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The Role of Soil Pollution in Worsening Water Quality and Environmental Health

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دور تلوث التربة في تدهور جودة المياه والصحة البيئية

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Abstract:
Deteriorating water quality and environmental health are significantly influenced by soil degradation. The way that pollutants from soil, including pesticides, heavy metals, and plastic trash, seep into water sources and cause widespread water contamination is examined in this research. Human health is at risk, agricultural output is decreased, and the linked impacts jeopardize aquatic habitats. To lessen the ripple effects on water quality and the general health of the ecosystem, this study emphasizes the urgent need for sustainable land management and pollution control methods by looking at case studies and scientific evidence. This study will use a qualitative approach to examine the role of soil pollution in worsening water quality and environmental health. Data will be gathered through scientific literature to provide evidence of the connection between soil and water pollution. Thematic analysis will identify key patterns and recommendations for sustainable land management and pollution control.

Keywords: Water Quality, Soil, Pollution, Environmental, Health.

الملخص:
يُعدّ تدهور جودة المياه والصحة البيئية من أبرز التحديات البيئية الراهنة، ويقع تدهور التربة في مقدمة العوامل المؤثرة فيهما تأثيرًا بالغًا. تتناول هذه الدراسة الآليات التي تتسرب من خلالها الملوثات المنبثقة من التربة- كالمبيدات الحشرية والمعادن الثقيلة والنفايات البلاستيكية-.إلى مصادر المياه، فتُفضي إلى تلوث مائي واسع النطاق.
ويُشكّل هذا التلوث خطرًا جسيمًا على الصحة الإنسانية، إذ يُقلّص الإنتاجية الزراعية، كما تُهدد تداعياته المتشعبة الأنظمة البيئية المائية. وانطلاقًا من دراسة حالات موثقة وأدلة علمية رصينة، تُؤكد هذه الدراسة الحاجة الملحّة إلى تبني ممارسات مستدامة لإدارة الأراضي وتطبيق منظومة فعّالة للتحكم في التلوث، وذلك بهدف الحدّ من الانعكاسات السلبية التتالية على جودة المياه والصحة الشاملة للنظام البيئي.
وتعتمد هذه الدراسة المنهجَ النوعي كأداة لفحص دور تلوث التربة في تفاقم جودة المياه والصحة البيئية، إذ تُجمَع البيانات عبر المسح المنهجي للأدبيات العلمية لتوفير الأدلة الدامغة على الصلة الوثيقة بين تلوث التربة وتلوث المياه. كما يُوظَّف التحليل الموضوعاتي لاستخلاص الأنماط الجوهرية وصياغة توصيات عملية لإدارة الأراضي بصورة مستدامة ومكافحة التلوث.

الكلمات المفتاحية: جودة المياه، التربة، التلوث، البيئة، الصحة.

1. Introduction

One of the biggest environmental problems of the contemporary period is soil contamination, which broadly influences ecosystem health and water quality. The number of contaminants entering the soil has significantly increased due to intensive agriculture, urbanization, and industry. [1] The natural equilibrium of soil and water is frequently upset by pollutants, including pesticides, heavy metals, and plastic debris. Water is absorbed and filtered by soil, which serves as a natural buffer before it reaches surface or groundwater sources. [2]
However, the natural buffering role of soil is compromised when it is polluted with harmful substances. For instance, the residues left by applying pesticides in contemporary farming

methods are frequently difficult for the soil to break down. Rainwater may carry these pollutants to water sources, contaminating water supplies widely. The effects endanger aquatic life and agricultural output and lower water quality suitable for human use. [3]

Among the most hazardous contaminants found in soil are heavy metals, including lead, mercury, and cadmium. Chemical fertilizers, unregulated waste disposal, and industrial operations are frequently the sources of these contaminants. [4] Because of their bioaccumulation characteristics, heavy metals may build up in the bodies of organisms at every stage of the food chain. The health of people and animals is seriously threatened when heavy metals enter water sources through the soil. Exposure to heavy metals in drinking water has been connected to diseases like cancer, renal damage, and neurological issues. [5]

Even though it's sometimes seen as a surface issue, plastic trash has a major role in polluting the soil and water. Plastic discarded on the ground may decompose into microplastics, entering the water cycle. There are significant concerns over the long-term health effects of these microplastics as they have been discovered in drinking water sources and even in human tissue. Furthermore, soil-contaminated plastic garbage frequently prevents water from penetrating, eventually reducing groundwater availability. [6]

Water resource degradation is a well-researched phenomenon that can be brought on by human activity (such as urban waste and agricultural practices), natural processes (such as climate change, water-rock interactions, and geological factors), and significant chemical compounds since the Industrial Revolution. [7] Despite this, there are still numerous situations in which managing surface water and groundwater as resources is difficult, and important data is still unknown. In addition to human activity, natural rock, and soil heterogeneities interact with water to impact water quality in all domains and natural water cycles. Figure 1 illustrates the kinds, channels, and sources of pollutants and their effects on groundwater and surface water systems depending on natural and man-made sources. [8]

Surface water contaminations (specifically in rivers and streams) are mostly caused by factory runoff, agriculture, and urbanization. Furthermore, physical environmental elements can also lead to pollution, while warm water released from power plants can create temperature fluctuations in aquatic environments. Furthermore, if hydro-heated water or water with certain toxins is diluted immediately by mixing with surface water, it could not pose a problem at any time of the year. Furthermore, metals, pesticides, viruses, minerals, and salts that affect surface water are among the pollutants discharged by agricultural operations. Furthermore, urban operations' hazardous materials released into river water can be found in construction waste, untreated and partially treated sewage, and solid/liquid waste components**.** [8]

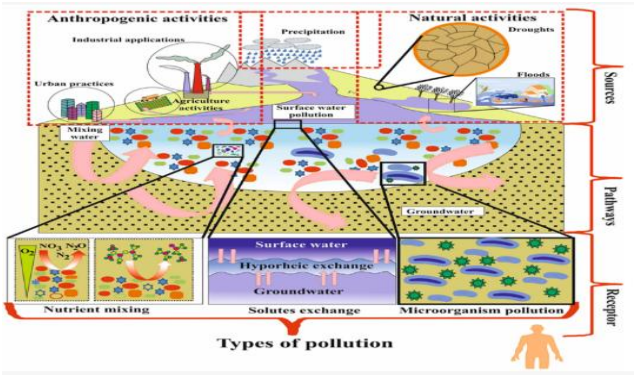

Figure 1. A schematic graphic shows the channels, receptors, and other forms of pollution that cause water contamination from human (industrial, agricultural, and urban) and natural (droughts and floods) sources. [8]

The connection between soil degradation and water quality also impacts ecosystem health. Rivers, lakes, and wetlands are examples of aquatic environments that are especially vulnerable to the infiltration of contaminants from the soil. Fertilizer runoff from polluted soil

is frequently the source of eutrophication or the accumulation of excess nutrients in aquatic bodies. Excessive algal blooms caused by this occurrence lower the water's oxygen content. Many aquatic species experience heightened stress, which may even cause them to go extinct. [9]

Soil contamination has serious economic repercussions and effects on the ecosystem. Governments and private groups must spend money on water treatment to restore degraded water quality. Food security is also threatened by lower agricultural yields from polluted soil, particularly in emerging nations. Another burden on communities is the rise in medical expenses brought on by illnesses linked to contaminated water. [10]

Prior research has demonstrated a robust correlation between deteriorating soil and declining water quality. These studies emphasize the necessity of tackling the problem holistically, encompassing pollution prevention, public education, and sustainable land management. Crop rotation, organic fertilizers, and soil conservation strategies are examples of sustainable land management methods that lessen the adverse environmental effects of human activity. Pollution control, on the other hand, entails stringent regulations on using dangerous chemicals and industrial waste disposal.

This study uses a qualitative method to investigate how soil contamination contributes to declining water quality and environmental health. This study will find important trends and suggest improved land management by examining pertinent scientific literature. This method is crucial for both enhancing our comprehension of the effects of soil contamination and creating workable remedies for both domestic and international settings.

2. Literature Review

2.1. Soil Pollution

A physical or chemical alteration in the soil that alters its usage and prevents it from yielding any advantages without management is known as soil pollution. A situation known as "soil pollution" occurs when chemicals or other dangerous materials permeate the soil, lowering its quality and damaging ecosystems, human health, and the environment. Numerous factors, such as industrial operations, excessive fertilizer and pesticide usage in agriculture, domestic trash, and unlawful waste disposal, can contribute to this contamination. Substances like hydrocarbons, heavy metals, and toxic organic compounds. [11] commonly cause soil contamination.

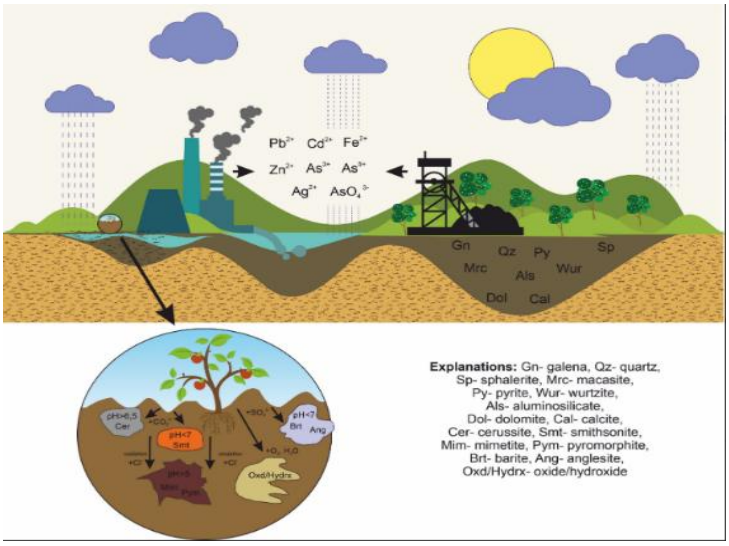

Figure 2. Harmful Elements (As, Sb, Cd, Pb) in Soil Polluted[12]

Metal, metalloid, and sulfur concentrations were higher than the area geochemical background, as seen in Figure 2. According to the study's findings, the level of soil chemical transformation in the examined areas of Ruda Śląska, Bytom, and Bukowno has advanced. This emphasizes how historical Zn-Pb ore mining and Zn and Fe metallurgy have resulted in significant concentrations of most metals, such as arsenic, antimony, and sulfur, in the topsoil,

the soil's outermost layer. The mineral composition of soils and slags contained silicates, aluminosilicates, carbonates, oxides/hydroxides, sulfides, and sulfates of primary and secondary metals. Pollution interferes with the soil's natural capacity to recycle nutrients, retain water, and support plant life. Furthermore, polluted plants and groundwater might allow dangerous compounds to enter the food chain due to soil contamination. [12]

2.2. Water Quality

The situation known as water pollution is brought on by introducing waste loads and pollutants in the form of particles, dissolved compounds, and gas. The atmosphere, soil, runoff from agricultural land, household, urban, and industrial waste, among other sources, can all introduce pollutants into water bodies. Pollution occurs when environmental substances result in unanticipated physical, chemical, or biological changes. When human activity introduces live organisms, materials, energy, and/or other elements into the water, the water quality deteriorates, so it can no longer be used as intended. This is known as water pollution, [13] as shown in Figure 3.

Although the causes of water contamination are many, they may generally be divided into two categories: direct and indirect pollutant sources: [14]

1.Direct source (point source)

A direct source is an identifiable source of pollution at a specific site along the receiving body of water. Industrial waste pipelines that do not treat their waste or discharge waste processing results at the IPAL (Wastewater Treatment Plant) that enters the receiving water body are the primary sources of pollution at the point location.

2.Indirect source (non-point source)

Indirect sources include home consumption of consumer products, small and medium-sized businesses, livestock, and agricultural activities.

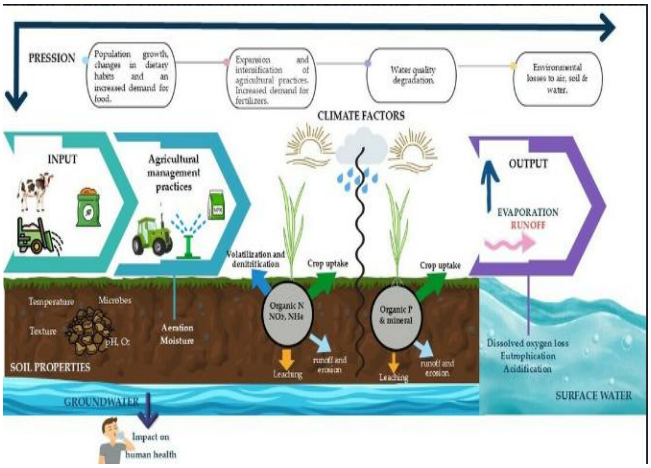

Figure 3. Pollution and Human Health Relationship [15]

2.3. Environmental Health

A subfield of health research known as "environmental health" studies how people interact with their physical, biological, chemical, social, and cultural surroundings and how this affects their overall health. Efforts to comprehend, control, and lower health hazards resulting from environmental factors, both from natural processes and human activities, are included in environmental health. This covers several topics, including waste management, food safety, infectious disease prevention, air, water, and soil quality, and reducing the negative health effects of climate change. Establishing a safe, hygienic, and healthy environment to promote the best possible human quality of life is the primary objective of environmental health. [16]

Numerous health issues, such as respiratory illnesses, cardiovascular disease, cancer, and infectious diseases, can be brought on by unhealthy environmental conditions such as air

pollution, water contamination, and exposure to dangerous chemicals. Thus, it's critical to put preventive measures in place, such as proper waste management, restrictions on dangerous chemicals, and public awareness campaigns on the value of keeping the environment clean. Furthermore, a cross-sectoral strategy, including the community, business, and government, must address environmental health issues properly. Therefore, attaining the sustainable development goals (SDGs) about both the environment and health depends heavily on environmental health. [17]

3. Methodology

The influence of soil contamination on water quality and environmental health is investigated in this study using a qualitative methodology. The study aims to create evidence-based links between soil and water pollution and their combined impacts on environmental health by analyzing scholarly literature extensively. The relationship between soil and water pollution will be collected from reliable reports, books, and peer-reviewed research papers. To systematically find, examine, and interpret recurrent themes and patterns in the gathered data, thematic analysis will be employed. [18]

This approach guarantees a thorough analysis of previous research, emphasizing important elements that worsen water and soil pollution and its effects on environmental health. After that, the results will be combined to provide practical suggestions for efficient pollution control methods and sustainable land management techniques. Additionally, by choosing literature that offers precise methodology and empirical support, the study will guarantee the validity and dependability of its sources. All references will be properly cited, and the study method will be transparent, following ethical considerations. This qualitative method highlights the significance of implementing integrated solutions for enhancing environmental sustainability and health and illuminating the complex linkages between soil and water contamination.

4. Result and Discussion

4.1. Relationship Between Soil Pollution and Water Quality

Because soil serves as both a filter and a channel for contaminants entering water systems, there is a close connection between soil contamination and water quality. Surface and groundwater resources are frequently contaminated due to soil pollution, brought on by the buildup of dangerous materials such as heavy metals, pesticides, industrial chemicals, and untreated garbage. Pollutants from the soil are carried into water bodies by runoff, erosion, and leaching, substantially impacting ecosystems and water bodies. [19]

One of the main ways that soil degradation affects water quality is by leaching. Pollutants, including phosphates, nitrates, and hazardous metals, can move into groundwater supplies as they seep into the soil. This is especially troubling in agricultural areas where overuse of pesticides and fertilizers is prevalent. When utilized for drinking or irrigation, groundwater polluted in this way presents serious health hazards since contaminants like arsenic, lead, or mercury may be harmful to both people and plants. [20]

Another important channel linking soil contamination to deteriorating water quality is surface runoff. Sediments and soluble contaminants are carried into neighboring rivers, lakes, and reservoirs by water flowing over contaminated soils during irrigation or rainfall. For example, eutrophication of aquatic bodies is frequently caused by the discharge of agricultural fertilizers high in phosphate and nitrogen. Excessive algal growth results from this process, which lowers oxygen levels and disturbs aquatic ecosystems, killing fish and reducing biodiversity. [21]

Furthermore, the movement of contaminants into water systems is made worse by soil erosion. When wind or water dislodges polluted topsoil, it carries dangerous materials like untreated trash or industrial pollutants into streams and rivers. In addition to carrying pollutants, these sediments make the water murky, lowering its quality and harming aquatic

life. Because turbid water hinders light penetration, aquatic plants' ability to perform photosynthesis is disrupted, and ecological equilibrium is changed. This link has serious health implications for people and harms the ecosystem. Diseases, including gastrointestinal infections, neurological conditions, and developmental problems brought on by extended exposure to hazardous chemicals, are related to contaminated water sources that are connected to polluted soil, as shown in Figure 4. [22]

Figure 4. Diagrammatic representation of environmentally hazardous metals[22]

4.2. Health Risks of Heavy Metal Ions For Humans

Human health at all ages is seriously threatened by heavy metal contamination of the air, water, and soil, including lead, mercury, arsenic, cadmium, and zinc. These harmful metals can harm some organs and enter the body through the mouth, nose, and drink. Because heavy metals build up in the body, poisoning by them can cause both acute and long-term damage. Nausea, vomiting, diarrhea, headaches, dizziness, tremors, numbness, and muscular weakness are some of the symptoms that may appear. Heavy metals can also negatively impact the nervous system, resulting in neurological problems such as numbness, muscular weakness, tremors, impaired memory and focus, and even paralysis. [23]

Additionally, they may harm the digestive tract, leading to constipation, diarrhea, vomiting, nausea, and stomach discomfort. Exposure to heavy metals can also result in respiratory issues, such as cough, dyspnea, chest discomfort, and lung infections. Furthermore, the reproductive system may be harmed by heavy metals, leading to birth abnormalities, miscarriages, and infertility. Lead and arsenic are two examples of heavy metals that are known to cause cancer and increase the likelihood of developing different types of cancer. [24]

Children are more susceptible to heavy metal exposure because of their growing bodies and weakened immune systems. Their brains and neural systems may not grow and develop as a result of such exposure, which may lead to behavioral issues, learning difficulties, and attention problems. Heavy metals can cross the placental barrier and impact the health of both the mother and the fetus, increasing the risk of birth abnormalities, miscarriages, and preterm births in pregnant women. Due to their increased physical activity and deeper breathing, adolescents and young adults are more likely to be exposed to airborne heavy metals, which can impair lung and cardiovascular health. [25]

4.3. Environmental and Health Impacts

The health impacts of environmental pollution caused by heavy metal ions in different places worldwide are detailed in Table 5. The World Health Organization's (WHO) guidelines state that the levels of heavy metal ions lead, zinc, cadmium, mercury, and arsenic in soil can be as low as 35, 300, 3, 1, and 20, respectively.

Table 1. Health impacts of environmental pollution in various countries

Country	Pollution Factor	Pollution	Symptoms	Preventive Measures
China	Industry, Coal	Lead	Headache, Fatigue, Irritability, Memory Impairment, Abdominal pain, Diarrhea	Air filters, Water purification, Catalytic converters[26]
India	Industry, Traffic	Lead	Headache, Fatigue, Irritability, Memory Impairment, Abdominal pain, Diarrhea	Air filters, Water purification, Catalytic converters[27]
Japan	Industry	Mercury	Tremors, Muscle weakness, Visual problems, Hearing problems	Air filters, Water purification, Mercury emission control[28]
Mexico	Traffic, Industry	Lead	Headache, Fatigue, Irritability, Memory Impairment	Use of air filters, drinking water purification, Thorough washing of fruits and vegetables, Mask wearing in polluted areas[29]
Egypt	Traffic, Industry	Lead	Headache, Fatigue, Irritability, Memory Impairment	Use of air filters, drinking water purification, Thorough washing of fruits and vegetables, Mask wearing in polluted areas[30]
South Korea	Industry	Mercury	Tremors, Muscle weakness, Visual problems, Hearing problems	Mercury poisoning, Neurological problems[31]
India	Traffic, Industry	Lead	Headache, Fatigue, Irritability, Memory Impairment	Lead poisoning, Respiratory diseases, Neurological problems[32]
Brazil	Traffic, Industry	Lead	Headache, Fatigue, Irritability, Memory Impairment	Lead poisoning, Respiratory diseases, Neurological problems[33]
China	Metal smelting	Cadmium	Abdominal pain, Diarrhea, Vomiting, Kidney damage	Air filters, Water purification, Thorough washing of fruits and vegetables, Avoiding contact with contaminated soil[34]
China	Coal industry	Arsenic	Nausea, Vomiting, Diarrhea, Abdominal pain, Numbness, and tingling in hands and feet	Air filters, Water purification, Thorough washing of fruits and vegetables, Avoiding consumption of contaminated water[35]

An overview of environmental pollution caused by heavy metal ions, the health impacts these pollutants have, and the precautions taken to lessen those effects are shown in Table 1. The chart emphasizes that the people living in the impacted cities are in serious danger of health

problems due to lead, mercury, cadmium, and arsenic, frequently present in industrial and transportation emissions.

In several nations, including China, India, Mexico, and Egypt, lead pollution is a persistent problem mostly caused by vehicle emissions and industrial processes. Headaches, exhaustion, irritability, memory loss, gastrointestinal discomfort, and diarrhea are common signs of lead exposure in these areas. These signs point to a major issue with neurological and cognitive development, especially in youngsters and other susceptible groups. Preventive methods, including water purification, air filters, and catalytic converters, are frequently advised to lower lead exposure. To lessen the detrimental effects of lead on human health, these actions seek to reduce airborne lead particles and enhance drinking water quality. [26,30]

Mercury exposure causes symptoms including tremors, muscular weakness, and visual and auditory issues. This is especially noticeable in South Korea and Japan. Industrial activities, such as mercury emissions from the coal and metal smelting sectors, are the main cause of mercury contamination in these areas. Mercury is neurotoxic; therefore, its effects on the neurological system are especially concerning. Controlling mercury emissions, cleaning water, and encouraging the use of air filters are the main preventive strategies in these areas. Mercury poisoning is a serious concern in these nations due to the long-term neurological issues it causes, which highlights the necessity of strict emission limits and public health initiatives. [28,31]

Cadmium, linked to metal smelting activities in China, poses serious health risks such as abdominal pain, diarrhea, vomiting, and kidney damage. The symptoms suggest that cadmium exposure is particularly harmful to the renal system. Preventive measures, such as air filtration, water purification, and proper washing of fruits and vegetables, are recommended to reduce exposure. These steps limit cadmium intake through air, water, and food, thus minimizing its toxic effects. [34,42]

Symptoms of arsenic poisoning, which is linked to coal industry pollution in China, include diarrhea, vomiting, nausea, stomach discomfort, and numbness in the hands and feet. Chronic exposure to arsenic has been linked to serious health problems, such as organ damage and cancer. To lessen both direct exposure and absorption of arsenic through drinking water and food, preventive measures include air filtering, water purification, and avoiding polluted water and soil. [35.43]

4.4. Recommendations for Mitigation

A complex strategy involving industrial practices, public awareness, government restrictions, and technology advancements is needed to lessen the negative consequences of soil contamination on water quality and environmental health. These actions should prioritize safeguarding vulnerable groups, limiting the spread of pollutants, and cutting pollution at its source. Governments should enforce stronger laws governing waste management, industrial emissions, and agricultural practices to reduce soil pollution. [36,44] Regulatory frameworks must establish clear limitations on heavy metal contaminants in soil and water per global norms, such as those established by the World Health Organization (WHO). To identify and regulate the quantities of dangerous materials like lead, mercury, and cadmium, authorities should regularly monitor metropolitan areas, agricultural fields, and industrial locations. Stronger sanctions for non-compliance should also be implemented to discourage businesses and individuals from participating in ecologically detrimental activities. [37,45]

Agriculture significantly contributes to soil pollution, especially by excessively using pesticides, fertilizers, and untreated garbage. Farmers should be encouraged to embrace sustainable techniques, including crop rotation, integrated pest control, and organic farming, to lessen the effect of agricultural operations. These methods lessen the need for chemical inputs, preserve the health of the soil, and stop contaminants from leaking into water sources. The risk of heavy metal pollution in soil can also be considerably reduced by using environmentally suitable substitutes for dangerous fertilizers and pesticides. Industries should invest in pollution control systems to stop dangerous pollutants from leaking into the environment. To lower emissions of heavy metals like lead and mercury, catalytic converters, air filters, and water purification systems should be used. Companies engaged in metal smelting, coal burning, and chemical manufacturing should adopt cleaner technologies, such as closed-loop systems that reduce the release of pollutants into the air, soil, and water. [38,46]

Educating the public on the risks posed by soil pollution and how it affects water quality is crucial to increasing community support for environmental projects. Public awareness should be raised through educational efforts about preserving clean water supplies, lowering pollution, and disposing of trash safely. Monitoring and reporting pollution in their neighborhoods may also be a critical function of local communities. Through training programs, community people may be empowered to become environmental champions and support their ecosystems' long-term health. [39,47]

Prioritizing restoration efforts is necessary for places already affected by soil and water pollution. A natural and affordable way to decontaminate soil is by phytoremediation, a technique that uses plants to extract contaminants. To neutralize contaminants, soil may occasionally need to be removed or chemically treated. Rehabilitating contaminated areas should be the main goal of restoration initiatives to stop more pollution and bring the ecosystem's natural equilibrium back. [40]

Lastly, tackling soil and water contamination globally requires international cooperation. To fight pollution, nations should exchange best practices, technology, and expertise. Developing new, more efficient pollution detection, removal, and prevention techniques should be the main goal of cooperative research projects. Together, nations can develop all-encompassing solutions to lessen the consequences of soil degradation and safeguard water quality globally. [41]

5. Conclusion

The connection between soil contamination and water quality significantly impacts environmental health, public safety, and sustainable development. When soil pollution levels increase, heavy metals, pesticides, and industrial chemicals can leak into groundwater, spill into surface water bodies, and cause soil erosion. Ultimately, these actions degrade water quality, which impacts ecosystems, biodiversity, and human health. Numerous and severe health risks are associated with exposure to heavy metals, such as lead, mercury, arsenic, and cadmium. Children and pregnant women are particularly vulnerable to reproductive, neurological, gastrointestinal, and respiratory issues. The study's data highlights the major health risks of these pollutants, particularly in urban and industrial locations where pollution is often most common.

A comprehensive strategy incorporating public awareness, technological advancements, sustainable habits, and governmental actions is necessary to solve these issues. Governments must impose stronger rules on waste management and industrial emissions while encouraging sustainable farming methods to lessen the use of dangerous chemicals. To reduce the number of harmful substances released into the environment, industries must also invest in pollution control technology. Campaigns for public education can increase knowledge of the risks posed by soil contamination and promote ecologically conscious behavior.

Additionally, efforts to restore polluted environments and rehabilitate impacted regions require harsh techniques like soil remediation and phytoremediation. By being proactive, we can lessen the negative consequences of soil and water pollution, protect public health, and preserve the planet's natural resources. In the end, governments, businesses, communities, and international organizations must work together to address the issue of soil contamination and its effects on water quality. It is feasible to lessen pollution, restore ecosystems, and advance sustainable development for future generations by pooling information, implementing better practices, and working together.

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DISCLOSURE

Only individuals who requested disclosure are included in this section. If the experts who examined your article agreed to sell disclosure to you, their names will be listed here. Since it

is a public endorsement of your results and may be used for various purposes, each reviewer can set their price for it.

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