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The Impacts of Environmental Pollutants on Human Health: A Review

Disha Sharma, Vipin Kumar Saini, Saba Rana, Ankit Kumar

Department of Biosciences, Shri Ram College, Muzaffarnagar

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ABSTRACT

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Many environmental pollutants have a substantial impact on human health, contribute to climate change, and affect both public and individual health, leading to higher rates of morbidity and mortality. Further research on the link between pollutants and health effects is necessary due to the lack of data on pollution exposure from less developed countries with poor waste management, greater rates of poverty, and slower adoption of new technologies. In many sophisticated nations, a similar situation exists, where answers are found only after the harm has been done and the need for safeguards has diminished.

The risk of cardiovascular illnesses is increased by exposure to soil tainted with plastic compounds. Emerging pollutants are those that have just recently entered the atmosphere and are typically not monitored, such as hormones, pharmaceuticals, and biological. Numerous environmental pollutants have a substantial impact on human health, influencing both public and individual health as well as climate change, leading to higher rates of illness and mortality. The association between pollutants and health impacts has to be further studied because there is a dearth of data on pollution exposure from less developed countries with poor waste management, higher rates of poverty, and slower adoption of new technologies. Similar circumstances exist in many industrialized nations, when remedies are only found after the damage has been done and the need for precautions has diminished. Due to challenges in measuring exposure levels and a lack of systematic monitoring, the relationship between environmental contaminants and health has to be better understood. A variety of contaminants are responsible for acute and chronic illnesses.

Furthermore, when disease issues appear after extended exposure, study becomes difficult. In order to close this knowledge gap, this review will address current knowledge regarding the relationship between environmental pollutants and human health. This overview covers the genesis of cancer and the effects of several environmental contaminants on the cardiovascular, pulmonary, reproductive, perinatal, and neural health of the human body.

Corresponding Author
***Disha Sharma**

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INTRODUCTION

Environmental pollutants are substances that have entered the environment as a result of

human activities and are hazardous to human health. Additionally, natural occurrences like volcanic eruptions contribute to environmental

contamination. Pollutants are introduced by human activity through soil, water, and air pollution. Contaminants enter the human body primarily by eating, oral absorption, and inhalation. The term "dose" is commonly used to describe the quantity of a particular pollutant that is required to be consumed. The length and intensity of exposure determine the dosage [1]. Different health problems could arise depending on the level of exposure. Even if industrialization helps a nation grow, it also pollutes the environment and damages the health of people who are exposed to it.

Worldwide, environmental pollution exposure is a major cause of health hazards. The air is generally polluted by dangerous materials that come from both natural and artificial sources [2]. Power plants, burning trash, chemical firms, volcanic eruptions, and vehicle emissions are the primary sources of pollutants. Inhaled air contains a variety of pollutants, including ozone, carbon monoxide (CO), sulphur dioxide (SO₂), nitrogen oxides (NO_x), heavy metals, biological contaminants, and tobacco smoke. These pollutants disrupt the body's natural processes when consumed, leading to illnesses like cancer, heart disease, reproductive disorders, problems with the fatal central nervous system, and respiratory disorders. Health problems are caused by tobacco smoke, which contains dangerous substances like nicotine, formaldehyde, arsenic, benzene, and cadmium [3]. Both smokers and passive smokers—those who are exposed to tobacco smoke but do not smoke—will develop cancer as a result. Asthma, bronchitis, throat infections, and eye burning are all possible conditions. Asthma, hay fever, and other allergy illnesses can be brought on by exposure to biological pollutants such as germs, viruses, house dust, mites, cockroaches, and pollen. On the other hand, volatile organic compounds can induce headaches, nausea, and lack of coordination, as well as irritation of the eyes, nose, and throat. Long-term exposure can harm many bodily components, primarily the liver.

Exposure to lead can damage the gut and brain systems, and in certain cases, it can result in cancer [4]. Ozone exposure reduces our resistance to colds and pneumonia, causes burns and eye irritation, and increases the risk of respiratory conditions like asthma. Children who are exposed to nitrogen oxides throughout the cold months may experience respiratory issues. The effect could be short-term or long-term, depending on the type and degree of the exposure. Asthma, bronchitis, lung and heart issues, coughing, headaches, nausea, and dizziness are among the short-term side effects, which can also include irritation of the eye, skin, nose, and throat [5]. Long-term consequences will include cancer, respiratory, reproductive, and neurological issues.

The health of living things is disturbed when they pollutants like bacteria, viruses, and endocrine disruptors. Through the mouth, nose, and skin, these pollutants can enter the human body. Such soil exposure can result in a variety of immediate and long-term health issues. short-term health issues, including as skin irritation, headaches, coughing, chest pain, and nausea [6]. Because dust particles in the air are easily inhaled and can cause a variety of health problems, people who work with soil on a daily basis or live close to such locations are susceptible to inhalation. In several nations, people directly come into contact with soil because they eat it as part of their culture [4].

The presence of plastic compound-contaminated soil raises the risk of cardiovascular diseases. Emerging pollutants include hormones, medications, and biological pollutants including bacteria, viruses, and endocrine disruptors that are usually not monitored because they have only recently entered the atmosphere [7]. These contaminants have the ability to enter the human body through the mouth, nose, and skin. Such soil exposure can lead to a number of short-term and long-term health problems. temporary medical conditions such as headaches, nausea, coughing, chest pain, and

skin irritation [8]. People who work with dirt every day or live near such areas are vulnerable to inhaling dust particles because they are easily breathed and can lead to a number of health issues.

Additionally, naturally existing pollutants like fluoride or arsenic can pollute water. The main cause of heavy metal pollution in water is thought to be fertilizers used in agricultural operations. The prevalence of acute waterborne illnesses, such as cholera, hepatitis, diarrhoea, typhoid vomiting, skin conditions, and renal difficulties, is linked to water pollution. Travelers visiting impoverished nations are impacted by diarrheal illness, which is a serious health issue there [10].

METHODOLOGY

This evaluation summarizes and evaluates primary data produced and supplied by other professional and academic researchers who have investigated contaminants and their health impacts. We searched for pertinent studies on Google Scholar, PubMed, and Sci-Hub using the following search terms: particulate matter, disease, pollution, health, mortality, and morbidity [. The search was carried out without respect to a particular date. The comprehensive search that made it beyond title and abstract screening yielded more than 250 research, including conference papers, journal articles, master's theses, and doctoral dissertations. Keywords and document names, which usually include the research themes, were the only search parameters allowed.

Articles had to meet the following requirements to be included: 1. be published in a peer-reviewed journal; 2. include pollutants as an exposure; 3. include effects on the respiratory, reproductive, prenatal, cancer, and cardiovascular systems as an outcome; and 4. look into any connections between pollutants and these health outcomes. Articles that did not discuss the health impacts of pollutants, were written in a language other than English, or did not feature human subjects were also excluded. A total of 120 literary works were

used in the review following the filtration process based on the inclusion and exclusion criteria.

1. Respiratory Health: Pollutant exposure and respiratory diseases are closely related. Nitrogen dioxide (NO₂), sulphur dioxide (SO₂), carbon monoxide, ozone (O₃), heavy metals, and particulate matter are among the substances found in vehicle and industry emissions. In addition, pesticide-, heavy metal-, and plastic additive-contaminated soil and water can harm lung health [9]. There have been reports of upper and lower respiratory tract ailments in humans exposed to these pollutants, such as bronchitis, pneumonia, chronic obstructive pulmonary disease, and coughing up phlegm [11]. By decreasing mucociliary clearance, restricting macrophage function, and increasing epithelial permeability, breathing in toxic particles and gases from the environment impairs the lung's natural defences. It has been demonstrated that inflammatory cells such as mast cells, T lymphocytes, neutrophils, and macrophages are more commonly recruited and activated in human, animal, and in vitro organism studies [13].

The generation of inflammatory mediators such as cytokines and chemokines, free radicals such as superoxide, hydrogen peroxide, and hydroxyl radicals, and the breakdown of enzyme and antioxidant defences all contribute to intracellular oxidative stress [12]. By controlling the redox-sensitive transcription factors nuclear kB and activator protein-1 and sending signals via the mitogen-activated protein kinase pathway, this results in inflammation. Certain demographic groups are more likely than others to be impacted by pollutants. These show a rise in mortality associated with exposure, mostly to particles and sulphates [14]. Due to their inferior biological defences compared to the general population, several groups are at risk. Exposure to air pollution is also associated with smoking behaviour. Smokers' lung capacities are 30% lower than those of non-

smokers of the same age. Mesothelioma and asbestosis are two examples of diseases that are peculiar to specific pollutants, such as asbestos and bagasse's, which are brought on by exposure to organic dust. Shortness of breath, wheezing, coughing, chest tightness, dry or scratchy throat, and airway inflammation have all been linked to pesticide exposure. Workers who handle pesticides are at a considerable risk of respiratory problems, including chronic coughing in women, according to a study of workers at bottling factories [15].

By releasing chemicals into the atmosphere, burning plastic bags leads to respiratory disorders like emphysema and asthma, long-term health problems, and serious lung damage. Polyvinyl chloride contains chlorine, which irritates the human respiratory system when it burns. According to a prospective birth cohort research, a child's asthma is linked to the amount of bisphenol A (BPA) in their urine [16]. Because cigarette smoke contains heavy metals like lead (Pb) and cadmium (Cd), generations who are exposed to it may develop emphysema and chronic obstructive lung disease. Exposure to Cd fumes causes chemical pneumonitis. The rate of Cd absorption in the lungs is substantially higher than in the digestive system [18].

The association between manganese (Mn) and infant blood pressure was also impacted by maternal cigarette smoking, as smoking during pregnancy is a source of Cd [17]. Additionally, several studies have demonstrated that smoking by mothers during pregnancy may encourage the buildup of Cd in the placenta. There is a correlation between Mn levels in urine samples from young adults with pulmonary functions, according to a study [19].

2. Reproductive Health:

Pollution of the environment has a negative effect on reproduction. Small-scale pollutant exposure has a major effect on both male and female reproductive function. Environmental toxicant exposure raises oxidative stress and

decreases the synthesis of antioxidant enzymes such glutathione peroxidase, catalase, and superoxide dismutase. ROS are produced in reaction, damaging cells' lipids, proteins, carbohydrates, and DNA. Male infertility is caused by oxidative stress, which also contributes to apoptosis and anomalies in germ cells. The damaged sperm may cause early pregnancy loss or other developmental issues by passing on genetic damage to the growing embryo. Pregnancy-related or prenatal maternal exposure to PM_{2.5} reduces the reproductive organ's capacity to function as antioxidants [20].

Oocytes and granulocytes exposed to PM_{2.5} may undergo apoptosis induction, apoptotic pathway activation, and mitochondrial dysfunction. Acute toxicant exposure causes necrosis and apoptosis in testicular cells [21]. Usually, public exposure is sublethal and persistent When PM_{2.5} enters the bloodstream, it produces pro-inflammatory factors including chemokines. More free radicals are produced as a result, and inflammatory cells release more cytokines and adhesion factors, which exacerbate damage and set off a series of processes that ultimately lead to systemic immunological and inflammatory reactions [22]. Exposure to PM_{2.5} alters the amount of DNA methylation in the non-coding repetitive regions of the genome. This change affects gene expression or genomic instability and is linked to oxidative stress, inflammation, and other health issues.

According to a study, agricultural families who are exposed to phenoxy herbicides experience spontaneous abortions. Exposure to phthalates can damage the male reproductive system. Most reproductive problems are caused by mono-ester metabolites, which are produced in the liver. Human testosterone deficiency syndrome (TDS), which is characterized by reduced sperm counts, hypospadias, cryptorchidism, and testicular cancer, is brought on by phthalate exposure. During the production process, complex chemical combinations are employed and

generated, exposing workers in the plastics sector. A study of women employed in the plastics industry found poor reproductive results, infertility, and miscarriages [8]. Acute, sub chronic, genetic, developmental, and reproductive damage are all demonstrated by exposure to the inorganic form of As.

3. Cancer: Many environmental pollutants have the ability to cause cancer and mutagenesis. Between 70 and 80 percent of all cancer types have been connected to environmental pollutants. The molecular processes of carcinogenesis linked to pollution have received little attention. Nonetheless, a number of inverse models show how pollution impacts cancer and cell division. A meta-analysis has confirmed the nonlinear dose-response connection between DNA adducts and air pollution. In human epithelial cells exposed to PM_{2.5}, a variety of genes and microRNAs can become hypomethylated and activated during transcription, changing signaling pathways linked to cancer [23]. Because they can affect tumor suppressor genes, gene mutation and silencing are especially significant during the carcinogenic process. There are multiple stages involved in carcinogenesis, including initiation, promotion, and progression.

Although the effects of pollutants on the transformation of cancer cells have been well studied and understood, they are affected by both individual and time-dependent doses. Numerous molecular processes are disrupted by certain carcinogens and their combinations, which cause tumor suppressor gene (TSG) inactivation and oncogene activation, somatic cell proliferation, apoptosis inhibition, chromosome instability, a shift in a cell cycle that is dependent on TP53 activation, and energetic dysregulation [17].

According to a study, occupational groups exposed to fossil fuel combustion products have seen an increase in lung cancer. The PAH found in coal is a significant source of organic pollution, which is absorbed on the surface of particulate matter in the air in urban areas and

released during combustion, coking, pyrolysis, and other coal preparation processes. In their research of coke oven workers, Lloyd and colleagues found that workers who were exposed to low, medium, and high levels of coal combustion were more likely to develop lung cancer. In 1775, scrotal cell cancer was discovered in British sweeps as a result of coal smoke, and PAHs were the carcinogen that caused it [24]. A link between bladder cancer and pesticide applicators' use of herbicides such as imazethapyr and imazaquin was discovered in a study conducted in the United States.

The chance of developing either squamous cell carcinoma or urothelial cell carcinoma of the bladder is increased by occupational and environmental exposure to farming, according to a study conducted in Egypt [18]. An Australian study of women who reported having "ever noticed" pesticide spray drifting from agricultural areas found that they were at higher risk for breast cancer. A US study that included pesticide applicators from Iowa and North Carolina as participants found that their risk of lung cancer was higher than that of nonusers of herbicides such as acetochlor [25].

According to certain research, the plastic ingredient bisphenol A raises the risk of metabolic disorders, endometrial hyperplasia, recurrent miscarriages, infertility, breast and prostate cancer, and polycystic ovarian syndrome [19]. Through pregnancy, the fetus, and breastfeeding, phthalates and BPA can both enter the body of the baby. According to a systematic review and study, female breast cancer was adversely correlated with the phthalate metabolites MBzP and MiBP. DEHP, or di (2-Ethylhexyl) phthalate, is carcinogenic. It raises the risk of cancer when inhaled from the environment. Women who work in the plastics business have been linked to breast cancer. Through a complicated mechanism, intracellular activities are disrupted by direct or indirect exposure to heavy metals [26]. We discovered some genes and processes that are shared by the harmful

impacts of As, Cd, Cr, and Ni during the pathway analysis. These processes could be potential indicators of carcinogenesis brought on by heavy metals.

4. Neural Health: Many neurological conditions are caused by environmental contaminants. Neurotoxicity is mostly caused by exposure to environmental pollutants such as pesticides, industrial waste, vehicle exhaust, laboratory waste, and burning of terrestrial waste. The brain and circulation can be reached by exposed PM_{2.5} after it passes through the alveolar area. Via the olfactory nerves, ultrafine particulate matter (UFPM) travels over the blood-brain barrier and into the central cortex and cerebellum. They can cause astrocytes, microglia, and neurons to produce reactive oxygen species (ROS), which raises lipid peroxidation and neuroinflammation in several brain regions. These particles swiftly make their way to the central nervous system [14].

Epidemiological research indicates that exposure to particulate matter raises the risk of developing neurological disorders such as Alzheimer's. Burning cow dung results in biomass smoke, according to an *in vitro* study. Strong cell inflammation is more likely to occur after exposure to this. Most agricultural insecticides are designed to affect the pests' nervous systems. Because of the comparable neurochemical processes, exposure to pesticides causes neurotoxicity in humans [9]. It is common to see neurodevelopmental anomalies such as learning disabilities, attention deficit hyperactivity disorder, autism spectrum disorders, developmental delays, and behavioral issues. Pesticides that can cause neurodevelopmental toxicity include carbamates, organophosphates, ethylene bithiocarbamates, and chlorophenoxy herbicides.

Fatigue, hallucinations, delirium, lack of feeling, emotional disturbances, and crani are all symptoms of thallium (Ta) exposure. Combinations of Pb, As, and MeHg heavy metals have been shown to negatively impact

the central nervous system in experimental studies. Epidemiological studies have connected heavy metals like mercury and lead in hair to memory issues and cognitive impairment [26]. Skeletal Pb is found in the bone during pregnancy, becomes mobilized, and is transferred to the fetus via the placenta. The fetus receives lead transfers from the mother's skeleton while nursing. The central nervous system development of the fetus will be inhibited by the accumulating lead [23].

5. Cardiovascular Health: Pollutant exposure causes a variety of illnesses and deaths. More than 60% of cases in this group are related to cardiovascular disease. These are the main reasons why people die and become disabled. Environmental variables account for a greater number of cardiovascular disease deaths than risk factors related to metabolism, tobacco use, and behaviour. Depending on its size, airborne particulate matter dispersed in the atmosphere raises the risk of cardiovascular disease [27]. Cardiovascular disease, stroke, and changes in blood pressure have all been associated with nitrogen oxide (NO₂), elemental carbon, and PM_{2.5} and PM₁₀. When fine and ultrafine particles pass through the alveolar epithelium and enter the systemic circulation, they adversely affect target tissues like the heart and blood vessels. Particulate matter that has been inhaled settles in the circulatory system's alveoli. Systemic inflammation comes from oxidative stress's activation of the transcription factors AP-1 and NF- κ , which raises the expression of inflammatory mediator genes. Thus, the two primary pathways for the development of cardiovascular diseases such myocardial infarction and atherosclerosis are particulate matter-induced oxidative stress, inflammation, and cardiac arrhythmias [24].

ISSUES, ACTIONS, AND CONSEQUENCES FOR THE FUTURE

The implementation of robust governmental policies, contemporary infrastructure, and technology could significantly mitigate the issue of pollutants. A major issue that makes overcoming the present challenges difficult is

unscrupulous human behaviour. The public's indifference in pollution control measures and an insufficient ecological management system are two obstacles to reaching the goal of a clean environment. A significant decline in infrastructure investments may result from public indifference in some government initiatives. Reforming everything will take decades, which is a massive task. However, the goals of this transformation must be defined, and its spirit must be agreed upon, in order to decide how future actions would go [16]. To control pollution, the newest technologies must be employed. To evaluate the mechanism of accumulation, studies on particular pollutants are needed. It's critical that the public understands pollution. Research data on pollution-related health trends should be made available by the government to increase public awareness of pollution management and generation [23].

CONCLUSION

Even though pollutants are not new to the environment, exposure to them continues to be the biggest threat to humanity and a major contributor to environmental disease and death. Mining, exploration, urbanization, and industrialization are some of the human endeavors that have contributed most to global environmental contamination. Both developed and developing nations share responsibilities for environmental conservation, even if wealthier nations' knowledge and stricter laws have contributed more to this cause. Pollutants continue to have an impact despite receiving more attention as a result of their serious long-term impacts.

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