

Exposure Pathways and Risk Assessment of soil pollution and human health: A review

Abdullahi Bappayo Mohammed³, Yilni Edward Bioltif² Sulaiman Waziri Dahiru³
Abbas Muhammad Babanyaya⁴ Abdulkarim Babangida Mustapha⁵ Ansar Bilyaminu
Adam⁶ and Musa Yahaya Abubakar⁷

Department of Chemical Sciences, Federal University Wukari, Taraba State^{6,7}

*Department of Chemistry, Aliko Dangote University of Science and Technology¹
Wudil³.*

Department of Chemistry Abubakar Tafawa Balewa University Bauchi^{4,5}

Department of Chemistry Modibbo Adama University Yola²

Department of Geography Federal College Of education(T) Bichi, Kano³

Corresponding Author: yahayaabubakarmusa2015@gmailcom

Abstract

Soil pollution has emerged as a critical environmental issue with significant implications for human health. This review explores various pathways through which individuals are exposed to contaminated soils, including ingestion, inhalation, and dermal contact, as well as the consumption of food grown in polluted environments. The sources of soil pollution, including industrial activities, agricultural practices and improper waste disposal have introduced hazardous chemicals such as heavy metals, pesticides, and persistent organic pollutants into the soil. These contaminants pose serious health risks, including respiratory disorders, neurological damage, and an increased likelihood of cancer. The review examined current risk assessment methodologies used to evaluate the potential human health impacts of soil contamination, emphasizing the importance of accurate exposure assessments and the identification of vulnerable populations. The study indicated that soil contaminated with heavy metals like lead, cadmium, and mercury is a significant health concern, particularly for children in urban areas, leading to cognitive and developmental issues, pesticides and persistent organic pollutants in agricultural soils are linked to neurological, reproductive, and endocrine disorders when they enter the food chain, inhalation of contaminated dust or dermal contact with polluted soils has been associated with respiratory problems and skin diseases. Ultimately, a comprehensive understanding of exposure pathways and improved risk assessment tools are essential for developing effective strategies to mitigate the adverse effects of soil pollution on public health.

Keywords: Soil pollution, human health, exposure pathways, risk assessment, heavy metals, persistent organic pollutants, environmental health.

Voies d'exposition et évaluation des risques de la pollution des sols et de la santé humaine : Une revue

Résumé

La pollution des sols est devenue un problème environnemental majeur ayant des implications importantes pour la santé humaine. Cette revue explore les différentes voies par lesquelles les individus sont exposés à des sols contaminés, notamment

l'ingestion, l'inhalation, le contact cutané, ainsi que la consommation d'aliments cultivés dans des environnements pollués. Les sources de pollution des sols, telles que les activités industrielles, les pratiques agricoles et l'élimination incorrecte des déchets, ont introduit des produits chimiques dangereux tels que des métaux lourds, des pesticides et des polluants organiques persistants dans les sols. Ces contaminants présentent de graves risques pour la santé, notamment des troubles respiratoires, des lésions neurologiques et un risque accru de cancer. La revue examine les méthodologies actuelles d'évaluation des risques utilisées pour évaluer les impacts potentiels de la contamination des sols sur la santé humaine, en soulignant l'importance d'évaluations d'exposition précises et l'identification des populations vulnérables. L'étude indique que la contamination des sols par des métaux lourds tels que le plomb, le cadmium et le mercure représente une préoccupation majeure pour la santé, en particulier pour les enfants vivant dans les zones urbaines, entraînant des problèmes cognitifs et de développement. Les pesticides et les polluants organiques persistants dans les sols agricoles sont liés à des troubles neurologiques, reproductifs et endocriniens lorsqu'ils pénètrent dans la chaîne alimentaire. L'inhalation de poussières contaminées ou le contact cutané avec des sols pollués a été associé à des problèmes respiratoires et des maladies de la peau. En fin de compte, une compréhension approfondie des voies d'exposition et des outils d'évaluation des risques améliorés sont essentiels pour développer des stratégies efficaces pour atténuer les effets néfastes de la pollution des sols sur la santé publique

Mots-clés : Pollution des sols, santé humaine, voies d'exposition, évaluation des risques, métaux lourds, polluants organiques persistants, santé environnementale

ملخص

برز تلوث التربة كمسألة بيئية حرجية لها آثار كبيرة على صحة الإنسان. يستكشف هذا الاستعراض مسارات مختلفة يتعرض من خلالها الأفراد للتربة الملوثة، بما في ذلك الابتلاع والاستنشاق والتلامس الجلدي، فضلاً عن استهلاك الأغذية المزروعة في البيئات الملوثة. وقد أدخلت مصادر تلوث التربة، بما في ذلك الأنشطة الصناعية والممارسات الزراعية والتخلص غير السليم من النفايات، مواد كيميائية خطيرة مثل الفلزات الثقيلة ومبيدات الآفات والملوثات العضوية الثابتة في التربة. تشكل هذه الملوثات مخاطر صحية خطيرة، بما في ذلك اضطرابات الجهاز التنفسي والتلف العصبي وزيادة احتمالية الإصابة بالسرطان. ودرس الاستعراض المنهجيات الحالية لتقييم المخاطر المستخدمة لتقييم الآثار المحتملة لتلوث التربة على صحة الإنسان، مع التأكيد على أهمية إجراء تقييمات دقيقة للتعرض وتحديد الفئات السكانية الضعيفة. أشارت الدراسة إلى أن التربة الملوثة بالمعادن الثقيلة مثل الرصاص، والكاديوم، والزنك مصدر قلق صحي كبير، لا سيما للأطفال في المناطق الحضرية، مما يؤدي إلى مشاكل إدراكية ونمائية، وترتبط بمبيدات الآفات والملوثات العضوية الثابتة في التربة الزراعية بالمبيدات العصبية، اضطرابات الإنجاب والغدد الصماء عندما تدخل السلسلة الغذائية، وقد ارتبط استنشاق الغبار الملوث أو ملامسة الجلد للتربة الملوثة بمشاكل في الجهاز التنفسي وأمراض جلدية. وفي نهاية المطاف، فإن الفهم الشامل لمسارات التعرض وتحسين أدوات تقييم المخاطر ضروريان لوضع استراتيجيات فعالة للتخفيف من الآثار الضارة لتلوث التربة على الصحة العامة.

الكلمات الرئيسية: تلوث التربة، صحة الإنسان، مسارات التعرض، تقييم المخاطر، المعادن الثقيلة، الملوثات العضوية الثابتة، الصحة البيئية.

Introduction

Soil pollution occurs when harmful chemicals, waste materials, and biological agents contaminate the Earth's surface, leading to soil degradation and negative effects on ecosystems and human health. The causes of soil pollution are diverse, stemming from both natural processes and, more

significantly, human activities. As global population and industrial activities rise, soil pollution has become a major environmental issue, impacting agricultural productivity, food security, and public health. A significant contributor to this contamination is the unsystematic anthropogenic activities, especially those related to industrial

processes. Urbanization, industrialization, and population pressures are placing immense stress on the environment, while shifts in lifestyle and consumption habits further compound the challenges. Environmental issues, including soil contamination, often vary across different regions and times (Adam *et al.*, 2024).

Pollution is driven by several factors, such as industrial activities, agriculture, and improper environmental practices like the irregular disposal of waste, contaminant release into water bodies, and refuse burning (Abubakar *et al.*, 2024). Heavy metal contamination in aquatic ecosystems is a critical environmental challenge with serious consequences for ecological and human health. Various harmful substances, including heavy metals, pesticides, industrial chemicals, and pharmaceutical residues, enter aquatic systems and soils through pathways like agricultural runoff, industrial discharges, waste mismanagement, and atmospheric deposition. Once introduced, these pollutants persist, accumulating in soils and water systems over time (Danladi *et al.*, 2024).

There are ongoing debates and differing opinions on the fundamental causes of the environmental crisis. The rapid development of new materials, especially in advanced industries, contributes to environmental degradation, with byproducts from these industries often leading to pollution (Shamsuddeen, R. *et al.*, 2024). Human activities such as deforestation, overgrazing, and unsustainable farming practices degrade land, contributing to desertification and further pollution (Gabriel *et al.*, 2024). Additionally, climate change plays a significant role in exacerbating soil pollution. Extreme weather events and changing precipitation patterns mobilize contaminants and disturb the soil's natural detoxification processes. The emergence of new pollutants, including microplastics, pharmaceuticals, and nanomaterials, adds to the growing complexity of soil contamination (de Souza Machado *et al.*, 2018; Zhang *et al.*, 2020). Climate change further exacerbates these issues by increasing soil erosion and spreading contaminants over wider areas (IPCC, 2014).

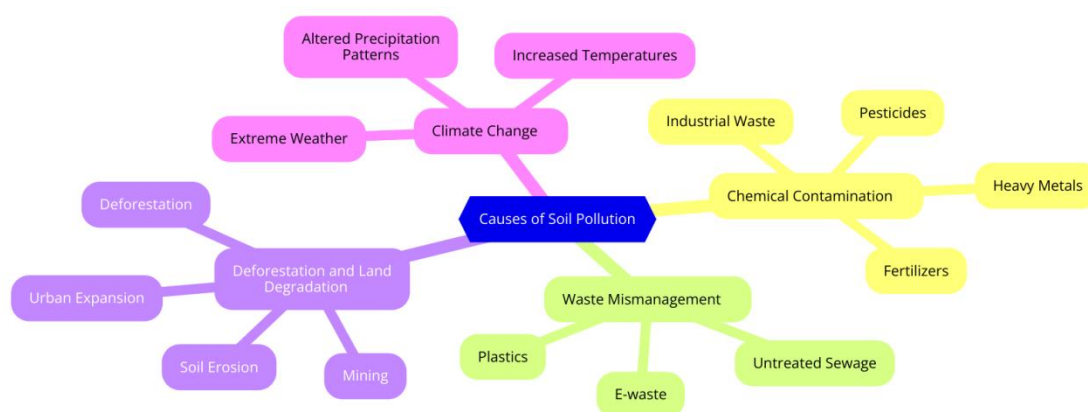


Fig 1: Causes of Soil Pollution

Sources of Soil Pollution

Soil pollution originates from various human activities, each contributing different types and quantities of pollutants. These sources can be broadly categorized into industrial, agricultural, and urban activities:

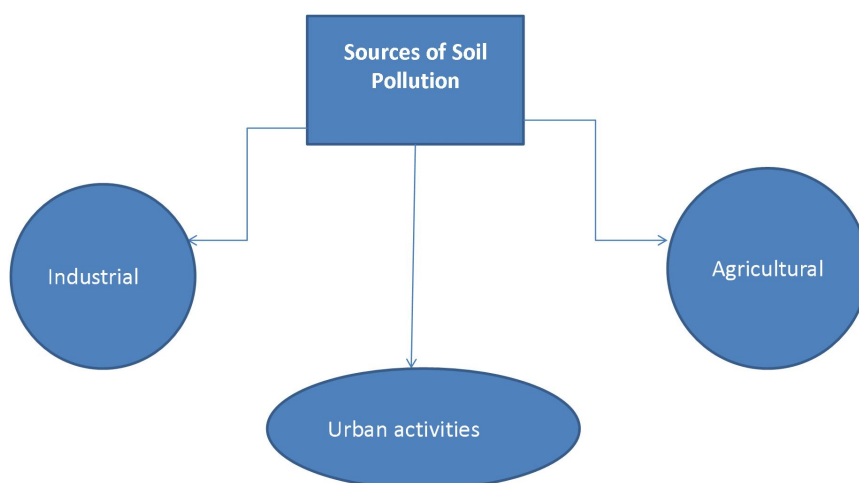


Fig 2: Sources of Soil Pollution

Industrial Sources

Mining activities release heavy metals like lead, mercury, arsenic, and cadmium into the surrounding soils, especially in areas with intense mining operations. These metals can linger for decades, posing serious threats to both human and environmental health. Mining also produces large amounts of waste that are often rich in heavy metals, which are released into the environment in an uncontrolled manner, causing extensive ecosystem contamination. While some heavy metals are essential for biological processes and provide social and economic benefits to nations, their unmanaged release is harmful (Abubakar *et al.*, 2024).

The Industrial Revolution significantly worsened soil contamination. With mechanized industries, increased mining, and extensive coal use, heavy metals like lead, mercury, and cadmium were widely released. Factories and industrial

plants often discarded their waste directly into nearby soils due to the absence of environmental regulations. A notable example is the industrial areas of England, where coal mining and steel production contaminated soils with heavy metals and other pollutants (Pacyna and Pacyna, 2001). The lack of waste management systems resulted in by-products accumulating in soil, causing long-lasting contamination.

Factories producing chemicals, textiles, and electronics often disposed of hazardous waste into land or waterways, which seeped into the soil. Industrial accidents, such as oil spills and chemical leaks, could also cause severe but localized contamination. The extraction, transport, and burning of fossil fuels release contaminants like petroleum hydrocarbons and polycyclic aromatic hydrocarbons (PAHs), which pollute soils near refineries, pipelines, and power plants.

Agricultural Sources

Modern agriculture heavily depends on chemical inputs, such as pesticides and herbicides, which can persist in the soil, accumulate, and affect deeper layers, harming soil organisms and entering the food chain. Before industrialization, soil pollution was minimal and localized. Early agricultural societies changed landscapes for farming but didn't introduce significant chemical pollutants. However, ancient mining and smelting activities in Europe and the Middle East left traces of heavy metals like lead and mercury in the soil (Nriagu, 1996). Early urban settlements also contributed to organic pollution through improper waste disposal.

The excessive use of nitrogen and phosphorus-based fertilizers alters soil chemistry, causing nutrient imbalances and the accumulation of harmful byproducts like nitrates, which degrade soil structure and contaminate water sources. Large-scale livestock

Urban Sources

Rapid urbanization often results in soil being sealed under concrete, diminishing its regenerative capacity. Construction activities can introduce contaminants like asbestos, lead, and fuel residues into the soil. Municipal solid waste, particularly in developing regions, is frequently disposed of in open landfills, where harmful chemicals from household and industrial waste leach into the soil. Exhaust emissions, tire wear, and deicing salts also contribute pollutants like micro plastics and heavy metals to soils, particularly along roadsides.

production also generates waste like manure, antibiotics, and hormones, which can infiltrate soils and disrupt natural nutrient cycles when mismanaged. Though pesticides have been effective in controlling diseases and pests, their prolonged use has led to biomagnification, insecticide resistance, and restrictions on exports, creating risks to human health and the environment, such as contaminated soil and water (Ruslan S. *et al.*, 2024).

A famous case of agricultural pollution is DDT (dichlorodiphenyltrichloroethane), a synthetic pesticide introduced in the 1940s. Despite its effectiveness, DDT became infamous for its persistence and harmful environmental and health impacts. Rachel Carson's *Silent Spring et al.* (1962) highlighted the dangers of DDT, leading to its ban in many countries (Carson, 1962). Heavy metal-based fertilizers and pesticides, such as lead arsenate, also contributed to soil contamination over time, posing long-term health risks (Alloway, 2013).

The rapid growth of electronic devices has led to the creation of e-waste, which contains heavy metals like lead, cadmium, and mercury. In developing countries, improper disposal and recycling of e-waste have caused significant soil contamination (Huo *et al.*, 2007). Persistent organic pollutants (POPs), including dioxins, furans, and PCBs, remain a global threat to soil quality due to their resistance to degradation, allowing them to accumulate in soils and enter the food chain. The Stockholm Convention on Persistent Organic Pollutants (2001) aimed to curb the production of these harmful substances (Stockholm, 2001).

Soil Quality and Human Health

Soil quality is essential for ecosystem health, food production, and public health. High-quality soil supports plant growth, ensuring food security by providing nutrient-rich crops. It also influences water filtration, air quality, and human exposure to beneficial nutrients and harmful contaminants. Poor soil quality can lead to reduced crop yields and nutrient deficiencies in food, contributing to malnutrition, especially in regions reliant on agriculture. Contaminated soils can accumulate toxic substances in crops, posing health risks like cancer, developmental disorders, and neurological damage.

Soil acts as a natural filter, trapping pollutants and pathogens before they reach water sources. When soil quality deteriorates, its filtration ability decreases, leading to water

Evolution of Soil Contamination Over Time Due to Industrialization and Agriculture

The development of soil contamination is intricately linked to the advancement of human civilization, especially due to industrialization and intensified agricultural practices. As societies progressed, the extent and complexity of soil pollution increased, resulting in heightened risks to ecosystems, food security, and public health. This overview outlines how advancements in industry and agriculture have led to the gradual rise of soil pollution. Soil contamination has evolved significantly alongside industrial growth and agricultural intensification. The Industrial Revolution marked the onset of extensive pollution, as factories, mining activities, and urbanization released heavy metals and industrial

contamination and associated health risks, particularly in rural areas where clean water access is limited. Soil quality also affects air quality through carbon sequestration. Healthy soil captures carbon dioxide, reducing greenhouse gas concentrations and mitigating climate change. However, poor soil quality diminishes this ability, contributing to higher CO₂ levels and worsening global warming.

Soil contamination is a growing environmental and public health issue, especially in urban and rural areas affected by industrial activities, agricultural practices, and urban expansion. Toxic substances like heavy metals and persistent organic pollutants accumulate in soils, threatening food security, water safety, and environmental sustainability. Immediate actions are required to prevent further soil degradation and protect human health.

waste into the soil. Substances like lead, arsenic, and cadmium infiltrated the environment with minimal oversight, accumulating in industrial regions (Pacyna & Pacyna, 2001). At the same time, early agricultural methods employed synthetic pesticides such as lead arsenate and copper compounds, which persisted in soils and caused considerable contamination. Although this era laid the groundwork for extensive pollution, awareness regarding soil degradation was still quite limited.

By the mid-20th century, the Green Revolution prompted a dramatic increase in synthetic fertilizer and pesticide use, further worsening soil contamination. Chemicals like DDT gained notoriety for their environmental persistence, while over-fertilization caused nutrient imbalances and soil acidification (Carson, 1962; Alloway,

2013). In the late 20th and early 21st centuries, new pollutants like electronic waste, microplastics, and pharmaceutical residues emerged, posing additional threats to soil health—especially in developing countries with poorly regulated e-waste recycling (Huo *et al.*, 2007; de Souza Machado *et al.*, 2018). While regulatory measures have improved, challenges such as climate change and the introduction of new contaminants continue to undermine soil quality and sustainability worldwide.

Common Soil Pollutants

Soil pollutants frequently arise from industrial operations, agricultural practices, and inadequate waste management, resulting in serious environmental and health hazards. Prominent contaminants include heavy metals like lead, cadmium, and mercury, as well as pesticides and herbicides, which compromise soil fertility and bioaccumulate in the food chain. Additionally, persistent organic pollutants such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs), released from industrial activities and vehicle emissions, are toxic and carcinogenic to both humans and wildlife.

Other significant pollutants include petroleum hydrocarbons from oil spills, plastics and microplastics, and radioactive materials. Nutrient overload from excessive fertilizer usage contributes to soil degradation and water eutrophication, while pharmaceuticals, volatile organic compounds (VOCs), and acid rain further compromise soil quality. The cumulative impact of these pollutants disrupts soil ecosystems, harms microbial communities, and poses long-term health risks to humans and agriculture.

Heavy Metals (Lead, Mercury, Arsenic)

Heavy metals such as lead, mercury, and arsenic rank among the most hazardous

soil pollutants, typically introduced through industrial activities, improper waste disposal, and agricultural practices. Lead, which often comes from old paints, gasoline, and batteries, accumulates in soil and can persist for decades. Mercury, primarily released from coal combustion and industrial emissions, can spread widely and accumulate in the food chain, especially within aquatic ecosystems. Arsenic, entering the soil through mining and pesticide use, is highly toxic and can leach into water sources, threatening both environmental and human health.

Organic Pollutants (Pesticides, Dioxins)

Organic pollutants, including pesticides and dioxins, are prevalent in soils due to their extensive use in agriculture and industry. Although pesticides effectively manage pests, they often linger in the environment long after application, contaminating soil and surrounding ecosystems. Dioxins, generated as by-products of industrial combustion, are highly toxic compounds that degrade slowly, posing a persistent threat to soil health and biodiversity. These organic pollutants can be absorbed by plants and animals, entering the food chain and impacting human health.

Microbial Contamination

Microbial contamination in soil typically results from untreated sewage, animal waste, and agricultural runoff. Pathogenic microorganisms, including bacteria, viruses, and parasites, can persist in soil, creating potential health risks. In regions with inadequate sanitation, these microorganisms can infiltrate food and water supplies, causing diseases such as cholera, dysentery, and gastrointestinal infections. Human exposure to contaminated soil can occur through direct contact, the consumption of crops grown in polluted areas, or through groundwater contamination.

Emerging Contaminants (Pharmaceuticals, Nanomaterials)

Emerging contaminants, such as pharmaceuticals and nanomaterials, pose a growing concern in soil pollution. Pharmaceuticals enter the environment via wastewater, agricultural runoff, and improper disposal, disrupting microbial communities and potentially entering the food chain. Nanomaterials, utilized in various industrial and consumer products, are relatively new pollutants whose long-term effects on soil and ecosystems remain under investigation. These tiny particles can interact with living organisms in complex, sometimes harmful ways, raising significant concerns for environmental health.

Health Impacts of Soil Pollution / Toxicological Effects on Humans

Soil pollution has serious toxicological consequences for human health, particularly concerning exposure to heavy metals and persistent organic pollutants. For instance, exposure to lead and mercury can result in neurological disorders, developmental delays, and cognitive impairments, especially in children. Arsenic exposure is associated with an increased risk of certain cancers, including skin and lung cancer. Chronic exposure to pesticides and dioxins has been linked to hormonal disruptions, reproductive issues, and immune system damage, leading to long-term health complications.

Chronic Exposure and Non-Communicable Diseases

Prolonged exposure to contaminated soil can contribute to the onset of non-communicable diseases, such as cardiovascular disease, cancer, and metabolic disorders. Heavy metals and organic pollutants can act as endocrine disruptors, interfering with hormonal balance and elevating the risk of conditions like diabetes and infertility. Over time, even low-level exposure can accumulate within the body, resulting in

chronic health issues and diminishing overall life expectancy.

Exposure Pathways in Human Populations (Direct Ingestion of Contaminated Soil)

Children, particularly in urban and industrial environments, are especially susceptible to soil pollution through direct ingestion. Their tendency to play in contaminated areas can result in the ingestion of small soil quantities, leading to the accumulation of toxic substances like lead, which can cause developmental delays and other health problems. In heavily polluted regions, this exposure poses a significant public health challenge.

Food Chain Contamination

Soil pollution can infiltrate the food chain as plants absorb pollutants like heavy metals and organic compounds from the soil. These toxins accumulate in plant tissues, which are then consumed by animals and humans. Over time, bioaccumulation can lead to the ingestion of harmful toxin levels, negatively affecting human health and contributing to diseases such as cancer, organ damage, and neurological disorders.

Groundwater Contamination

Contaminants in the soil can leach into groundwater, a crucial drinking water source for many communities. Once these pollutants contaminate the water supply, they pose significant health risks to consumers. Heavy metals like arsenic and mercury can taint groundwater sources, resulting in long-term health issues such as cancer, neurological damage, and kidney disease. The contamination of groundwater by heavy metals can have widespread consequences, including the degradation of drinking water quality, disruptions to agricultural productivity, and adverse health outcomes for local populations. Chronic exposure to contaminated water, even at low concentrations, has been associated with various health problems,

from neurological damage to cancer. Additionally, the ecological effects are concerning, as toxic metals can bioaccumulate in aquatic organisms, leading to biodiversity loss and disruption of food chains. Divergent and conflicting opinions regarding the potential fundamental causes of the environmental catastrophe are evident. Every year, new materials and modifications are created and observed. But these materials come from advanced industries, and some of the ones that are left were created during their construction (Shamsuddeen, et al., 2024).

Dermal Contact and Inhalation of Soil Particles

Human exposure to soil pollution can also occur through skin contact and inhalation of contaminated dust particles. This risk is particularly significant for individuals working in agriculture, construction, and other outdoor sectors. Dermal contact with polluted soil can cause skin issues, while inhaling contaminated dust can lead to respiratory problems, chronic lung diseases, and other health complications over time.

Health Implications of Soil Pollution

Soil pollution presents significant health risks, impacting human, animal, and ecosystem health. Contaminants enter the soil primarily from industrial activities, agricultural chemicals, mining, and improper waste disposal. These pollutants can cause direct and indirect health issues. The health impacts of soil pollution are diverse and significant, affecting physical, mental, and social well-being.

Heavy metals, including lead, mercury, cadmium, and arsenic, are commonly found in polluted soils due to industrial waste, mining operations, and the use of fertilizers and pesticides. Exposure to these metals is linked to severe health conditions.

Lead exposure is particularly dangerous for children, leading to cognitive impairment and developmental delays (Wuana and Okieimen, 2011; Lanphear et al., 2005). Long term cadmium exposure, often resulting from contaminated soil in agricultural areas, can lead to kidney dysfunction (Bernard, 2008). Arsenic contaminated soils, often linked to industrial pollution and pesticide residues, have been associated with increased risks of skin, lung, and bladder cancers (Smith et al., 2002).

Pesticide Residues

Pesticides are generally used to protect the crop, but there are several ways in which they can also contaminate the soil. Some of the common reasons include inappropriate use, a lack of information on how to use them in terms of amount, a high amount of runoff into water bodies, and pesticides that are adsorbed, desorb, and broken down during their passage through soil, and these phenomena are dependent on pesticide properties such as persistence, bioaccumulation, and toxicity (Ruslan S. et al., 2024).

The excessive use of pesticides in agriculture contributes to soil pollution, leading to potential health risks:

Endocrine disruption: Certain pesticides, such as DDT, are known to interfere with hormone systems, affecting reproductive health and development (Diamanti-Kandarakis et al., 2009).

Long term exposure to some pesticides, such as organophosphates and carbamates, has been linked to cancers, including leukemia and non-Hodgkin lymphoma (Alavanja et al., 2004). Inhalation of pesticide-contaminated soil dust can cause chronic respiratory conditions in agricultural workers and nearby populations (Hernández et al., 2011).

Soil-Borne Pathogens

Polluted soils, particularly in areas with poor sanitation, can harbor harmful

pathogens, including bacteria, viruses, and parasites, which pose health risks through the food chain. Consumption of food grown in pathogen-contaminated soils can result in infections such as diarrhea and cholera (WHO, 2018). Contaminated soils can foster the growth of harmful bacteria like *Clostridium tetani*, causing diseases such as tetanus (Steele et al., 2021).

Organic Contaminants

Persistent organic pollutants (POPs), including polychlorinated biphenyls (PCBs), dioxins, and polycyclic aromatic hydrocarbons (PAHs), are prevalent in polluted soils due to industrial activities and the burning of fossil fuels. These pollutants have severe health implications. PCBs and dioxins are known carcinogens, with strong links to liver and breast cancer (Longnecker et al., 1997; Steenland et al., 2004).

Immune suppression: Dioxin exposure can impair immune function, making individuals more susceptible to infections (Van den Berg et al., 2006). PAHs are associated with reduced fertility and developmental issues in offspring (Bocskay et al., 2005).

Impact on Food Safety

Soil pollution directly affects the safety and quality of food crops, which can result in long-term health impacts for populations dependent on contaminated agricultural produce. Heavy metals and other pollutants can accumulate in the tissues of plants grown in contaminated soil, entering the human food chain. For example, cadmium can accumulate in rice, posing a risk to consumers (Clemens et al., 2013).

Nutritional deficiencies: Soil pollution can degrade the nutrient content of crops, leading to essential vitamin and mineral deficiencies (Alloway, 2004).

Short-term and Long-term Health Effects

The short-term and long-term health effects of soil contamination are vast

and complex, disproportionately affecting vulnerable populations such as children, pregnant women, the elderly, and those with pre-existing conditions.

Immediate Toxicological Effects

Skin Irritation and Rashes

Direct contact with contaminated soil often leads to acute dermal reactions. This is common in areas where people may work in agriculture, construction, or mining. For example, exposure to soil containing pesticides or heavy metals can result in skin irritation, rashes, and in more severe cases, chemical burns. Certain pollutants, such as polycyclic aromatic hydrocarbons (PAHs) and industrial solvents, have been known to cause dermatitis, exacerbating pre-existing skin conditions (Washington State Department of Health, 2023).

Gastrointestinal Issues

Ingestion of contaminated soil, either directly or through contaminated food sources, can result in acute gastrointestinal symptoms such as nausea, vomiting, abdominal pain, and diarrhea. Children, due to their hand-to-mouth behavior, are particularly susceptible to ingesting small amounts of contaminated soil, which can cause these symptoms. Lead poisoning, which is a common concern in contaminated soils near industrial sites, can also result in severe abdominal cramps and vomiting in cases of acute exposure (Manitoba Health, 2024).

Chronic Diseases Linked to Soil Pollution Exposure

Cardiovascular Diseases

Long-term exposure to pollutants such as heavy metals and persistent organic pollutants (POPs) has been linked to increased risks of cardiovascular diseases. For instance, arsenic exposure from contaminated soil has been associated with hypertension and heart disease. These effects often result from the bioaccumulation of heavy metals in the body, leading to oxidative stress and damage to the cardiovascular system.

Studies have also shown that chronic exposure to soil contaminated with lead and mercury increases the risk of stroke and heart attacks (Raw Earth Environmental, 2023).

Respiratory Issues

Soil particles contaminated with chemicals can become airborne as dust, especially in dry conditions. Inhalation of these contaminated particles can lead to respiratory problems such as chronic bronchitis, asthma, and other lung diseases. Dust from contaminated soil in industrial or mining areas, where substances like asbestos or cadmium are present, significantly increases the risk of respiratory issues. Prolonged exposure to these pollutants has been associated with decreased lung function, chronic obstructive pulmonary disease (COPD), and lung cancer (Farming Farmers Farms, 2024).

Cancer

One of the most alarming long-term health effects of soil contamination is an increased risk of cancer. Persistent exposure to carcinogenic substances such as arsenic, dioxins, and benzene in the soil has been shown to elevate the likelihood of developing cancers, including liver cancer, bladder cancer, and skin cancer. A well-known example is the Love Canal incident, where toxic chemicals buried beneath the neighborhood eventually led to an increase in cancer rates among residents (Washington State Department of Health, 2023).

Vulnerable Populations

Certain populations are more vulnerable to the health impacts of soil contamination due to factors such as age, health status, and socioeconomic conditions.

Children

Children are particularly vulnerable to soil contamination because of their developing immune systems and their tendency to engage in behaviors such as

playing in the dirt, which increases their exposure to contaminated soil. Additionally, their smaller body mass means that even small amounts of toxic chemicals can have a more significant impact on their health, leading to developmental delays, cognitive impairments, and behavioral problems, particularly from lead and mercury exposure.

Pregnant Women

Pregnant women are at a higher risk of adverse health effects from soil contamination because exposure to certain chemicals, such as lead and arsenic, can affect fetal development. These chemicals can cross the placental barrier, leading to congenital disabilities, low birth weight, and premature births. Long-term exposure can also increase the risk of miscarriage and stillbirths.

Elderly Individuals

The elderly population is more susceptible to the chronic effects of soil contamination due to their age-related decline in immune function and physiological resilience. Long-term exposure to contaminated soil can exacerbate pre-existing conditions, particularly respiratory and cardiovascular diseases. Furthermore, bioaccumulation of heavy metals over the years can lead to higher incidences of cancers, kidney damage, and neurodegenerative diseases in this population.

Individuals with Pre-existing Health Conditions

People with pre-existing conditions such as asthma, cardiovascular disease, or weakened immune systems are at a heightened risk of adverse outcomes from soil contamination. Their health conditions can be aggravated by exposure to environmental toxins, leading to faster disease progression or increased mortality risks.

Risk Assessment Models

The assessment of risks posed by soil contamination is essential for safeguarding human health and environmental integrity. Risk assessment models help quantify potential health impacts by analyzing contaminant concentrations, exposure pathways, and population vulnerabilities. However, while several models are used globally, they are often limited in addressing complex exposure scenarios and adequately protecting vulnerable populations. This section examines existing risk assessment models, their limitations, and proposed improvements for more comprehensive risk evaluation.

Existing Models

Current environmental risk assessment models are generally based on well-established frameworks designed to evaluate the potential adverse effects of contaminants on human health and ecosystems. These models typically include four major steps: hazard identification, dose-response assessment, exposure assessment, and risk characterization. Below is an overview of some widely applied models:

U.S. Environmental Protection Agency (EPA) Risk Assessment Framework

One of the most commonly used models, the EPA's framework is applied in contaminated land sites, such as Superfund cleanups, to determine human health risks posed by soil pollution. This model evaluates both direct and indirect exposure pathways, including ingestion of contaminated soil, inhalation of soil particles, and dermal contact. It quantifies risks by integrating toxicity data and exposure levels to estimate both short-term and long-term effects (EPA, 2023).

Health Canada's Risk Assessment Model

Health Canada's framework emphasizes site-specific assessments, incorporating local conditions such as soil type, land use, and demographics. It

considers multiple exposure routes and integrates data from environmental monitoring to provide a more tailored assessment. This model is frequently applied to Canadian sites impacted by industrial pollution, mining activities, and agricultural contaminants (Health Canada, 2024).

European Union (EU) Risk Assessment of Chemical Substances (RAC)

The EU's RAC model focuses on the risks posed by chemical substances, including those present in soil, to human health and the environment. This framework integrates human health risks with ecological impacts, assessing how contaminants affect soil biodiversity and ecosystem functions. It also emphasizes compliance with European regulatory standards to guide decision-making in contaminated land management (EU RAC, 2023).

These models play a pivotal role in soil pollution management by providing a standardized methodology to assess risks. However, their applications are often constrained by certain limitations.

Limitations of Current Models

Despite their widespread use, existing risk assessment models have notable limitations that can undermine the accuracy and effectiveness of soil contamination evaluations.

Inadequacies in Addressing Complex Exposure Pathways

Many current models are based on simplified assumptions of exposure routes, often focusing on a single pathway (e.g., ingestion or dermal contact) rather than the combined or synergistic effects of multiple pathways. In real-world scenarios, people may be exposed to contaminants through ingestion, inhalation of soil dust, and consumption of food grown in contaminated areas. The failure to consider multiple pathways in an integrated manner may lead to underestimating the overall risk, especially in highly polluted

environments (Raw Earth Environmental, 2023).

Gaps in Accounting for Vulnerable Populations

Most existing models assess risk for the general population and do not adequately account for the heightened sensitivity of vulnerable groups, such as children, pregnant women, the elderly, and those with pre-existing health conditions. These populations are more susceptible to the toxic effects of soil contaminants like heavy metals and organic pollutants. For example, children are more likely to suffer from lead poisoning due to their frequent contact with soil and higher absorption rates. Models that fail to incorporate specific risk factors for these groups provide an incomplete assessment of public health risks (Manitoba Health, 2024).

Incomplete Consideration of Cumulative Exposure

Cumulative exposure, or the long-term accumulation of toxins from multiple sources, is often overlooked in standard models. Many models assess the risks of individual contaminants, neglecting the combined effects of multiple pollutants present in contaminated soil. This is a significant shortcoming, as chemical mixtures can have additive or even synergistic effects that increase overall health risks. Additionally, chronic low-dose exposure over time can lead to serious long-term health issues, such as cancer and neurological disorders, which are not fully captured in single-substance assessments.

Proposed Improvements

To enhance the effectiveness of risk assessment models and address the gaps in current frameworks, several improvements can be implemented. These improvements should focus on developing more holistic models that consider the complex realities of

exposure and incorporate advanced technological and analytical tools.

Development of More Holistic Risk Assessment Frameworks

Future models should integrate a broader range of factors, including genetic, demographic, and behavioral aspects that influence susceptibility to environmental toxins. This would allow for more individualized risk assessments that account for population diversity. Key areas for improvement include:

Genetic Factors: Understanding genetic predispositions that make certain individuals more vulnerable to soil contaminants. For example, some people may be genetically predisposed to cancers or respiratory diseases when exposed to heavy metals like arsenic or cadmium.

Demographic Factors: Incorporating specific data on age, gender, and socioeconomic status, low-income populations may be more exposed to contaminated soil due to living near industrial sites.

Behavioral Factors: Considering lifestyle habits such as gardening, outdoor recreation, or dietary patterns that increase exposure to soil pollutants. Individuals who grow and consume food in contaminated soil are at a higher risk of ingestion-based exposure.

Integration of Real-time Monitoring Data

One of the major limitations of current models is their reliance on static datasets. Integrating real-time monitoring data from environmental sensors into risk assessments can provide more accurate and up-to-date information on contamination levels. Continuous monitoring of soil, air, and water around contaminated sites can help track fluctuating contaminant levels and their potential impacts. This approach enables a dynamic assessment that reflects

current conditions rather than historical averages (EPA, 2023).

Use of Advanced Simulation Techniques

Advances in computational modeling and simulation techniques offer significant opportunities to improve risk assessments. Methods such as Monte Carlo simulations and machine learning models can be used to analyze a broader range of exposure scenarios, helping to predict health outcomes more accurately. These techniques allow for a more comprehensive evaluation of complex interactions between multiple contaminants, exposure pathways, and population vulnerabilities. For instance, machine learning algorithms could analyze large datasets to identify patterns in health risks associated with soil contamination, enabling more precise risk estimates.

Emphasis on Cumulative Risk Assessment

Future models should prioritize cumulative risk assessment, which accounts for the combined effects of multiple contaminants over time. This approach provides a more realistic evaluation of long-term health risks, especially in environments where multiple chemical exposures are common. Incorporating cumulative risk frameworks will help address the additive and synergistic effects of various pollutants, leading to better risk management strategies. Additionally, cumulative risk assessments should factor in multi-generational impacts, particularly for contaminants that affect reproductive health and fetal development.

Regulatory Framework and Policies

Effective regulation of soil pollution is crucial for mitigating its impacts on human health and the environment. Various international and national organizations have established guidelines and policies to regulate soil

contamination. However, there are significant variations in these regulations across regions, with some countries facing challenges in enforcement and monitoring. This section explores the existing regulatory frameworks, identifies gaps in legislation, and provides recommendations for policymakers to improve soil health protection.

International and National Guidelines

Regulatory frameworks and guidelines for soil contamination focus on setting limits for hazardous chemicals, providing risk assessments, and ensuring proper remediation strategies. Some of the key regulatory bodies that set standards for soil pollution are the World Health Organization (WHO), the U.S. Environmental Protection Agency (EPA), and the European Union (EU).

World Health Organization (WHO) Guidelines

The WHO provides global guidelines on managing soil contamination, with a focus on the health impacts of soil pollutants like lead, mercury, cadmium, and arsenic. These guidelines are designed to minimize the health risks associated with exposure to soil contaminants, particularly for vulnerable populations like children and pregnant women. WHO standards are widely adopted by countries as benchmarks for developing national soil pollution policies (WHO, 2023).

U.S. Environmental Protection Agency (EPA) Standards

The EPA regulates soil pollution under laws such as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund, and the Resource Conservation and Recovery Act (RCRA). The EPA has established soil screening levels (SSLs) to assess the risk of contaminants in residential, industrial, and agricultural soils. These SSLs guide cleanup efforts to protect

human health, particularly by preventing exposure to harmful chemicals like lead, mercury, and polychlorinated biphenyls (PCBs) (EPA, 2023).

European Union (EU) Soil Pollution Standards

The EU has established a comprehensive framework for managing soil health under its Soil Thematic Strategy and the European Soil Framework Directive. These regulations aim to protect soils from degradation, prevent contamination, and promote sustainable land management. EU regulations are based on the precautionary principle, which focuses on preventing environmental harm even when scientific certainty is not fully established. The EU also emphasizes the remediation of polluted soils to ensure food safety and public health (EU Environment, 2024).

Regional Policy Variations and Enforcement Challenges

Despite the existence of international guidelines, the effectiveness of soil pollution policies varies widely across regions. The variation in policies and enforcement levels can be attributed to differences in economic development, governmental capacity, and industrial activities.

Developed Regions

In developed regions like the United States and the European Union, strict soil contamination laws are in place, and there are robust environmental agencies to oversee enforcement. For example, the EPA's Superfund program and the EU's Soil Framework Directive require that contaminated sites be identified, monitored, and remediated. However, challenges remain in terms of funding and political will to clean up large-scale industrial contamination.

Developing Regions

Many developing countries face significant enforcement challenges,

despite adopting international guidelines. In regions like Southeast Asia, Africa, and parts of Latin America, rapid industrialization, urbanization, and weak regulatory oversight have led to widespread soil contamination. In many cases, soil pollution is not adequately monitored, and environmental agencies lack the financial and technical resources to enforce existing regulations effectively (UNEP, 2023).

Emerging Economies

Countries with emerging economies, such as China and India, have begun to adopt more comprehensive soil pollution policies in response to increasing environmental degradation. China's Soil Pollution Prevention and Control Action Plan (2016) aims to address the extensive soil contamination caused by decades of rapid industrialization. However, enforcement remains a challenge due to the scale of pollution and competing economic interests (China Soil Action Plan, 202).

Existing Gaps in Legislation

While international and national guidelines provide a foundation for regulating soil contamination, significant gaps remain in the legislative frameworks of many regions, particularly in developing nations and emerging economies.

Lack of Comprehensive Soil Health Protection Laws

In many countries, soil health is not regulated as thoroughly as air and water pollution. This lack of comprehensive soil-specific legislation means that soil contamination often goes unaddressed, particularly in rural and agricultural areas. Without specific legal frameworks for soil health, issues like heavy metal contamination, pesticide residue, and industrial waste dumping are inadequately managed.

Inadequate Cumulative Exposure Consideration

Existing regulations often fail to consider the cumulative exposure to multiple contaminants. Most laws focus on individual chemicals, setting limits for each pollutant without accounting for the potential additive or synergistic effects of various contaminants present in the soil. This oversight can result in underestimating the real health risks posed by complex chemical mixtures in contaminated soils.

Limited Focus on Vulnerable Populations

Current legislation frequently does not account for the increased susceptibility of vulnerable populations, such as children, pregnant women, and individuals with pre-existing health conditions. Soil pollution standards tend to use general population exposure limits, which may not provide adequate protection for those most at risk of harm from soil contaminants like lead and arsenic.

Recommendations for Policy Makers

To address the challenges associated with soil contamination and protect public health, policymakers should consider the following recommendations:

Strengthening Soil Contamination Regulations

Governments should prioritize the development of comprehensive soil health protection laws that address both individual and cumulative contaminants. These laws should set strict limits on hazardous substances, particularly in high-risk areas like industrial zones and agricultural lands. Stricter penalties for non-compliance and illegal dumping practices should also be implemented to deter violations.

Improving Monitoring Systems and Enforcement Mechanisms

Monitoring soil health in real-time is essential for early detection of contamination and timely intervention. Governments should invest in advanced

monitoring technologies, such as remote sensing, soil sensors, and geographic information systems (GIS), to track soil quality across large areas. Enhanced enforcement mechanisms, including regular inspections and audits of industrial sites, can ensure compliance with soil health regulations.

Promoting Public Awareness and Education

Raising public awareness about the risks of soil pollution and the importance of soil health is vital for encouraging responsible practices. Governments should launch educational campaigns that inform citizens about the sources and impacts of soil contamination, particularly in agricultural and urban settings. Promoting community engagement in soil monitoring efforts, such as citizen science programs, can also help bridge gaps in enforcement and encourage more sustainable land use.

Prioritizing Protection for Vulnerable Populations

Policymakers should tailor soil contamination regulations to account for the unique risks faced by vulnerable populations. Exposure limits should be adjusted to provide additional protections for children, pregnant women, and individuals with health conditions that increase their sensitivity to pollutants. Risk assessments should also focus on long-term exposure to low-level contaminants to better capture the health impacts on these groups.

Encouraging Global Collaboration and Information Sharing

Given the global nature of many pollutants, international collaboration is crucial for addressing soil contamination. Policymakers should work to strengthen global treaties like the Stockholm Convention on Persistent Organic Pollutants and promote cross-border efforts to reduce pollution. Sharing best practices, technology, and data between

countries can enhance global efforts to mitigate soil contamination and protect public health.

Discussion

Exposure to soil contaminants occurs through several pathways, including ingestion, inhalation, and dermal contact. The relative risk levels of these pathways vary based on the type of contaminant, the level of exposure, and the population involved. For example, ingestion is a significant pathway for children, particularly in residential areas where lead contamination is prevalent, such as near former industrial sites. Inhalation of contaminated soil dust poses substantial risks in dry regions or areas with high levels of industrial activity, where airborne particles containing heavy metals like arsenic or cadmium can lead to respiratory issues and other long-term health problems (Manitoba Health, 2024). Dermal contact, though typically less concerning, can still lead to acute effects, such as skin irritation or chemical burns, especially in areas with high pesticide or solvent contamination.

One of the greatest challenges in assessing soil contamination is accounting for cumulative and long-term health risks. Soil pollutants often exist in mixtures, where the combined effects of multiple contaminants can be significantly more harmful than the effects of individual substances. For instance, mixtures of pesticides, industrial chemicals, and heavy metals can have synergistic effects that increase toxicity. Moreover, chronic low-level exposure over time can lead to severe health outcomes, such as cancer, reproductive issues, and neurological disorders. However, assessing these risks accurately is difficult due to the

Conclusion

Soil contamination presents significant risks to human health through various

complexity of exposure scenarios and the lack of longitudinal data linking soil contamination directly to specific health outcomes. Many current risk assessment models fail to consider the additive and cumulative effects of pollutants, further complicating the evaluation of long-term health risks (Raw Earth Environmental, 2023). Collecting accurate exposure data is a persistent challenge in the study of soil contamination and its health impacts. Many contaminants, such as lead, arsenic, and pesticides, can accumulate in the environment over long periods, with varying degrees of exposure among different populations. Accurately measuring the exposure levels for individuals or communities is difficult due to factors such as geographical variability, changes in contaminant concentrations, and differences in individual behavior (e.g., outdoor activity, gardening, food consumption). Furthermore, exposure data is often collected at a single point in time, which may not reflect the cumulative or fluctuating nature of soil contamination. Establishing a direct causal link between soil pollution and specific health outcomes is complex due to the multitude of factors involved. Human health is influenced by a range of environmental, genetic, and lifestyle factors, making it difficult to isolate the effects of soil contamination. Additionally, many health effects, such as cancer or chronic respiratory diseases, take years or even decades to develop, complicating efforts to attribute these outcomes directly to soil pollutants. The lack of longitudinal studies and comprehensive exposure data further hinders the ability to definitively link soil contamination to long-term health impacts

exposure pathways, including ingestion, inhalation, and dermal contact. Key pollutants, such as heavy metals (e.g., lead, arsenic), pesticides, and industrial

chemicals, can lead to both short-term and long-term health effects. Short-term exposure often results in symptoms such as skin irritation, gastrointestinal distress, or respiratory issues, while long-term exposure can cause severe outcomes like cancer, cardiovascular diseases, and neurological disorders. Vulnerable populations, including children, pregnant women, and those living near industrial sites, are particularly at risk. Furthermore, the cumulative effects of multiple contaminants, along with chronic exposure, complicate efforts to assess the full impact of soil pollution on public health. The findings highlight an urgent need for increased monitoring of

soil contamination and its effects on public health. Public health interventions should focus on preventing exposure, particularly for at-risk populations, through stricter enforcement of soil quality standards and more robust soil remediation efforts. Public awareness campaigns should inform communities about the dangers of soil pollution and promote behaviors that reduce risk, such as safe gardening practices and soil testing in contaminated areas. Governments and health organizations must also ensure that comprehensive soil health regulations are in place and that they address both acute and chronic exposure risks.

References

- Abubakar M. Y., Mohammed H., Ogunwale A. T., & Adam A. B (2024):** Effect and Remediation of Environmental Pollution on the Concept of Chemistry Review. African Journal of Sciences and Traditional Medicine. Volume 1, Issue 1, July 2024; 440-449.
- Abubakar, M. Y., Ahmad, K. B., Mathew, T. S., Shamsudden, R., Muhammad, H. M., Haladu, M., & Adam, A.B. (2024).** Heavy Metal Pollution in Aquatic Ecosystems: A Review of Toxic Impacts and Remediation Strategies. Kwaghe International Journal of Sciences and Technology, 1(1), 416-427.
- Abubakar, M. Y., Danladi M. D., Danladi M. D., Shittu A. M., Usman S. U. (2024):** Assessment of Lead and Cadmium of Hand Dug Well Around Gold Mining Areas of Rimi Sumaila Local Government Area, Kano State, Nigeria. African Journal of Sciences and Traditional Medicine Volume 1, Issue 1, July 2024; 450-457.
- Abubakar, M. Y., Kaugama, A. A., Japhet, A. T., Ataitiya, H., Ahmad, K. B., Idris, S. A., & Adam, A. B.(2024).** Effects and remediation of heavy metals contamination in soil and vegetables from different areas: A review. Earthline Journal of Chemical Sciences, 11(3), 445-456.
- Abubakar, M. Y., Shehu I. U., Sulaiman W. D., Mohammed H., & Adam A.B (2024):** Climate Change Impacts On Water Quality: A Review Of The Current State Of knowledge. 4th Bİlşel International Truva Scientific Researches And Innovation Congress 17-18 August, 2024 Çanakkale/Türkiye <https://Bilşelkongreleri.Com/719>.
- Adam A. B., Shehu I. U., Sulaiman W. D., Haladu M., Abubakar, M. Y., & Shamsudden R (2024):** Soil remediation techniques for heavy metal contamination. A review of recent development. 4th Bİlşel International Truva Scientific Researches and Innovation Congress 17-18 August, 2024, Çanakkale/Türkiye pp 709-716.
- Alavanja, M. C. R., Ross, M. K., & Bonner, M. R. (2004).** Increased cancer burden among pesticide applicators and others due to pesticide exposure. CA: A Cancer

- Journal for Clinicians, 54(6), 339-353.
- Alloway, B. J. (2004).** Contamination of soils in domestic gardens and allotments: A brief overview. *Land Contamination & Reclamation*, 12(3), 179-187.
- Alloway, B. J. (2013).** Heavy metals in soils: Trace metals and metalloids in soils and their bioavailability (Vol. 22). Springer Science & Business Media.
- Bernard, A. (2008).** Cadmium & its adverse effects on human health. *Indian Journal of Medical Research*, 128(4), 557-564.
- Bocskay, K. A., Tang, D., Orjuela, M. A., Liu, X., & Perera, F. P. (2005).** PAH-DNA adducts in cord blood and behavior scores in New York City children. *Environmental Health Perspectives*, 113(1), 74-79.
- Carson, R. (1962).** Silent spring. Houghton Mifflin.
- Clemens, S., Aarts, M. G. M., Thomine, S., & Verbruggen, N. (2013).** Plant science: The key to preventing slow cadmium poisoning. *Trends in Plant Science*, 18(2), 92-99.
- Danladi, M. D., Abbas B., Abdulkarim B., M., Adam A. B., Abubakar M. Y., Shittu A. M. (2024):** Assessing The Environmental And Human Health Impacts Of Contaminants In Aquatic Ecosystems And Soil: A Comprehensive Review Of Toxicity And ecosystem Disruption. 4. *Bİlssel International Ahlat Scientific Researches Congress*, 21/22 September
- Danladi M. D., Abubakar M Y., Adam A. B, Shittu A M., & Edmond L. O. (2024):** Heavy Metal Leaching From Landfills: A Review Of Groundwater Contamination And Long Term Environmental Impacts. 4. *Bİlssel International Ahlat Scientific Researches Congress, Turkey*.
- De Souza Machado, A. A., (2018).** Impacts of microplastics on the soil biophysical environment. *Environmental Science & Technology*, 52(17), 9656-9665.
- De Souza Machado, A. A., Kloas, W., Zarfl, C., Hempel, S., & Rillig, M. C. (2018).** Microplastics as an emerging threat to terrestrial ecosystems. *Global Change Biology*, 24(4), 1405–1416.
- Diamanti-Kandarakis, E., Bourguignon, J. P., Giudice, L. C., Hauser, R., Prins, G. S., Soto, A. M., & Gore, A. C. (2009).** Endocrine-disrupting chemicals: An Endocrine Society scientific statement. *Endocrine Reviews*, 30(4), 293-342.
- Ding, G., Gao, Y., Zhou, Y., & Sun, H. (2016).** Health and mental health impact assessment of environmental pollution. *International Journal of Environmental Research and Public Health*, 13(4), 354.
- EU RAC. (2023).** Risk Assessment of Chemical Substances.
- Gabriel S. J., Nura U. A., Ibrahim H., Hassan A., & Adam A. B. (2024):** Investigating The Effects Of Desertification On Livestock Productivity In yobe State. 4th *Bİlssel International Gordİon Scientific Researches Congress* 19-20 September, 2024Ankara/Türkİye<https://Bilselkongreleri.Com> /413.
- Health Canada. (2024).** Human Health Risk Assessment for Environmental Contaminants.
- Hernández, A. F., Parrón, T., & Alarcón, R. (2011).** Pesticides and asthma. *Current Opinion in Allergy and Clinical Immunology*, 11(2), 90-96.
- Huo, X., Peng, L., Xu, X., Zheng, L., Qiu, B., Qi, Z., Zhang, B., Han, D.,**

- & Piao, Z. (2007).** Elevated blood lead levels of children in Guiyu, an electronic waste recycling town in China. *Environmental Health Perspectives*, 115(7), 1113–1117.
- IPCC. (2014).** *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Cambridge University Press.
- Kovacs, J. J. (1992).** Environmental law and policy: CERCLA, the Superfund. *Boston College Environmental Affairs Law Review*, 19(3), 641.
- Lanphear, B. P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D. C., & Roberts, R. (2005).** Low-level environmental lead exposure and children's intellectual function: An international pooled analysis. *Environmental Health Perspectives*, 113(7), 894-899.
- Levine, A. G. (1982).** *Love Canal: Science, Politics, and People*. Lexington Books.
- Longnecker, M. P., Rogan, W. J., & Lucier, G. (1997).** The human health effects of DDT (dichlorodiphenyltrichloroethane) and PCBs (polychlorinated biphenyls) and an overview of organochlorines in public health. *Annual Review of Public Health*, 18, 211-244.
- Manitoba Health. (2024).** Gardening and Soil Contaminants.
- Nriagu, J. O. (1996).** A history of global metal pollution. *Science*, 272(5259), 223-224.
- Pacyna, E. G., & Pacyna, J. M. (2001).** An assessment of global and regional emissions of trace metals to the atmosphere from anthropogenic sources worldwide. *Environmental Reviews*, 9(4), 269-298.
- Pacyna, E. G., & Pacyna, J. M. (2001).** An assessment of global and regional emissions of trace metals to the atmosphere from anthropogenic sources worldwide. *Environmental Reviews*, 9(4), 269–298.
- Raw Earth Environmental. (2023).** The Dangers of Contaminated Soil.
- Ruslan S., Twan S. M., Mohammed H., Ahmad. K. B., Adam B. A., & Abubakar M. Y. (2024):** Recent Advances in Biopesticides: A Review of Efficacy and Environmental Impact. *African Journal of Biochemistry and Molecular Biology Research* Volume 1, Issue 1, July 2024; 706-725.
- Shamsuddeen, R., Adam, A. B., Mathew, T. S., & Abubakar, M. Y. (2024).** Environmental Remediation Using Nanoparticles: A Review. *Kwaghe International Journal of Sciences and Technology*, 1(1), 428-442.
- Smith, A. H., Lingas, E. O., & Rahman, M. (2000).** Contamination of drinking-water by arsenic in Bangladesh: A public health emergency. *Bulletin of the World Health Organization*, 78(9), 1093-1103.
- Steele, M., O'Reilly, K. M., & Watkins, R. E. (2021).** Soil-borne diseases: An overview of research on soil contamination and health impacts. *Environmental Research*, 190, 110024.
- Stockholm Convention on Persistent Organic Pollutants. (2001).** *United Nations Environment Programme*.
- UNEP. (2017).** Global Environment Outlook – GEO-6: Healthy Planet, Healthy People. United Nations Environment Programme, Nairobi.
- Van den Berg, M., Birnbaum, L., Denison, M., De Vito, M., Farland, W., Feeley, M., & Rose, M. (2006).** The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like

- compounds. *Toxicological Sciences*, 93(2), 223-241.
- Washington State Department of Health. (2023).** Hazards of Short-Term Exposure to Arsenic Contaminated Soil.
- WHO. (2023).** Environmental Health Standards.
- Wuana, R. A., & Okieimen, F. E. (2011).** Heavy metals in contaminated soils: A review of sources, chemistry, risks, and best available strategies for remediation. *International Scholarly Research Notices*, 2011, 402647.
- Zhang, G. S (2020).** Microplastics in soils: A review of possible sources, analytical methods and ecological impacts. *Journal of Chemical Technology and Biotechnology*, 95(8), 2052-2068.