium enterprises.

1.2.3.1 Organic Wastes

Different kinds of organic waste offer pollution risks. When left in piles or disposed of inappropriately, household waste, municipal sewage, and industrial waste adversely impact the health of people, plants, and animals (Crane and Giddings, 2004). Borates, phosphates, and detergents are abundant in organic waste. They will have an impact on plants' vegetative growth if left untreated. Organic compound likes coal and phenols are the principal organic pollutants.

1.2.3.2 Sewage and Sludge

According to Tarazona *et al.* (2005) and Evans *et al.* (2006), uncontrolled waste wastes from domestic water use, urban drainage, irrigation water runoff, animal husbandry liquid waste, and industrial untreated as well as treated effluent have a number of pollutants which are responsible for soil pollution. When crops are irrigated with sewage water, heavy metals and other hazardous substances accumulate, changing the soils' physical and chemical characteristics. Among the many changes that occur in the soil as a result of sewage water are physical changes such as porosity, leaching, and decline in bulk density and chemical changes like soil reaction; salinity; base exchange capacity; and the content and form of nutrients such as nitrogen, phosphorus, and potash. Sewage sludges contaminate the land by accumulating heavy metals such as lead and cadmium, which can cause plant phytotoxicity.

1.2.3.3 Inorganic Compounds

Industrial waste containing inorganic wastes poses major disposal challenges. They include metals with high toxicity potential. Fluorides, arsenic, and sulfur dioxide (SO_2) are other significant emissions from industrial operations (Richardson *et al.*, 2006). The superphosphate, aluminum, steel and ceramic, phosphoric acid, and aluminum industries all contribute fluorides to the atmosphere. Acidic soils may result from sulfur dioxide emissions from industry and thermal plants. These metals damage leaves and kill vegetation.

The elements that can build up in the soil include copper, mercury, cadmium, lead, nickel, and arsenic if they enter through sewage irrigation and industrial waste. Additionally, some fungicides that include heavy metals worsen soil pollution. Lead, which is hazardous to plants and gets absorbed by soil particles, is present in the smoke from automobiles. By application of organic manure, amending soils with lime, and maintaining soil alkalinity, the detrimental effect of particular elements can be reduced (Van Zorge, J. A., 1996).

1.2.3.4 Heavy Metals

Heavy metals are metals with an elemental density greater than 5. They mainly find particular absorption sites on the soil particles, at which they are strongly held on either inorganic (clay particles) or organic colloids (humus). These heavy metals are abundant in the environment, soils, animals, and plants, as well as in plant tissues. In trace amounts, they are required by plants and animals. Heavy metal pollution is mostly caused by urbanization and industrialization, livestock waste including solid and liquid, human excreta, fuel combustion, mining byproducts, agrochemicals, and so on.

1.2.3.5 Organic Pesticides

Today, many different species of pests are controlled by the application of pesticides. It is found that pesticide application may have detrimental effects on soil macro- and microorganisms, which could impact plant growth. These issues could be caused by pesticides that do not break down quickly. Higher quantities of pesticide residue accumulation are hazardous. Pesticides can enter foods and pose a health risk due to their persistence in soil and migration into water streams. Pesticides, especially aromatic chemical compounds, have a lengthy persistence time because they do not break down quickly.

1.3 CAUSES OF ENVIRONMENTAL POLLUTION

1.3.1 Expansion of Urban Areas and Development of Real Estate

Since the industrial revolution, we have rapidly identified and delivered a variety of elements, toxic compounds, and dangerous products into the environment. Urbanization; industrialization; economic development; and natural resources like soil, water, the biosphere, and the environment are all linked by a variety of beneficial and bad impacts. Globally, urbanization and fast socioeconomic development have an impact on people's willingness to migrate.

Even though rapid urbanization promotes soil pollution, deteriorates soil health, disturbs water bodies, deteriorates ecosystems, and lowers air quality, developing countries do not take it as a serious issue. Many non-biodegradable materials, including plastic bags, polythene bags, plastic water bottles, plastic residue, glass bottles, glass items, stone/cement pieces, vegetable waste, livestock wastes, papers, furniture waste, carcasses, plant material, and textile industry waste, is considered soil pollution (Nawrot *et al.*, 2006). According to estimates, Indian cities generate 50,000–80,000 metric tons of solid trash per day. If it is not collected and degraded, it can create a variety of issues, including: (1) major drainage issues, such as burst or leaky drainage lines, which can lead to health risks. (2) Solid wastes have substantially harmed how water normally moves, leading to flooding issues, damage to building foundations, and risks to the public's health. (3) A considerable amount of methane and other gases are produced by the decomposition of organic material, which pollutes the soil and water. Small and multispecialist hospitals produce a larger quantity of solid waste, which is responsible for health issues and a number of diseases. Beside this, dangerous drugs and medicine also promote health problems. (4) Foul odor is produced due to disposing of garbage.

1.3.1.1 Pollution of Underground Soil

Cities' underground soil is likely to contain pollutants: (1) chemical waste releases from industries or (2) materials made of sanitary waste that has partially or completely degraded. Many hazardous substances, such as chromium, cadmium, lead, selenium, and arsenic, are likely to accumulate in subsurface soil. Similarly, sanitary waste–polluted subsurface soils produce a plethora of hazardous compounds. These can disrupt typical subterranean soil activity and ecological equilibrium.

Solid waste, in general, encompasses garbage and waste materials from commercial sources, home refuse, agricultural practices, and industrial byproducts. It is increasingly made up of paper, cardboard, plastics, glass, expired raw construction products, packaging material, and toxic or other harmful substances. The bulk of urban solid waste is degradable or biodegradable in landfills since food and paper waste make up a sizable portion of it. Similar to how mining explorer material is left on location, the majority of agricultural and animal waste is recycled. We must pay close attention to the hazardous portions of solid waste, such as heavy metals, metals from smelting industries, oils, and organic solvents. Long-term deposition of these can contaminate nearby soils by changing their chemical and biological properties (Patterson *et al.*, 2007).

1.3.2 Mining and Exploration

From the mining industries, various pollutants are released like dust from surface mining and greenhouse gas emission by coal industries, and other heavy metals are released in the atmosphere, which is able to negatively influence the soil, water, and air quality. The concentration of a particular pollutant depends on which level of mining is carried out. Heavy metals like lead are prominent in polluting the environment. Precious metal mining, such as gold mining, is necessary to do, but at the same time, it causes heavy metal pollution in the environment as a byproduct. The depreciation of soil characteristics, water ecosystem, and air quality has accelerated due to large-scale exploration.

1.3.3 Agricultural Activities

Any nation, developed or developing, depends on its agriculture industry for economic success. But, as we know for the production of every product, there are some byproducts. For produce, a number of pesticides and agrochemicals are utilized, which leaves their residue in the soil. These residues are not easily degradable and remain in the soil for a long time. In this way, it can pollute the soil; by leaching, it can contaminate water and reduce air quality. This pollution directly affects human health. It is caused by the burning of waste by products such as cotton husk and rice straw from agricultural practices such as clearing land for sowing the next crop, providing more fertilizer than plants require, and using chemically strong herbicides which have high persistence. So, these agrochemical residues contaminate natural resources.

Various industries, such as agriculture and animal husbandry, can pollute the soil. Some farming techniques contaminate the soil. They include the use of fertilizers; some agricultural methods; and long-lasting insecticides, fungicides, herbicides, and nematicides. Vital nutrients, such as nitrogen, phosphorus, potassium, sulfur, magnesium, calcium, and others, must be received from the soil. Fertilizers are commonly used by farmers to supply soil essential nutrient deficiencies. Heavy metals present in fertilizers contaminate the soil with contaminants derived from the basic materials used in their production. Nitrogen, phosphorous, and potassium are common components of mixed fertilizers. Arsenic, lead, and cadmium, for example, which are present in very small quantities in rock phosphate mineral, are transported to super phosphate fertilizer.

Because the metals are not biodegradable, they accumulate in the soil to dangerously high amounts due to overuse of phosphate fertilizers, which poisons the soil and reduces crop yields. Additionally, nitrates produced by agricultural operations are well-known chemical contaminants in aquifers of groundwater. Due to lack of awareness, farmers apply excess quantities of nitrogenous fertilizer, which leads to leaching of nitrate in the ground water or surface runoff. This may promote the eutrophication process and thereby build up unnecessary growth of plants and organisms which contaminate the water ecosystem. Also, leached nitrates go into ground water, which will get into the food system through drinking water or as irrigation.

Food-producing plants must fight with weeds for nutrition while being attacked by insects, fungi, bacteria, viruses, rodents, and other animals. Farmers employ insecticides to eradicate undesirable populations that are present in or on their crops. At the conclusion of World War II, dichlorodiphenyltrichloroethane (DDT) and gammaxene were first widely used as insecticides. DDT was quickly overcome by insect resistance, and because it took a long time to degrade, it remained in the environment. It affected calcium metabolism in birds, generating thin and brittle eggshells, and biomagnified up the food chain because it was soluble in fat rather than water. Large raptors like the brown pelican, ospreys, falcons, and eagles became threatened as a result. Most Western countries have now outlawed DDT. Ironically, a lot of them, including the USA, continue to make DDT for export to other developing countries whose needs outweigh the issues it causes (Toccalino and Norman, 2006).

When weathered soil particles are displaced and moved away by wind or water, soil erosion occurs. This erosion is a result of deforestation; agricultural expansion; temperature extremes; precipitation, particularly acid rain; and human activities. Through construction, mining, lumber harvesting, overcrowding, and overgrazing, humans hasten this process. Floods and soil erosion are the results. The soil is kept clean and healthy by the great binding properties of grasslands and forests. The fragile rainforest environments of South America, tropical Asia, and Africa are under threat from population increase and development, particularly in the areas of agriculture, forestry, and building. Many scientists think that these trees contain a variety of medicinal compounds, including cancer and AIDS treatments. The most productive areas of flora and wildlife in the world, which also make up large tracts of an extremely valuable CO_2 sink, are slowly being destroyed by deforestation (Leon Paumen, M., 2008).

1.3.3.1 Emerging Contaminants

Emerging contaminants (ECs) have numerous meanings. Since their presence and significance are now understood, they may be substances that have been present in the environment for a long time instead of the typical novel chemicals. They could be chemicals or microbes that are not typically monitored in the environment yet have the potential to harm the environment or negatively affect people. Although there are numerous definitions of what "emerging contaminants" are, it is crucial to clarify that the term refers to chemical substances that are either unknown or that have not undergone considerable study. Another definition of emerging contaminants is chemical substances or compounds that are distinguished by a perceived threat to human health or the environment without meeting established health standards. A new human exposure, a new detection method, or a new detection technology could all be used to identify them (Murnyak *et al.*, 2011).

There are numerous and regionally specific definitions of emerging pollutants. They could be substances that, through various channels, have been demonstrated to pose a risk to the environment or to human health without sufficient information to examine the magnitude of that risk.

Once more, identified chemicals with undiscovered negative effects on human health and the environment can be classified as emerging contaminants. Emerging pollutants can infiltrate the ecosystem and have negative biological and ecological effects, even if their detection can be more difficult (Snow *et al.*, 2007). They are described by Boxall (2012) as contaminants from a chemical class that hasn't been thoroughly studied, where scientists, regulators, NGOs, or other stakeholders are worried that the contaminant class may have an impact on human health or the environment or that current environmental assessment paradigms aren't appropriate for the contaminant class.

It has long been understood that contaminants from agricultural operations are caused by both natural and artificial human activity. It is alarming to think about their growing impact on the natural system and the ensuing greenhouse effects. Although agricultural toxins can generally be divided into a few primary categories, animal manure and the methane gas (CH_4) it releases into the atmosphere are a serious environmental hazard. Through the reuse of effluent water for irrigation purposes and the application of sewage to fields as fertilizers, agriculture not only contributes to the introduction of such pollutants into aquatic ecosystems, but it is also a source of developing pollutants. According to Thebo *et al.* (2017), wastewater is used indirectly on an estimated 35.9 Mha of agricultural land. It is important to pay attention to the possible dangers to human health provided by contact with developing contaminants through contaminated food products.

The three basic classifications that can be used for different new contaminant release routes are as follows.

1.3.3.1.1 Use of Livestock

This includes all veterinarian composts, artificial fertilizers, hormones used in livestock, manure and flatulent gas (methane) generated directly from animals, and their compost that releases methane gas into the atmosphere. In the past 20 years, new agricultural contaminants have arisen, including antibiotics, vaccinations, growth boosters, and hormones. These pollutants are increased by the careless treatment of organic manures in aquaculture and animal husbandry, and they may also spread through runoff and leaching processes (OECD, 2012b). Heavy metal residues in agricultural inputs like insecticides and animal feed are another rising danger. More than 700 emerging pollutants, along with their metabolites, are common in aquatic environments across Europe, according to NORMAN (2016).

1.3.3.1.2 Human Use Activities

These include substances that are emitted both directly and indirectly, such as novel chemical compounds and medications created by humans. Normally, these substances move through wastewater treatment, producing sludge and biosolids, or through irrigation, land, producing wastewater effluent. This group also includes pesticides that have higher absorption rates, higher solubilities, or higher toxicities and may be dispersed as nanoparticles.

Higher rates of fertilizer application to field crops resulted in either adsorption by clay lattices or leaching through soil into ground water, which contaminated the water with nutrients. Extra phosphates and nitrogen can seep into the groundwater or enter streams through surface runoff. Since phosphate is less soluble than nitrate and ammonia, it often binds to soil exchange sites and seeps into water sources through soil erosion. High nitrogen loads can eutrophize lakes, reservoirs, ponds, and coastal areas when combined with other stresses, resulting in algal blooms that end many aquatic lives. Despite data shortages, 415 coastal regions throughout the world have been acknowledged as being affected by eutrophication in some way, 169 of which are hypoxic (WRI, 2008). The overabundance of nutrients may potentially increase harmful health effects, such blue baby syndrome, as a result of the high amounts of nitrate in drinking water.

1.3.3.1.3 Plant Protection Activities

Pesticides, such as rodenticides, fungicides, bactericides, weed killers, zootoxins that kill small animals like rodents, phycotoxins that prevent algae growth, and various personal and household products, all have the ability to form new substances that are subsequently released either directly or indirectly into the environment as emerging contaminants, particularly through air and wastewater. These mostly consist of nanoparticles created to function as "smart" chemicals or pesticides with the capacity for selective toxicities. Unfortunately, these nanomaterials practically go undetected as they penetrate the natural system.

Numerous nations use insecticides, herbicides, and fungicides heavily in agriculture (Schreinemachers and Tipraqsa, 2012). They can contaminate water supplies with carcinogens and other substances that can harm humans if improperly chosen and managed. By destroying plants and insects and having detrimental effects on the food channel, pesticides can also have an adverse impact on biodiversity.

While older broad-spectrum pesticides are still widely used and produced in the USA and Europe, there is a trend toward the use of newly created pesticides that are more selective and only need a small amount to cover a large area. Nevertheless, agriculture uses millions of tons of active pesticide components (FAO, 2016a). Globally, pesticide poisoning significantly increases the number of deaths in humans through various diseases, particularly in underdeveloped nations where subsistence farmers frequently use extremely dangerous pesticide formulations.

1.3.3.2 Emerging Contaminants from Agricultural Activities

Different channels allow emerging contaminants to enter the agricultural environment. When manure, biosolids, or other solid waste is supplied to the soil, it can enter the soil indirectly or directly (in the case of veterinary medications used for animals in pasture). The persistence of the EC and its interactions with soil and air determine the level of transfer.

1.3.3.2.1 Agricultural Soils

The main portion of the agricultural sector's emissions of greenhouse gases (GHGs) comes from the management and handling of manure and enteric fermentation of agricultural soil N_2O emissions. As a result, the sources of GHG emissions from agriculture are as follows: nitrous oxide from fertilizers (37%), methane from livestock (32%), residue burning/forest cleaning (13%), methane from rice cultivation (11%), and methane and nitrous oxide from management of manure (7%) (US Environmental Protection Agency). Nitrous oxide (N_2O), which contributes 37% of the agricultural sector's GHG emissions, is the main source of these emissions. It is made naturally from soil through the processes of nitrification and denitrification. Anthropogenic agricultural practices may directly or indirectly enrich soils with nitrogen. Due to increased nutrition and the strong demand for agricultural products, these emissions are anticipated to rise in the future (Delgado *et al.*, 1999). Direct addition of fertilizers, both synthetic and organic, including nitrogen, may play a significant role in the rise in N_2O emissions, with developing countries using 36 million tons more fertilizer than industrialized countries (Bumb and Baanante, 1996). The construction of equipment, the utilization of pesticides, fertilizers, on-farm fuel consumption, and the transportation of agricultural goods are additional anthropogenic sources of GHG emissions from agriculture (Rosegrant *et al.*, 2008).

1.3.3.2.2 Livestock

Globally, there is a significant rise in both the demand and production of cattle products, although the following areas take the lead: the central and eastern United States of America, northern Argentina, southern Brazil, Uruguay, Europe, China, and India. Thirty percent of the world's land surface is covered by livestock production, and 70% of all agricultural land is used for this purpose. The cattle sector is one of the top three causes of the most significant environmental problems, including the decline in water quality, on all scales, from the local to the global (FAO, 2006).

Major structural changes in the livestock sector are associated with the growth of modern and extensive livestock production methods, which often involve large numbers of animals concentrated in relatively small regions. Intensive livestock systems increasingly rely on domestically and internationally traded feed concentrates. The vast majority of waste products such as manure, liquid, and wastewater that is used to wash cattle is released back into the environment. These developments are placing growing pressure on the environment, and specifically on the quality of the water. Excreta from livestock contain significant amounts of nutrients, compounds that deplete oxygen, infections, heavy metals, medication remnants, hormones, and antibiotics. When livestock accumulates, the associated waste generation frequently exceeds the capacity of the ecosystem to serve as a buffer, which is polluting the surface waters and underground.

Livestock-related emissions account for 9% of the CO_2 equivalent produced by all human-related activities and are responsible for 64% of ammonia emissions, 37% of methane, and 65% of nitrous oxide, mostly from manure. According to Steinfeld *et al.* (2006), the livestock industry accounts for close to 80% of total emissions. Due to all of these pollutants, livestock is a top target for mitigation. The main source of methane production in this category is enteric fermentation in sheep and cattle, which accounts for 34% of worldwide agricultural emissions followed by rice farming, which accounts for 11% of global agricultural emissions. Horses, swine, and poultry are some other domesticated species that release methane (methanogenesis) as a byproduct of enteric fermentation. About 80,000 Gg of enteric methane from ruminants is thought to be produced globally (Carlos *et al.*, 2020).

1.3.3.2.3 Aquaculture

Greater production intensity and greater concentrations of one species are being caused by market forces and differentiation. Because of these changes, people are using more medications (such as antibiotics and fungicides), which leads to contamination further down the food channel. The largest amount of aquaculture development has taken place in developing nations, which produce 91% of the world's aquaculture; low-income developing countries have the greatest concentration of aquaculture. Nearly 90% of the world's aquacultural production is in Asia, with China leading the way with 45.5 million tons produced annually (FAO, 2016b).

1.3.3.2.4 Salts

Irrigation can release trapped salts in the soil, which can be carried by water from drainage systems to receiving bodies of water and cause salinization. Overwatering can also raise the water tables in saline aquifers and facilitate the seepage of saltwater from the ground into watercourses. The penetration of saline into aquifers, which typically occurs as a result of overuse of groundwater for agriculture, is another important factor contributing to the salinization of coastal areas (Mateo-Sagasta and Burke, 2010). Australia, Argentina, India, China, the Sudan, the United States of America, and numerous nations in Central Asia have all reported serious water-salinity issues (FAO, 2011). According to IGRAC (2009), 1.1 billion people in 2009 resided in areas with shallow or intermediate depths of saline groundwater.

Lorenz (2014) says that when salinity increases, there is typically a loss in the biodiversity of bacteria, algae, plants, and animals. Herbert *et al.* (2015) claim that excessively salinized waters have a broad effect on ecosystems by altering the cycles of significant elements such as carbon, iron, nitrogen, phosphorus, silicon, and sulfur.

1.3.3.2.5 Sediments

Many types of contaminants are found in rivers and lakes, which are rich with inorganic and organic material. The capacity of dams can be decreased by sediments, which can also block fish gills and cover and ruin fish spawning beds. Sedimentation can clog streams, harm watercourses, and require filtration to use for irrigation purposes and urban water supplies. Additionally, it may have an impact on delta dynamics and navigational potential. Sedimentary clay particles have surfaces that can adsorb a wide range of substances, including inorganic and organic pollutants. Therefore, one important method for bringing such pollutants to water bodies is through sediment.

An enormous amount of soil is lost and carried to aquatic bodies annually as a result of improper tillage, unsustainable land use, and inadequate management of soil in agriculture. These elements promote the release of sediment into streams, lakes, and reservoirs, causing erosion. Approximately 193 kilogram of soil organic carbon per ha per year is the global rate of cropland erosion. Approximately 1.7 Mg per ha per year and about 40.4 kg of soil organic carbon per hectare per year accounted for pastureland. According to Doetterl *et al.* (2012), Asia accounts for 43% of agricultural sediment flux.

1.3.3.2.6 Management of Manure and Organic Matter

Manure handling, treatment, and storage are responsible for 7% of agricultural emissions. Methane is produced during the anaerobic decomposition of manure (methanogenesis), whereas nitrous oxide is produced during the aerobic processing of manure (nitrification), which is subsequently converted to nitrogen dioxide for use by plants (denitrification) (Urzelai *et al.*, 2000). Methane emissions from enteric fermentation are anticipated to rise by 32% because of the high demand for beef and dairy products anticipated worldwide, particularly from emerging countries (US Environmental Protection Agency).

1.3.3.2.7 Pathogens

Despite the fact that humans are constantly exposed to a wide variety of microbes in their surroundings, only a small percentage of these bacteria are able to interact with the host in a way that leads to disease. Numerous multicellular parasites and zoonotic bacteria that can be dangerous to the health of humans are present in livestock excrement. Waterborne or foodborne pathogenic bacteria are both possible. The pathogen typically has to develop inside or on the host in order to cause sickness. The incubation period is the period of time between contamination and the onset of medical signs and symptoms. When excrement is left on land, some germs can linger there for days or even weeks before contaminating water sources through runoff (WHO, 2012; FAO, 2006).

1.3.4 Burning of Fossil Fuels

Our energy needs are met by burning gas, coal, and oil, which is what is generating the present global warming problem. Burning fossil fuels release a number of air pollutants that harm the ecosystem and the surrounding environment. Fossil fuels have the potential to release harmful air pollutants years before they are burned. Several major and secondary pollutants are released during the burning of fossil fuels, such as airborne particles, hydrocarbons, chemicals, nitrogen oxides (NOx), CO_2, CO, SO_2, and organic compounds. The greenhouse gases, like nitrous oxide and carbon dioxide, are all present in the emissions from burning fossil fuels.

1.3.5 Particulate Matter

Particulate matter concentration and type of particulate material are considered very seriously when we talk about the biosphere and atmosphere. From natural sources, a number of tons of this matter is released into the environment each year. Among them, some examples are volcanic eruptions, rock material, deforestation, dust storms, greenhouse gas emission, and soil degradation. On other hand, anthropogenic activities also contribute to disturbing the atmosphere through contamination of particulate matter. The waste from steel industries, petroleum refinery byproducts, mining of coal and its exploration, agrochemical residues in the soil and water bodies, industries related to chemical production, emissions from power plant systems, and combustion of fuels and petroleum products all are responsible for contamination of the environment through producing particulate matter.

1.3.6 Utilization of Plastics

Acrylic, polyethylene, polyvinyl chloride, polyester, and polycarbonates are all examples of types of plastic materials. Because plastic bags are inexpensive and long-lasting, they are frequently used in developing nations for carrying, buying, and storing food. The United States' municipal solid waste generation between 1960 and 2013 increased by 188%, whereas plastic generation increased by 8238% (Tsiamis *et al.*, 2018). However, the production of metallic and glass garbage decreased, while the production of plastic waste increased. While secondary microplastics (MPs) are created as larger plastic waste breaks down, MPs are primarily found in consumer goods, including paints, cosmetics, and fibers in cleaned synthetic garments (Auta *et al.*, 2017). People are becoming aware of the environmental damage caused by plastic pollution. However, regulating commercial use and reducing the use of plastic is extremely difficult. There are no alternative materials or products on the market that can rival the plastic carry bag.

1.4 EFFECTS OF ENVIRONMENTAL POLLUTION

The majority of developing countries, which are the most severely impacted by pollution, still lack adequate documentation on its effects due to a lack of understanding of the potential harm that pollution can have for the environment and public health as well as unstable database management systems. In low-income nations, where people prioritize food and shelter over their health and the environment, pollution and its effects are intensifying. Public choices for conserving the environment are known to be highly associated with socioeconomic determinants of health, including education and income. Some African regions completely attribute certain health problems, such as birth defects, cancer, stunted growth, pregnancy loss, and early death, to bad luck and "acts of the gods," which draws attention to pollution and its effects.

1.4.1 Effects on the Environment

The biosphere, water, soil, and atmosphere form the environment, which serves as a repository for all harmful substances. Environmental pollution is so called because the environment always faces the greatest damage as a consequence of an increase in pollution. Increases in GHGs have the potential to drastically alter our civilization, either positively or badly, but the full extent of these effects is unknown. A warming globe causes climate change; it has a number of negative impacts on the weather. Therefore, as the climate alters, the worst weather poses serious risks to human civilization. The temperature of the ocean, height of the sea surface, sea ice, temperature of the biosphere, heat level of the surface water of aquabodies, snow area on hills, and tropospheric temperature are all indicators of global warming. It is anticipated that increased droughts, floods, storms, and heatwaves may result from climate change. According to IPCC estimates, temperatures could increase by 2 to 6°C in years to come (Singh and Singh, 2012).

Despite recent evidence suggesting that the stratospheric ozone layer is healing because of reduced chlorofluorocarbon emissions, the stratospheric ozone layer decreasing in the past decades might be due to emissions of nitrous oxide and chlorofluorocarbons, which protect the earth from solar ultraviolet (UV) radiation (Solomon *et al.*, 2016). The Arctic ozone, on the other hand, exhibits substantial year-to-year fluctuation, while ozone depletion continues to occur each year in Antarctica (Andrady *et al.*, 2015).

The loss of land for agricultural production is a result of subsequent damage such as erosion, soil mineral leakage, landslides, and soil and crop contamination by pathogens from humans or animals, salt, or chemicals (Lindgren *et al.*, 2011; Miraglia *et al.*, 2009). Flooding or drought-related declines in crops and cattle are examples of direct repercussions, as is damage to infrastructure that may have an impact on food production. After extreme weather events, a number of infectious illnesses that harm livestock, including anthrax and blackleg, may appear (Bezirtzoglou *et al.*, 2011; Skovgaard, 2007). Furthermore, a rise in insects that could serve as infection vectors may be seen following floods, particularly when they occur in combination with high temperatures. For instance, Rift Valley fever infects animals through eggs, which rely on still water (Nardone *et al.*, 2010; Githeko *et al.*, 2000). Extreme weather conditions may also additionally affect the dynamics of how pathogens spread and the existence of insects and pests, which can harm agricultural productivity (Jaggard *et al.*, 2010; Miraglia *et al.*, 2009).

The repercussions for land include waste littering, tree damage, wildlife species, soil sterility reducing crop yield, degradation of roofing sheets, influence on historical monuments and structures, and the staining of automobiles. Continuous mining, for example, devastates soil–plant systems and decreases soil productivity (Feng *et al.*, 2019), whereas anthropogenic activities cause landscape damage such as soil upper layer loss, habitat disturbances, loss of animal productivity, and resource loss, such as wetlands ecosystems (Vallero and Vallero, 2019). Food crises cause hunger and, in extreme cases, death of living organisms. The pH of the soil decreases due to changing soil chemical properties, and crucial cationic nutrients like magnesium, potassium, and calcium are lost. All of these generate scarcity of food for both humans and other living things, which can lead to starvation and even death.

Pollution typically modifies the biological, chemical, microbiological, and mechanical characteristics of bodies of water. The spreading of oil on the water's surface also limits sunshine and oxygen. Other instances include the presence of heavy metal contaminants in products, heated water bodies from UV radiation, improper irrigation water management that encourages salt sedimentation on the land's surface, and runoff from drainage that enriches the water ecosystem with nutrients like nitrogen and phosphorus. All these events affect the biological oxygen demand for aquaculture, deteriorate the quality of water, and cause unnecessary growth of vegetation. Several pollutants have been identified as being delivered by air and subsequently deposited on soil and in water bodies. Water bodies become odiferous and unpleasant as a result of the introduction of sulfur- and nitrogen-containing compounds, which leads to loss of the aesthetically pleasing qualities of water, and they are abandoned.

A main or significant source of anthropogenic CH_4 and CO_2 greenhouse gas emissions has been identified as livestock production, which is an agricultural food-based industry (Audsley and Wilkinson, 2014). Because of the significant amount of greenhouse gases created during ruminal fermentation of feeds, they significantly contribute to global warming, pollution, and environmental deterioration. Therefore, the livestock industry accounts for approximately 18% of total CH_4 and 9% of total CO_2 emissions (FAO, 2013), with methane accounting for 50–60% of emitted gases during livestock production (Mirzaei-Ag *et al.*, 2012). For instance, greenhouse gases emitted into the environment are responsible for climate change at every step of the making of eggs, meat, and milk in agriculture, which disturbs the temperature, weather, and ecosystem health. It will be necessary to alter agricultural methods and cattle consumption in order to mitigate these issues.

1.4.2 Effects on Crop Production

It is possible to isolate a number of unique elements that have somewhat diverse effects on agricultural output within the framework of human climate change. According to experimental data, a boost in atmospheric CO_2 concentration boosts the vegetation growth and photosynthetic activity in a variety of crop (C3) species (Ainsworth and Long, 2005). A research experiment indicated that high temperatures have a detrimental effect on the physiological processes, and its combined effect of high temperatures and increased CO_2 may result in reduced photosynthesis and biomass production (Ruiz-Vera *et al.*, 2013). Furthermore, heat stress during pollination will make some commodity crops more vulnerable (Semenov and Shewry, 2011), particularly in places where crops are planted near the temperature that is the critical limit for photosynthesis (Ruiz-Vera *et al.*, 2013). Higher temperatures, on the other side, may extend cultivation seasons and result in greater yields in northern latitudes and colder locations (Eckersten *et al.*, 2011). Ainsworth *et al.* (2012) found that as temperatures rise, tropospheric ozone levels rise, which puts plants under oxidative stress and inhibits photosynthesis and plant growth.

According to Porter *et al.* (2014) and Smith *et al.* (2014), there are numerous direct and indirect ways that climate change will affect agricultural production. Crop yields will be directly impacted by changes in temperature and water availability, as well as by greater weather variability and more frequent episodic weather events (Lobell and Gourdji, 2012). Faster crop growth, shorter cropping seasons, and lower yields are all effects of rising temperatures. The rate of photosynthesis and respiration are also impacted by temperature. The optimum temperature for photosynthesis is higher for C4 crops than for C3 crops (cereals and the majority of vegetables and fruits), including maize, sorghum, and sugarcane.

The production of important crops will be significantly impacted by increased climatic variability (Lobell *et al*., 2008). Increased inter-annual weather variability might increase the probability of crop failures by making crop management strategies that aim to maximize yield and quality while minimizing environmental consequences more challenging. Furthermore, if biotic stressors increase due to, among other things, pests and the invasion of alien weed species, crop yield may suffer (Garrett *et al*., 2011; Anderson *et al*., 2004). Therefore, the influence of climate change on crop production can be either direct or indirect. The degree to which certain nations and areas are successful in adapting to climate change will depend on their capacity to create and use new technology (Varshney *et al*., 2011). In addition to the direct consequences, rising temperatures may have an indirect impact on fruit and vegetable production due to lower labor productivity of farmers (Kjellstrom *et al*., 2016). Since many fruit and vegetable crops demand significant labor inputs, particularly during planting and harvest, the industry may be disproportionately affected by heat stress caused by climate change.

The number and susceptibility of the host (crop plant), the abundance and virulence of the pathogenic organism, and favorable climatic conditions are crucial components of plant disease epidemics that define the occurrence and severity of a specific plant disease (Agrios, 2004). According to Ayliffe *et al*. (2008) and Stuthman *et al*. (2007), agricultural practices that increase host density, such as increasing field aggregation, field size, and crop species uniformity, tend to increase the severity of plant disease epidemics because they both make hosts more vulnerable and make it easier for the plant pathogen to spread. Additionally, little genetic variety is linked to few features that provide resistance to a particular pathogen, and genetic uniformity of cultivars makes the host more vulnerable (Tadesse *et al*., 2010). Therefore, if the disease evolves to beat the genetic resistance, the outcome could be widespread crop loss (Forbes and Jarvis, 1994). International trade in seed and planting stock also has a considerable effect on the abundance of plant diseases. In actuality, diseases have spread into different regions of the world where they were previously nonexistent due to global trade and interaction (Zadoks, 2008). Pathogens may also spread because of people traveling to and from low- and middle-income nations while bringing their own food and avoiding border checks. Therefore, the huge fields devoted to homogeneous crop cultivars, higher planting densities, and increased use of fertilizers typical of specialist agriculture in the industrial world may increase the possibility of the spread of plant disease (Stuthman *et al*., 2007). Nevertheless, it is typically challenging to forecast the infestation of plant diseases, and the severity of their effects depends on both environmental factors and interactions between plants and pathogens (Wellings, 2007).

Animal species are also impacted by climate change, and a decline in plant pollinator numbers, for instance, might have a variety of effects on agricultural output (Pacifici *et al*., 2015). Pests, diseases, fungus, and weeds are also predicted to cause more crop losses and damage due to climate change (Flood, 2010). According to estimates made by Bebber *et al*. (2013), between 1960 and 2012, hundreds of pests and pathogens traveled closer to the poles on average by 2.7 km yr^{-1}.

In some regions, losses in agricultural yield resulting from surface ozone exposure and heavy metal contamination may be significant (Chepurnykh and Osmanov, 1988). The importance of ozone in this area could increase in the future (Avnery *et al*., 2011). According to experimental data, some plants' ability to photosynthesize can be negatively impacted by cadmium at concentrations of less than 1 micro molar, which is observed in some soils (Prasad, 1995). Additionally, Kalantari (2006) hypothesized that decreased rice yields in Iran are related to concurrent increases in cadmium burden. Agricultural production and soil cadmium loads are directly related to one another because phosphate rock fertilizer is the main source of cadmium. According to Pan *et al*. (2010), sewage sludge used as fertilizer also contains cadmium.

1.4.3 Effects on Human Health

Could the fact that the results of humans' actions have come back to find them constitute "karma"? The bulk of human ailments have been connected to environmental pollution because of its correlation with human health. More information about the relationship between pollution and a number of serious health issues is being uncovered by recent studies. The quantity of studies examining the negative impacts of air pollution on health is alarmingly rising. The World Health Organization's report made it abundantly evident that indoor air pollution from fires used for cooking and heating was responsible for 3.8 million fatalities (WHO, 2018). This percentage varied, as one might expect, from 10% in developing countries to 0.2% in high-income nations.

Many people worldwide breathe air that contains elevated levels of pollutants that are beyond WHO guideline limits, according to the World Health Organization, raising the risk of various illnesses, including strokes, heart disease, lung cancer, respiratory illnesses, cognitive decline, and many more. There are several social and economic effects of atmospheric pollution that cannot be disregarded.

Additionally, according to the global burden of disease, one aspect of ambient (or outdoor) air pollution, PM2.5, was the fifth most important cause of death globally in 2015, accounting for 4.2 million deaths and more than 103 million disability-adjusted life years lost (Schraufnagel *et al.*, 2018). According to research by Song *et al.* (2019), third-trimester maternal exposure to PM2.5, PM10, CO, and SO_2 is linked to shorter infant telomere length. This suggests that these pollutants not only put us in danger but also provide serious risks to unborn children.

1.4.4 Effects on Animal Health

Heat stress can worsen metabolic disorders and increase mortality in farm animals. Additionally, it can lower fertility, feed intake, and immune response, all of which tend to lower output (Nardone *et al.*, 2010; Thornton *et al.*, 2009). Pig and chicken intensive indoor production is particularly susceptible to temperature increases since there may be an increase in mortality if additional cooling is not provided. The modern, high-yielding dairy cow is sensitive to heat stress because of its high metabolic rate (Black *et al.*, 2008; Sartori *et al.*, 2002). Long droughts may also directly result in feed and water shortages, which would further reduce output.

Vector-borne diseases are also impacted by rising temperatures. For instance, they boost the quantity and intensity of female mosquitoes' blood meals, the vector's reproductive rate, and the virus's rate of replication inside the vector (Pinto *et al.*, 2008). Ticks and biting midges, vectors of Lyme disease and blue tongue, respectively, have previously been observed moving northward in the northern hemisphere (Forman *et al.*, 2008; Van den Bossche and Coetzer, 2008). Furthermore, it is dangerous to store food and feed because of the increased prevalence of hazardous mycotoxins brought on by humidity and a warm temperature. Additionally, due to lignification, changes in the content of grass species triggered by climate change possibly will affect the productivity of grazing animals (Thornton *et al.*, 2009).

Transboundary animal illnesses are highly infectious and spread quickly within and among populations of animals. As a result, they endanger the farmers' way of life, the cattle industry's financial stability, and ultimately global food security. For reasons related to public health, livestock productivity may be hampered by zoonotic transboundary animal illnesses. The worldwide outbreak of the highly virulent avian influenza (H5N1) that started in East Asia in 2003 serves as a strong illustration of this (Kaufman, 2008; Sims *et al.*, 2005).

According to Harrus and Baneth (2005), changes in ecosystems can also make it easier for domestic and wild animals to contract the same diseases. The spread of the Nipah virus from fruit bats to farm pigs and ultimately to humans in Malaysia in 1999 is a prime illustration of this (Chua, 2003). Through worldwide travel and trade in animals, animal products, and consumables, an illness can quickly spread to nations with weak livestock populations once it has been established, endangering livestock output (Sherman, 2010; Thornton, 2010). In 1986, a swine flu outbreak in Great Britain made the value of trade clear. According to Williams and Matthews (1988), the sickness was believed to have been brought on by feeding animals with unprocessed food waste that contained imported pig flesh.

The devastating foot-and-mouth disease outbreak in Great Britain in 2001, which resulted in losses estimated to be over 3.1 billion GBP (Thompson *et al*., 2002), is a good example of the threat posed by transboundary animal illnesses to livestock productivity and food security. The severity of a contagious disease depends on the pathogen's virulence, farm and livestock density, biosecurity practices, the production system, the volume of trade in animals and animal products, the availability of veterinary services, and the population densities of people and wildlife and how close they are to livestock (Rossiter and Al Hammadi, 2009). The relative importance of these characteristics varies and could be affected by governance (Graham *et al*., 2008) and economic development (Forman *et al*., 2009).

In East Asia, there is a noticeable rise in the population of farmed animals, particularly poultry and pigs raised in enclosed production systems (Thornton, 2010). According to Steinfeld *et al*. (2006), large-scale intensive animal production plants are typically created in highly inhabited areas. Infection outbreaks could have catastrophic effects in these large-scale systems, which emphasizes the value of strong biosecurity (Sherman, 2010). There will unavoidably be human–animal interactions due to the rise in small-scale, backyard animal production that urbanization in type A and type B countries entails.

Moreover, genetic diversity and biodiversity of the ecosystem are affected by contaminants present in the atmosphere. It is demonstrated that the quantity of ribosomal duplicates of DNA regularly increases in response to environmental changes. This happens because these sequences are essential for preserving the integrity of the genome (Araujo da Silva *et al*., 2019). Studies show that fish living in heavily polluted environments have incredibly complex ribosomal sequences in their genomes.

The issues that plastics have created in the environment have been discussed recently. Animals are harmed by plastics either directly or indirectly. It also harms ecosystems and limits biodiversity. Ultimately, it could affect the lives of mostly fish, birds, lobsters, sea turtles, and other kinds of marine animals (Barboza *et al*., 2019). Ingestion stress issues can cause lesions, lacerations, and internal damage. Additionally, plastics have the ability to entangle and choke aquatic life; hinder photosynthesis in the principal food providers, such as algae; and have an impact on the growth and reproduction of crustaceans (Barnes, 2019).

Oil spills during refining, drilling, and transfer on the ground through transmission lines, including underwater, can have sub-lethal health effects on wildlife and aquatic organisms. When these animals inhale or eat substances from petroleum that contain hazardous compounds, their respiratory, digestive, and circulatory systems suffer. Beside these, seabirds are severely impacted by oil spills, yet they are often not recorded. According to studies, oil fouling is killing birds. Many oil spill–related deaths go unreported, despite the fact that certain oil-fouled birds are recognized and recorded when they die (Walker *et al*., 2019).

1.4.5 Effects on Microorganisms

Microbial pollution is the term used to describe pathogen contamination, which includes those caused by bacteria, viruses, and parasites. Infections may be species specific or zoonotic, meaning that they harm both humans and animals, and they can get into agricultural systems in a variety of ways. They may be spread by contaminated water or organic fertilizer (Tirado *et al*., 2010). Following an epidemic of a disease that produces significant amounts of pathogen-contaminated animal feces, pathogens of animal origin can build up in the environment. The nutrient cycle and transfer of energy in the aquatic food webs are critically dependent on microscopic populations in flowing water habitats, such as zooplankton (Xiong *et al*., 2019). Consequently, biotic reactions of microscopic organisms to their ambient condition could be used to accurately detect changes in the environment in aquatic habitats. However, pollution has had a considerable impact on the zooplankton community's geographic spread, which has decreased their effectiveness. Such garbage could contaminate water supplies or the land it is dumped on or used as fertilizer after being collected, stored, or buried. As a result, microbial pollution of an environment used for agriculture may make it impossible to engage in agricultural activity and provide potential hazards to both humans and animals.

1.4.6 Effects on Water Quality

A serious danger to the quality of irrigation water is salinization. From crop to crop, salt tolerance levels might differ significantly. Salinization primarily reduces crop yields, but it has a mixed effect on crop quality (Hoffman *et al.*, 1989). Salinity has a negative impact on a variety of vegetable crops and can significantly lower their market value. However, salinity can enhance the sugar content of some crops, like carrots and asparagus, while also increasing the amount of soluble solids in others, like tomatoes and melons. However, salinity-related yield reductions typically outweigh any positive effects (Hoffman, 2010).

Climate change may make salinity issues more severe, which will have an effect on health via nutrition and drinking water (Scheelbeek *et al.*, 2017; Khan *et al.*, 2014). The rising incidence of tropical cyclones and flooding is able to considerably impact sodium and other salts contained in soils and ground and surface water in a number of low-lying coastal locations. When farmers shift away from saltwater irrigation supplies and acquire water from deeper groundwater layers in coastal regions that are sensitive to climate change, like Bangladesh, an additional issue arises since significant arsenic concentrations have been recorded in these groundwater sources. After harvest, arsenic may still be present on the crop's surface, posing a major health risk to consumers (Su *et al.*, 2014; Das *et al.*, 2004). The quality of irrigation and drinking water may be impacted further inland by considerable increases in salt concentrations brought on by shifting precipitation patterns and drought (Jeppesen *et al.*, 2015).

Irrigation water contamination has a substantial impact on agricultural yield and quality. In low-income nations with dry and semi-arid climates, more than 10% of the world's population consumes food that has received irrigation from untreated wastewater or lakes or reservoirs water which is contaminated by feces (WHO, 2006). The main causes of the rising use of contaminated water for irrigation include the shortage of freshwater, growing populations, and awareness of the potential of wastewater as fertilizer. Food-borne disease outbreaks have been connected to the use of pathogen-contaminated municipal wastewater for irrigation and post-harvest procedures (Antwi-Agyei *et al.*, 2015). This is especially problematic for fruits and vegetables, which are frequently consumed raw.

The presence of excessive nutrients in irrigation water, particularly nitrogen, is a serious danger to water quality. This is frequently the result of over-fertilizing agricultural land, where excess fertilizer ends up in irrigation water sources and could harm marine ecosystems. High nitrogen concentrations cause excessive vegetative growth and a delay in maturity in crops that are susceptible to it, including apricot, citrus, and avocado. This reduces the amount of produce that can be harvested from leafy vegetables and may have a detrimental impact on fruit quality indicators such sugar content (Ayers and Westcot, 1985). Crops may become taller as a result, making them more susceptible to lodging during severe weather events like tropical storms.

High quantities of some harmful ions, such sodium, boron, and chloride, can cause damage to crops and lower yields when they are taken up by plants and accumulate in irrigation water (Banon *et al.*, 2011). Toxin concentrations in water are influenced by both industrial and agricultural factors, including the release of chemical wastes into irrigation watersheds and the disposal of agrochemicals on farms. The majority of irrigation water sources have element quantities below toxicity criteria; nonetheless, the majority of vegetable crops have a rather limited tolerance to boron, and even very low boron concentrations can harm crops (Hoffman, 2010). The severity of the harm varies depending on the crop, and permanent perennial-type crops are thought to be the most vulnerable (WHO, 2006).

In general, water contaminated by human and animal pathogens is unfit for consumption since it may result in illnesses and subsequent loss of output. For a similar reason, this kind of water should not be used to irrigate crops meant for human or animal consumption. Internationally, the significance of preserving freshwater's good microbiological quality is generally accepted (Fewtrell *et al.*, 2005). Similar to this, applying pathogen-contaminated fertilizers to crops meant for direct human or animal consumption might be dangerous. Pathogens can be found in both human and animal feces (Barrett *et al.*, 2001). Exposures may occur in type C nations when untreated sewage water leaks into the water supply system because of severe weather or mishaps such as burst sewage pipes (Cabral, 2010). According to Bartram and Cairncross (2010), in both type B and type A countries, inadequate or absent wastewater treatment, poor sanitation, and outdoor defecation can all contribute to the discharge of human diseases.

1.4.7 Effects on Soil Quality and Health

A scarce natural resource is agricultural land. According to estimates, during the past 40 years, soil erosion and pollution have caused the loss of over a third of the world's arable land (Cameron *et al.*, 2015). Urbanization, sea level rise, the need for space for biofuels and other non-food crops, as well as the production of renewable energy (such as solar panels on agricultural land), are other factors contributing to the loss of agricultural land. Forests, on the other hand, have been turned into agricultural land, mainly because of rising meat consumption and a need for space for the production of animal feed. As a result, throughout the past few decades, the proportion of worldwide land that is used for agriculture has remained largely unchanged. Deforestation, on the other side, has a detrimental indirect influence on food security since it accelerates a number of environmental processes, such as global warming and biodiversity failure.

Acid rains or, in some cases, the usage of synthetic nitrogen fertilizers, contribute to soil acidification. Acid showers often come about due to an atmospheric reaction between water molecules and sulfur dioxide or nitrogen oxide, which are mostly produced by human activities such as energy production and industrial processes (Klimont et al., 2013). Except in alkaline soils, where moderate acidification can be advantageous, soil acidification can change the availability of nutrients and generally has a detrimental impact on plant growth. Crop losses brought on by acidification can be lessened with the use of lime and balanced fertilizers (Mason *et al.*, 1994). Phytotoxicity is the hazardous impact that substances like trace metals, allelochemicals, pesticides, phytotoxins, or salt have on plants. Both crop productivity and people's health are harmfully affected by toxic metal contamination of soil, such as that caused by cadmium and high levels of aluminum (Khan *et al.*, 2015). Plants experience oxidative stress from metals, which hinders the accumulation of biomass.

Persistent organic pollutants include low-use pesticides like DDT, industrial toxins, and some industrial compounds like polychlorinated biphenyls. According to research (Wang *et al.*, 2010; Holoubek *et al.*, 2009), certain pollutants, such as PCBs, can be hazardous to plants, however only in quantities that are several orders of magnitude higher than those discovered in soil that was irrigated with chemical-containing water. From the standpoint of food safety, these chemicals are a serious concern since they could contaminate foods of animal origin, notably seafood, and then make their way to people (Guo *et al.*, 2009; Zhao *et al.*, 2006).

The constant discharge of chemicals and radioactive materials from various sources, as well as more dramatic occurrences like industrial accidents or the purposeful transport or release of toxic waste, can all contribute to chemical and radioactive pollution of the environment. Chemical pollutants can enter agricultural soils through a variety of channels, including air, rain, irrigation, and direct application as pesticides (Montanarella, 2007). However, even in nations with sophisticated monitoring systems, it is difficult to find the extent of soil contamination.

According to Gibbs and Salmon (2015), the term "soil degradation" often refers to a number of processes, including desertification, salinization, erosion, compaction, and the invasion of exotic species. In order to keep soils productive over the long term, soil organic matter is crucial. One of the main causes of loss in soil organic matter levels is the increased use of industrial farming techniques, such as monocropping, minimum use of organic fertilizers, and removal of crop wastes from fields. According to experts' estimates, land degradation affects roughly 15% of the world's land surface severely, 46% of it moderately, and 38% of it gently (Bridges and Oldeman, 1999). These estimates have come under fire for being arbitrary and overstating the degree of land degradation, particularly in dry and semi-arid areas (Nkonya *et al*., 2011). The time series of the normalized difference vegetation index (NDVI) (1981–2006), as shown by more recent measures of plant cover (Bai *et al*., 2008), demonstrated ongoing land degradation in humid regions. Australia is the only country where dryland areas stood out. Sub-Saharan Africa later received confirmation of this global trend in land degradation (Vlek *et al*., 2010). With 13% of the world's current land degradation, Africa south of the equator experienced the most deterioration. Climate change is likely to be responsible for some of what was once thought to be anthropogenic land degradation near the Sahara (De Jong *et al*., 2011). From a methodological perspective, the use of NDVI as a stand-in for land degradation has also drawn criticism. New worldwide estimates of land degradation based on expert opinion are currently being developed, taking into account soil variables, ecosystem services, and land-use classifications (FAO, 2011).

1.4.8 Effects on Biodiversity

Because of how complicated ecosystem activities are, it is currently impossible to model the level of biodiversity needed to support agricultural production. Agro-ecosystems are therefore considered more resilient to environmental changes when a high level of biodiversity is maintained (Koohafkan *et al*., 2012; Lin, 2011). Diversification of agro-ecosystems, high genetic variety of crops, control of soil organic matter, integration of livestock and crop production, and water conservation are all farming techniques that lessen sensitivity to environmental change. Crop variety boosts resilience to increasing climate variability and extreme events while reducing pest, disease, and weed outbreaks. In low-income settings, farms with a high level of biodiversity have been found to be more resilient to climate disasters, such as hurricanes and droughts (Altieri *et al*., 2015). Smallholder farmers in tropical regions are particularly vulnerable to climate variability, including erratic rainfall, and as a coping mechanism, they rely on agricultural biodiversity, such as planting a high diversity of crops each year, including many varieties of the same crop, using drought-tolerant crop varieties, changing the locations of crops, and planting trees to provide shade and to maintain humidity (Meldrum *et al*., 2013).

In some instances, the availability of food can be directly impacted by biodiversity loss in regions whose diets largely consist of wild foods, such as wild fruits and vegetables. Numerous ecosystem services, such as pollination, natural pest control, and functions offered by soil macro- and microorganisms, are strongly reliant on by field-grown crops and cattle. Pollinator populations have decreased during the past ten years because of a stressor that includes parasites, insecticides, and habitat degradation (Goulson *et al*., 2015). Since so many fruit and vegetable species depend on pollinators, a total loss of pollinators has been anticipated to result in a 23% reduction in the global fruit supply, a 16% reduction in vegetable production, and a 22% reduction in nut and seed production (Smith *et al*., 2015).

1.5 REMEDIES

It has been recommended to employ several remediation strategies to stop pollution in order to facilitate the speedy and efficient restoration of the environment that has already been impacted. Chemical treatments degrade contaminants and further modify their physicochemical properties, hence reducing the ecological danger associated with them. Beside this, physical approaches to soil reclamation have no effect on the physicochemical properties of the impurities accumulated in the surroundings that need to be removed. More crucially, biological approaches that depend on the biological activity of higher plants and microorganisms have the power to break down accumulated contaminants and ultimately result in their mineralization, immobilization, or elimination.

Regulations for the environment should be effective. Essential environmental regulating systems and policies, such as pollutant emission limits, pollution fees, and emission trading schemes, must be developed and improved by governments (Zhou *et al*., 2018; Tai *et al*., 2014). Renewable energy technology development and use must be firmly supported. Governments have a duty to the public to assist the renewable energy industry with resources, money, and technology. Agenda 2030 provides a framework for both the creation of a more environmentally friendly future for humanity and the responsible utilization of the resources of nature on which we depend (Barboza *et al*., 2019). Several studies have indicated specific areas for investigation and creativity, including understanding the consequences on human and animal health, developing alternative resources for cleaning beaches and oceans, and reducing the use of plastics (Barnes, 2019). In summary, workshops, meetings, training sessions, and media use can all help to educate the public regarding the way to manage and strengthen the relationship between human community as well as the surroundings in a sustainable and integrated way.

Green agriculture has to be promoted and practiced. Green agriculture needs robust and sustainable agroecosystems that can handle long-term difficulties, together with well-organized management of natural resources, ecosystem services, and biodiversity (Tan *et al*., 2022). Precision farming and other technical advancements in agriculture can be advantageous. For example, drought-resistant crops (Hu and Xiong, 2013) or crop varieties with greater concentrations and bioavailability of micronutrients (Bhullar and Gruissem, 2013) can be produced using novel plant breeding approaches. Utilizing geographic information systems, remote sensing, and GPS, precision farming technologies enable farmers to target the application of fertilizers and pesticides where they are most required.

Limiting and optimizing the type, amount, and timing of crop treatments are two management strategies for lowering the risk of water contamination caused by organic and inorganic fertilizers and pesticides. It has been demonstrated that setting up protection zones along surface watercourses, inside farms, and in buffer zones around farms can effectively stop pollutants from migrating to water bodies. Pesticide waste and empty containers need to be stored and disposed of according to safety regulations. Additionally, effective irrigation plans will decrease water return flows, which will significantly lessen the migration of pesticides and fertilizers into water bodies (Mateo-Sagasta and Burke, 2010). Measures to reduce soil erosion include contour plowing and banning the cultivation of soils with steep slopes (USEPA, 2003). The ability of conservation agriculture to reduce erosion has also been demonstrated.

Farmers have the option of changing farm management procedures, such as crop varieties, planting dates, irrigation techniques, and residue management, or implementing significant systemic changes, such as switching to different crop species and changing farming systems, or even moving agriculture to new areas (Challinor *et al*., 2014). Farmers and societies have a variety of options for adjusting to and minimizing environmental changes (FAO, 2010; FAO, 2012). These procedures can involve small changes up to significant system-level alterations, and they can take place at different levels. Agriculture and food production sectors can put adaptation strategies into place that will guarantee increasing production of high-quality food while putting less strain on the environment. Food production could be revolutionized by cellular agriculture, or adaptation of cell culturing methods for agricultural production. Acellular and cellular goods are both produced by cellular agriculture. Live cells are used to manufacture cellular goods like cultured beef or leather, while yeast or bacteria are cultivated to produce the protein that ends up in the product, such as milk protein or egg albumin (Post, 2012).

Research needs to focus more on the paths of emerging agricultural pollutants such as animal hormones, antibiotics, and other pharmaceuticals and the threats they represent to human community and the biosphere. For instance, more knowledge is required regarding how animal medications contribute to the growing issue of pathogen antibiotic resistance. The following strategies can be applied to reduce emerging contaminants: (1) GHG emissions from rumen fermentation and stored manure will be reduced by increasing the intake of digestible fodder (Hristov *et al.*, 2013). (2) Encouragement should be given to reducing the application of fertilizers and pesticides and introducing natural pest-control techniques. (3) Due to the ease with which they can enter a fragile ecosystem, pollution releases at the point of production should be minimized. (4) Methane is converted into things like sugars before it is emitted into the environment by methanotrophs, sometimes referred to as methane-eating bacteria, which exist in the surroundings where methane is created. (5) Biochemical techniques for reducing greenhouse gas emissions. (6) Restoration of degraded pastureland using conventional methods or procedures. (7) The creation of sound environmental regulations to prevent the unintentional discharge of developing toxins, such as water quality requirements, enhanced pollution and emission testing, and analyses of the environmental impact of farms and irrigation systems.

It is obvious that preventing or limiting the export of pollutants from where they are applied is the most efficient strategy to reduce stresses on aquatic ecosystems and rural ecosystems more broadly. Once pollutants are in an environment, the costs of mitigation skyrocket. Remediation of contaminated waters, such as lakes and aquifers, is a lengthy, expensive, and occasionally impractical project.

1.6 CONCLUSION

An overview of pollution and its sources, impacts, and prevention strategies has been provided in this chapter. Developed and developing nations share the burden of pollution, but because of weak laws, low knowledge, and extreme poverty, the latter are more impacted than the former. The most vulnerable people in middle-class and lower-class nations suffer disproportionately from pollution. Moreover, air pollution seems to be the type of contamination that has received the most attention and study. This may be owing to increasing premature deaths and illnesses associated with air pollution. To be able to repair an already destroyed ecosystem, pollution awareness must be raised, and all hands must be on board to stop activities which contribute to environmental pollution.

Many anthropogenic activities, including experiments that contaminate the land, are the source of agricultural contamination. An urgent need exists for a tiered strategy in the evaluation of the breakdowns of ecosystems and biodiversity with polluted soils. Emerging agricultural contaminants contribute to climate alteration through global warming in both positive and negative ways. By addressing the root causes, such as the occasions that emitted important greenhouse gases, the impact can be lessened. Biological remediation techniques that utilize microorganisms have been deemed among the safest for both the environment and people among all other remediation techniques.

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Phytoremediation of Heavy Metal-Contaminated Soil

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Mycoremediation of Metallic Pollutants

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Biological Solutions for Metal-Contaminated Environments

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Phytoremediation of Organic Contaminants

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Microbial and Phytoremediation of Crude Oil-Contaminated Soil

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The Biological Remediation of Water and Wastewaters Using Different Treatment Techniques

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Effective Microorganisms

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Bacterial Reduction of Molybdenum as a Tool for Its Bioremediation

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