Exposure to Environmental Pollutants and Risk of Diarrhea: A Systematic Review

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ABSTRACT: This systematic review investigates the association between environmental pollutants and the risk of diarrhea, a critical public health issue, particularly in low- and middle-income countries. The review synthesizes findings from various studies that highlight the impact of contaminants such as pesticides, heavy metals, polycyclic aromatic hydrocarbons (PAHs), microplastics, and parabens on gastrointestinal health. Following PRISMA guidelines, a comprehensive literature search across databases including PubMed, Scopus, and Google Scholar yielded 496 articles, of which 11 met the inclusion criteria for detailed analysis. The results indicate a significant correlation between exposure to specific pollutants—particularly pesticides like dichlorodiphenyltrichloroethane (DDT), PAHs, arsenic, cadmium, and microplastics—and increased incidences of diarrhea. Notably, studies revealed that prenatal exposure to DDT is linked to higher diarrhea rates among boys in urban settings, while pesticide exposure in childhood correlates with inflammatory bowel disease in adulthood. Mechanistically, these pollutants may disrupt gastrointestinal function through cholinergic effects and endocrine disruption, leading to altered gut motility and microbiome imbalances. Moreover, the review emphasizes the immunosuppressive effects of heavy metals such as mercury and cadmium, which compromise the immune response and increase susceptibility to gastrointestinal infections. Despite the identified associations, there is a notable gap in research regarding geographic distribution and pollutant impacts on health outcomes. The review underscores the necessity for public health interventions aimed at reducing exposure to these environmental pollutants to mitigate their adverse health effects. In conclusion, this systematic review highlights the urgent need for further epidemiological studies in underrepresented areas to enhance our understanding of how environmental pollutants influence public health globally. Recommendations include rigorous monitoring of pollutant levels, public health initiatives to reduce exposure, and policies that restrict emissions of harmful substances. Addressing environmental pollution is crucial for mitigating diarrheal diseases and protecting vulnerable populations from its detrimental effects.

PLAIN LANGUAGE SUMMARY: Environmental polluatants (metals and non metals) are involved in diarrhea.

KEYWORDS: Diarrhea, environmental pollutants, heavy metals, microplastics, polycyclic aromatic hydrocarbons (PAHs), microbial balance, gut health

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Introduction

The world is plagued by several anthropogenic activities that produce environmental contaminants like pesticides, heavy metals, phenolic compounds, and polycyclic aromatic hydrocarbons (PAHs). The burning of petroleum and other fossil fuels releases a range of pollutants into the atmosphere, contributing to air and environmental contamination.[1,2] Most of these pollutants persist in the environment and may have harmful impact on human health, resulting in a variety of illnesses such as respiratory diseases, cancers, and gastrointestinal disorders.[3,4]

The most common illnesses in low- and middle-income countries are those caused by indoor air and water pollution, pneumonia, and the ancient maladies of loose stools. In every country, the age group younger than 5 years old has the highest death and morbidity rates (years lived with handicap [YLD]) from diarrheal illness.[5] A recent estimate by the World Health Organization[6] indicates that nearly 1.7 billion cases of childhood diarrhea are diagnosed yearly. Diarrhea has been rated as the leading cause of malnutrition in children under 5 years old and the third leading cause of deaths in children 1 to 59 months of age, accounting for about 443 832 deaths among children under the age of 5, yearly. Dehydration resulting from diarrhea is documented to causes fatalities, globally.[7-9] In addition, long-term effects of diarrhea such as growth hormone malfunction and cognitive deficit[10,11] further make it an important public health concern.

A significant proportion of diarrheal disease has been attributed to exposure to unsafe drinking-water and inadequate sanitation and hygiene, impaired immune system, lack of access to proper medical care, hunger, and destitution.[12] However, a growing number of reports suggest that exposure to environmental chemical pollutants may manifest as diarrhea and can increase the prevalence of these diseases.[13] The immune system defends the host from harmful substances, and a compromised immune system inevitably makes the host more vulnerable to invasive diarrheal pathogens including *Escherichia coli*, shigella, salmonella, and campylobacter.[14]There is a high prevalence of diarrhea due to the immune system being compromised by environmental contaminants.[15] Evidence have shown that heavy metals such as mercury and cadmium have immunosuppressive effects thereby playing significant role in gastrointestinal infections.[16]Through a variety of impacted pathways, they modify immune cell activity, eliciting notable immunotoxic consequences. Depending on the specific metal, its concentration, the exposure route and length of time, and the availability of biologics, the overall effect could be either immunosuppression or activation of immune cell activity.[17] According to Zheng et al[18] heavy metals can lower lymphocyte counts and decrease adaptive immunity, both of which are essential for the removal of infections. This may result in a heightened vulnerability to infections and a diminished capacity to generate a potent immune response. By first triggering an immune response to the heavy metal itself, which can result in the creation of specialized soldiers meant to combat the heavy metal, heavy metals can also cause autoimmunity.[19] Increased cytokine release has also been linked to heavy metal exposure and this can exacerbate other autoimmune diseases.[20]

Other environmental contaminants, like cigarette smoke, can change the microbiomes in the gut.[21] Diarrhea and other gastrointestinal disorders can arise from the alteration of the gut microbiomes caused by certain chemicals such as polyaromatic hydrocarbons found in cigarette smoke.[22,23] Furthermore, herbicides like dichlorodiphenyltrichloroethane (DDT), which farmers use to control weeds and pests, can persist in the environment for a very long time and expose people to a variety of harmful health effects, including immune system impairment.[24] For example, prenatal DDT exposure has been positively associated with GIT infections.[25] This systematic review aimed to identify the environmental pollutants associated with diarrhea and to draw attention of role played by the environmental pollutants on some communicable diseases. There are still gaps in our knowledge of the geographic and authorial contributions to pollutants influencing health outcomes like diarrhea, despite the fact that environmental pollution research is expanding. The systematic review and bibliometric analysis conducted in this work provide new insights into these understudied research dimensions.

Methodology

Information sources and search strategy: The bibliometric analysis looked at keyword co-occurrence patterns, author productivity, and country-wise contributions to give a thorough picture of research trends. This review was conducted according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines.[26] Literature search was done using the Google Scholar, Scopus, and PubMed databases. The keywords used for the search were: "environmental pollutants," "heavy metals," "PAHs," "parabens," "bisphenols," "microplastics," and "DDT," "diarrhea," "inflammatory bowel diseases," "functional gastrointestinal disease (FGD)," and "blood and stool toxicant levels." PRISMA flow diagram summarizing search study and selection process is illustrated in Figure 1.

Inclusion and Exclusion criteria:In this systematic review, studies were included if they fulfilled the following criteria: (1) original articles published in English Language. (2) Studied the association between diarrhea and any environmental toxicant or toxin. (3) Research was on humans, (4) study measured personal exposure level to environmental toxicants. There were no restrictions as to year of publication and age, sex, or nationality of study population. Only observational (cohort, case-control) were included. Excluded from review were animal studies, case studies, articles not published in English and articles whose full-text were not found.

Data extraction:The inclusion and exclusion criteria were applied to the screening of all titles, abstracts, and full texts. Two of the authors carefully read the included papers and extracted data using a data extraction form designed for this study. The extracted data included country of study, study design, study setting, study population, sample size, age of study participants, type of pollutant implicated, source of pollution, pollutant exposure assessment method, methods of outcome assessment, first authors' name and the year of publication.

Quality assessment:In order to present the best available evidence, the chosen studies containing data on health outcomes underwent a thorough evaluation. Six of the authors' own items served as the basis for the evaluation as follows: (a) The study design, which refers to the procedures and methods used to gather and analyze data on the variables included in the study, was the basis for evaluating the paper. (b) Sampling strategy: papers were evaluated according to the procedures and methods utilized to choose certain population members. (c) Covariates: papers were evaluated using a questionnaire to identify the variables that might have an impact on the study's findings. (d) Statistical analysis (a well-defined, methodical, and mathematical procedure and set of rules were used to score papers based on how the data was organized and interpreted). (e) Outcomes (the studies' conclusions and results were the basis for evaluating the papers) (f) Ethical consideration: the papers were evaluated in accordance with a set of guidelines that govern research design and methodology.

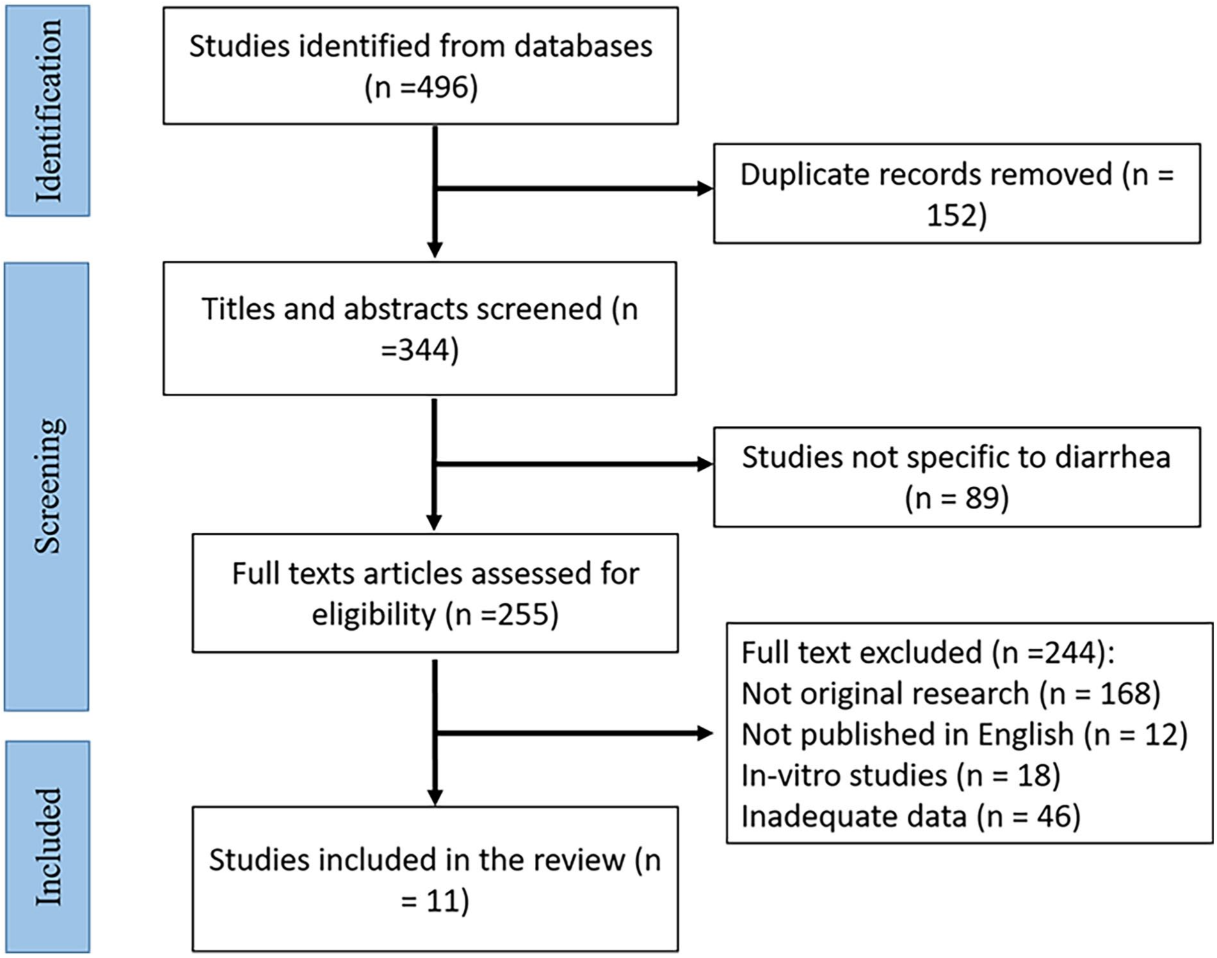

Figure 1. PRISMA flow diagram of study search and selection process.

Results

A total of 496 articles were obtained from the initial search from which 334 studies were retained after 152 duplicates were removed. Further to this, 89 irrelevant articles were excluded following title and abstract screening. After full-texts assessments, an additional 120 articles were excluded due to the following reasons: Not original research (68 articles), articles not published in English (12), in vitro studies (28), inadequate data (17). Ultimately, only 11 studies were eligible and were included in the present review.

Table 1 summarized the characteristics of studies included in the review. We identified 11 studies that independently measured associations between exposures to different environmental pollutants and diarrheal disease in humans. Three studies measured the association between diarrhea and pesticide exposure.[27-29] Two (2) studies each assessed arsenic[30,31] PAHs exposure,[32,33] and microplastics[34,35] while one (1) each assessed environmental phenols and parabens[36] and metals including Pb, Hg, and Cd.[37] Six of the studies were conducted in United States[27,28,32,33,36,37], two studies were conducted in China,[34,35] while one study each was conducted in Mexico,[29] Turkey,[30] and Bangladesh.[31] In all the studies except the report from de Silva et al,[36] exposure to the different pollutants were associated with increased risk of diarrhea. de Silva et al[36] in contrast, reported a negative association between paraben exposure and diarrhea. Xie and Lei,[37] determined the association between exposure to a group of metals (Lead, mercury, cadmium). In their report, blood cadmium levels (but not other metals) were positively associated with chronic diarrhea. Two studies measured the association between diarrhea and microplastics exposure.[34,35] The reports of these studies indicate that exposure to microplastics may play some role in diarrhea.

The results for Quality assessment/Critical appraisal for the included studies are shown in Table 2.

Discussion

This systematic review summarized available studies on the association between environmental pollutants and diarrheal diseases in humans. In general, the studys' global patterns show significant differences in research focus, with little attention paid to areas such as low and middle income countries, where pollution-related health problems are most prevalent. This supports the need for a more balanced global research approach and is consistent with findings by Kumar et al[38] on regional research contributions. The

Table 1. Summary of characteristics of included studies.

AUTHORS (COUNTRY)	STUDY DESIGN	STUDY POPULATION/ SAMPLE SIZE	POLLUTANTS IMPLICATED/METHOD OF ASSESSMENT	SOURCE OF POLLUTANTS	OUTCOME MEASURED	FINDINGS
Chen et al[27] (USA)	Prospective cohort	68 480 Participants (age not stated).	50 specific pesticides, including organochlorine and organophosphate insecticides, fungicides, and herbicides. (self-reported questionnaires)	Agricultural pesticide use by licensed pesticide applicators and their spouses.	Incidence of inflammatory bowel disease (IBD).	Exposure to specific pesticides was associated with elevated hazards of IBD
Chen et al[28] (USA)	Prospective cohort	women 35-74 y of age (n = 48 382)	(self-reported questionnaires)	residential and farm pesticide exposure	Incidence of inflammatory bowel disease (IBD).	Childhood and adolescent pesticide exposure was risk factor for IBD in adulthood
Zang et al[32] (USA)	Cross-sectional study	1348 participants age not stated	urinary PAH measured with CGC-MS	Not Stated	Self-reported incidence of chronic diarrhea	There was a clear association between PAH exposure and increased risk of chronic diarrhea
Xie and Lei[37] (USA)	Cross-sectional survey	Male and female adults aged ⩾ 20 y (N = 5265)	Metals (Lead, mercury, cadmium). (ICP-MS)	Combustion of petroleum and other fossil fuels. Incomplete burning of organic substances (eg, oil, grease, gas, and wood), Geologic formations	Diarrhea	The blood cadmium levels were positively associated with chronic diarrhea.
Bilici et al[30] (Turkey/Istanbul)	Case-control study	Children aged 6-18 y Females: (n = 80: 50 patients and 30 controls), Males: (n-80: 50 patients and 30 controls).	Blood and stool Arsenic Electrothermal (AAS)	Foods consumed daily, Drinking water	Abdominal pain	Blood and stool As values are an important marker in children with functional abdominal pain.
Wu et al[33] (United States)	Cross-sectional survey	Adults aged ⩾ 20 y 5225 males and 5312 females	Polycyclic aromatic hydrocarbons (PAHs) in urine.	Combustion of petroleum and other fossil fuels. Incomplete burning of organic substances (eg, oil, grease, gas, and wood).	Bowel disorders such as abdominal pain, diarrhea, rectal bleeding,	Exposure to PAHs was strongly linked to an increased risk of bowel disorders such as abdominal pain, diarrhea, rectal bleeding, fatigue, and weight loss in adult US population, particularly in non-obesity and female populations.

(Continued)

Table 1. (Continued)

AUTHORS (COUNTRY)	STUDY DESIGN	STUDY POPULATION/ SAMPLE SIZE	POLLUTANTS IMPLICATED/METHOD OF ASSESSMENT	SOURCE OF POLLUTANTS	OUTCOME MEASURED	FINDINGS
Cupul-Uicab et al[29] (Chiapas, Mexico)	Cohort study	Children; median age = 21.4 mo (747 boys)	p,p'-DDE and p,p'-DDT in maternal serum	Pesticide extensively applied to crops	Episodes of diarrhea	In-utero exposure to DDT and DDE were associated with an increased risk of diarrhea. The association was more significant among boy in rural areas.
De Silva et al[36] (USA)	Cross-sectional survey	Adults aged 20-80 y (N = 4721)	Environmental phenols and parabens.	Pharmaceutical preparations, self-hygiene products such as cleansers, antiperspirant, toothpastes, and soaps, along with certain food products such as marinated fish, canned products and certain processed foods	Diarrheal symptoms.	Paraben exposure (bot not phenols) was negatively associated with diarrhea.
Rahman et al[31] (Bangladesh)	Cohort study	1552 live-born infants.	Urinary Arsenic. Hydride generation AAS	Not stated	Diarrhea during infancy.	Arsenic exposure during pregnancy was associated with increased morbidity in infectious diseases such as diarrhea during infancy.
Yan et al[34] (China)	Observational cross-sectional study.	52 individuals diagnosed with inflammatory bowel disease (IBD) and 50 individuals who did not have IBD	Microplastics (measured via fecal sample analysis)	Environmental microplastics.	Concentration of microplastics in feces and its correlation with IBD severity.	Individuals with IBD had a significantly higher concentration of microplastics in their feces compared to controls, suggesting a potential link to inflammation.
Zhang et al[35] (China)	Cross-sectional study	40 participants (20 from a high-exposure plastic factory; 20 from a low-exposure park area).	Microplastics analyzed using laser infrared imaging; microbiological analysis via 16S rDNA sequencing.	Environmental samples (air, soil) from high-exposure areas, specifically near plastic manufacturing sites.	Microbiota composition	Increased levels of microplastics in high-exposure participants, altered microbial community structure associated with respiratory and digestive diseases.

Abbreviations: AAS, atomic absorption spectrometry; CGC-MS, capillary gas chromatography-mass spectrometry; IBD, inflammatory bowel disease; ICP-MS, inductively coupled plasma-mass spectrometry.

Table 2. Quality assessment for the included studies.

S/N	ITEMS	CHEN ET AL[27]	CHEN ET AL[28]	ZANG ET AL[32]	XIE AND LEI[37]	BILICI ET AL[30]	WU ET AL[33]	CUPUL-UICAB ET AL[29]	DE SILVA ET AL[36]	RAHMAN ET AL[31]	YAN ET AL[34]	ZHANG ET AL[35]
1	Study design and participants	+	+	+	+	+	+	+	+	+	+	+
2	Exposure assessment	+	+	+	+	+	+	+	+	+	+	+
3	Covariates	+	+	–	+	–	+	+	+	+	?	?
4	Statistical analysis	+	+	+	+	+	+	+	+	+	+	+
5	Outcomes	+	+	+	+	+	+	+	+	+	+	+
6	Ethical consideration	+	+	+	+	+	?	+	?	+	+	+
7	Sampling strategy	+	+	+	+	–	–	+	–	+	+	+

+, low risk of bias; –, high risk of bias; ?, unclear risk of bias.

results show that exposure to specific pollutants including pesticides such as 1,1-Dichloro-2,2-bis(p-chlorophenyl)ethene (p,p -DDE) and Dichloro-Diphenyl-Trichloroethane (p,p'-DDT), PAHs, arsenic, and cadmium may be associated diarrhea. However, there is limited number of studies for each of the investigated pollutants.

Persistent organic pollutants (POPs)

Cupul-Uicab et al[29] investigated the role of pre-natal exposure to DDT on incidence of diarrhea among Mexican boys. The study observed higher incidence of diarrhea among boys in the highest category of DDT exposure. The observed association was more significant among boys living in an urban area and was attributed to higher levels of pollution and exposure in the cities. Chen et al[27] examined the relationship between pesticide use and the incidence of inflammatory bowel disease (IBD) among a large number (68 480) of licensed US pesticide applicators and their spouses. The effect of childhood and adolescent pesticide exposure on the risk of IBD in adulthood was also assessed.[28] In their report, childhood and adolescent pesticide exposure was observed to be a risk factor for IBD in adulthood.

A proposed major mechanism (Table 3) by which pesticides may cause diarrhea is by their cholinergic effects, especially those of carbamates and organophosphates.[39] The enzyme acetylcholinesterase, which breaks down acetylcholine, a neurotransmitter essential to many physiological functions, including gastrointestinal motility and secretion, is inhibited by cholinergic insecticides.[40] Acetylcholine builds up in the body when acetylcholinesterase is blocked, which causes cholinergic receptors to become overactive. Numerous cholinergic consequences result from this overactivation, including enhanced motility of the gastro intestinal tract. The smooth muscles of the gut are stimulated by elevated acetylcholine levels, which increases peristalsis and gut motility. Due to the food passing through the digestive system quickly and not having enough time to be absorbed, this may cause diarrhea.[41] In addition to causing diarrhea, the overactivation of cholinergic receptors also causes increased gastrointestinal secretions of water and electrolytes. Persistent Organic Pollutants can also imitate or interfere with the body's normal hormone functions. This endocrine imbalance may impact the gastrointestinal tract, resulting in modifications to its motility, secretion, and absorption, which may give rise to diarrhea. POPs can weaken the immune system and induce inflammation, which increases the gut lining's permeability.[42] This may lead to the circulation being exposed to toxins and partially digested food particles, which may cause diarrhea and an immunological reaction. POPs are lipophilic (fat-soluble) and can accumulate in fatty tissues in the body, including those involved in nutrient absorption. This can disrupt the normal absorption and utilization of essential nutrients.[43,44] The gut microbiome can be altered by exposure to POPs, which can affect the ratio of harmful to helpful

Table 3. Comparative analysis of specific mechanisms for each pollutant.

POLLUTANT TYPE	MECHANISM	SPECIFIC PATHWAYS AND EFFECTS	REFERENCES
Persistent Organic Pollutants (POPs)	Cholinergic effects	Carbamates and organophosphates inhibit acetylcholinesterase, causing acetylcholine build-up, leading to overstimulated gut motility and increased secretions. This results in diarrhea due to rapid peristalsis and inadequate absorption time for nutrients.	Chen et al[27,28]; Cupul-Uicab et al[29]
	Endocrine disruption	POPs mimic or disrupt hormone function, altering GI motility and secretion. This hormonal imbalance can increase the risk of diarrhea.	
	Immune response and inflammation	Immune suppression and inflammation from POP exposure increase gut permeability, allowing toxins to circulate and leading to diarrhea and immune reactions.	
Polycyclic Aromatic Hydrocarbons (PAHs)	Enhanced permeability and inflammation	PAHs can induce inflammation in the gastrointestinal tract, leading to a damaged gut epithelium and loss of water/electrolytes.	Zang et al[32]
	Microbiome alteration	Alterations in gut microbiome composition affect nutrient absorption and short-chain fatty acid synthesis.	
	Oxidative stress	Induces inflammation and impairs gut epithelial function, contributing to diarrhea.	
Heavy Metals (eg, Arsenic, Cadmium)	Gut Microbiota Disruption	Heavy metals alter microbial populations, causing dysbiosis which can lead to chronic diarrhea or constipation.	Bilici et al[30]; Rahman et al[31]; Xie and Lei[37]
	Inflammation and Permeability	Prolonged inflammation increases gut permeability, allowing for nutrient loss and toxin absorption.	
	Oxidative Stress	Induces further inflammation and impairs intestinal barrier function, exacerbating gastrointestinal disturbances.	
Microplastics	Chemical Leaching	Microplastics can release toxic compounds into the gastrointestinal tract, increasing inflammation and permeability.	Bergmann et al[63]; Eerkes-Medrano et al[66]
	Microbiome Imbalance	Alters gut microbiota composition, leading to dysbiosis associated with diarrhea.	
	Physical Injury	Can cause physical damage to the gut lining through entanglement or ingestion, resulting in further complications.	
Parabens	Antimicrobial Activity	4-tert-octylphenol reduces competitive ability of beneficial gut microbes, allowing pathogenic microorganisms to thrive and potentially leading to inflammatory bowel disease (IBD).	De Silva et al[36]
	Gut Microbiota Impact	Alters microbial balance, which may correlate with symptoms like diarrhea.	

microorganisms. This may interfere with the gut's regular operation and result in diarrhea.[45]

Polycyclic aromatic hydrocarbons

Two large studies among US population[32,33] observed significant associations between diarrhea and urinary PAHs. The study by Zang et al[32] established an exposure-response relationships for each of the PAHs measured. One of the studies[33] further indicated that patients with previous history of heart issues, thyroid issues, or tobacco use were more susceptible to the toxic effects of PAHs and, consequently, had a higher risk of developing diarrhea. The association between PAHs and diarrhea remained significant even after controlling for variables such as gender and BMI.[33]

Diarrhea is caused by the loss of water and electrolytes due to enhanced permeability. One important barrier that controls the passage of chemicals through the gut lining is the gut epithelium (Table 3). The stomach becomes more permeable when this barrier is damaged by inflammation, which can lead to diarrhea by enabling toxins to be absorbed and vital nutrients to be lost.Most PAHs are lipophilic and can therefore be easily absorbed by the intestines.[1] Polycyclic aromatic hydrocarbons have the potential to induce inflammation in the gastrointestinal tract, which may result in increased permeability of the gut epithelium, water and electrolyte loss, and diarrhea.[46] In addition, PAHs could modify the gut microbiome's makeup, which can impact food absorption and the synthesis of short-chain fatty acids[44]). Furthermore, oxidative stress caused by PAHs has the potential to aggravate inflammation and impair the normal function of the gut epithelium.

Metal(loid)s

Bilici et al[30] determined the association between blood and stool As levels and abdominal pain among a sample of Turkish children and adolescents. The study reported that blood and stool As levels are important markers in children with functional abdominal pain. Rahman et al[31] reported that in-utero As exposure was associated with increased morbidity in infectious diseases such as diarrhea during infancy. In another study, Xie and Lei,[37] examined the connection between heavy metals and persistent diarrhea and constipation using 3 separate statistical techniques. The Survey-weighted generalized linear models (SVYGLM) as well as weighted quantile sum (WQS) regression all revealed a positive association between blood cadmium levels and chronic diarrhea. Furthermore, a linear dose-response relationship between the prevalence of chronic diarrhea and cadmium levels in the blood was observed.

There is growing evidence that heavy metals have a significant impact on gut microbiota (Table 3). For instance, exposure to cadmium has been shown to significantly alter the gut microbiome of mice.[47–49] Gao et al[50] highlighted that exposure to lead can result in altered gut microbiome as well as adversely affect its metabolic processes. According to a recent study,[51] children who are exposed to metals concurrently may develop microbial population profiles that are differentially abundant. Thus, chronic diarrhea or constipation may result from the disruption of gut microbiota and homeostasis by heavy metal poisoning. Furthermore, exposure to heavy metals (like lead, mercury, and cadmium) can result in prolonged inflammation (increased levels of IL-6, IL-8, and tumor necrosis factor), which may raise the permeability of the gut epithelium and contribute to the development of diarrhea.[16,52-54] Another important way that heavy metals may cause diarrhea is by impairing the function of the intestinal barrier, induction of oxidative stress, which may worsen inflammation, change the gut microbiome's diversity and composition, interfer with normal gastrointestinal function, and may hinder the absorption of nutrients leading to diarrhea.[55] Arsenic toxicity causes immunosuppression in neonates.[56-58] Exposure to arsenic results in reactive oxygen species, which lead to oxidative stress and immune system dysfunction.

Microplastics

Microplastics, defined as plastic particles smaller than 5 mm, are recognized as a significant environmental threat due to their widespread presence in both marine and terrestrial ecosystems.[59,60] The growing number of microplastics found in various ecosystems as well as their capacity to withstand prolonged exposure to the environment without experiencing appreciable deterioration emphasizes how critical it is to study and comprehend their effects on human safety and environmental health.[60,61] Research has found microplastics in a variety of foods, such as seafood, beer, and drinking water.[62]There is growing concern that ingestion of microplastics may cause inflammatory reactions or other negative health impacts. The reports from 2 of the reviewed studies indicated that increased exposure to microplastics may alter microbial community structure associated with respiratory and digestive diseases.[34,35]

Microplastics, like other environmental contaminants, may alter the composition of the gut microbiota (Table 3).This change may lead to diarrhea, which is associated with dysbiosis—a condition characterized by an imbalance between beneficial and harmful bacteria in the gut.[63] Furthermore, inflammatory reactions induced by microplastics in the gastrointestinal tract can compromise the integrity of the gut lining, increasing its permeability.[63] This enhanced permeability facilitates the passage of harmful chemicals across the intestinal walls, exacerbating gastrointestinal disturbances. Further, microplastics can absorb other toxic compounds including pesticides and heavy metals, making them even more toxic to life and can leach these toxic compounds into the gastrointestinal environment.[64,65]This chemical leaching may further heighten inflammation and contribute to gastrointestinal issues such as diarrhea.[66] As research in this area continues to evolve, understanding the effects of microplastics on gut health and overall well-being becomes increasingly crucial.

Parabens

DeSilva et al[36] showed that a decrease in the frequency and chronic bowel leakage—2 common symptoms of IBS-D—seems to be significantly correlated with increased exposure to parabens and o-phenyl-phenol. Even though there was little overall exposure to these substances, those who self-reported having diarrheal symptoms showed a significant drop in their levels. In the study, 4-tert-octylphenol levels were linked to a higher incidence of inflammatory bowel disease among the participants who self-reported having IBD (Table 3). The gut microbiota is negatively impacted by 4-tert-octylphenol's antimicrobial activity, which reduces the gut microbe's ability to compete, which gives pathogenic microorganisms the ability to potentially suppress and modulate the immune system.[67]

Limitations of the included studies

The study by Rahman et al[31] has several drawbacks. Results were categorized based only on reports of the mother's symptoms. No measurements were recorded of the infants' exposure to Arsenic. In addition, there were insufficient details regarding other potentially dangerous substances in food and water. Conclusions of the study by de Silva et al[36] revealed their data were self-reported and the database utilized lacked corroborating medical records. Although Xie and Lei,[37] were unable to completely rule out confounding variables, they made good efforts to reduce their influence by adjusting for additional covariates such age, education, race/ethnicity, PIR, BMI, and marital status. There are various drawbacks to the research on the relationship between inflammatory bowel disease (IBD) incidence and pesticide exposure in children and adolescents by Chen et al.[28] Self-reported data may be the source of recall bias, which causes inaccurate recall of prior exposures. The cohort's limited generalizability stems from the women's familial history of breast cancer. Some subgroup analyses didn't have enough sample sizes to draw reliable findings. Unmeasured confounding variables could impact the results, and the study might have included only some pertinent pesticide kinds and environmental exposures. Furthermore, the research's observational design needs to be revised to establish clear causal links. Other inherent limitations in the reviewed studies included the use of small sample size, potential confounding factors not controlled[34] and potential biases in participant selection and environmental exposure assessment.[35]

This systematic review on the impact of environmental pollutants on diarrhea has several limitations. There is significant heterogeneity in study designs and pollutant measurements, making comparisons difficult and findings potentially less generalizable. Publication bias and variable data quality may also skew results. The review focuses on specific pollutants, potentially excluding relevant contaminants, and may lack insights into biological mechanisms. Geographic, temporal, and language biases further limit comprehensiveness. Additionally, many studies are cross-sectional, hindering causal inference, and often do not fully account for confounding variables. The exclusion of non-English studies and the reliance on observational data due to ethical constraints add to the limitations. More rigorous, longitudinal research is needed to clarify these associations and inform public health strategies.

Conclusion

This systematic review provides a comprehensive analysis of the relationship between environmental pollutants and the incidence of diarrhea, emphasizing a critical public health issue that disproportionately affects vulnerable populations, particularly in low- and middle-income countries. The findings reveal a concerning association between exposure to various environmental contaminants, including pesticides, heavy metals, microplastics, and polycyclic aromatic hydrocarbons (PAHs), and diarrheal diseases. Notably, prenatal exposure to DDT was associated with higher diarrhea rates among boys in urban settings, while childhood pesticide exposure correlates with inflammatory bowel disease in adulthood. Despite these alarming findings, the review identifies significant gaps in the existing literature, particularly regarding geographic disparities in research focus. Most studies are concentrated in high-income regions such as the United States, with limited data from low- and middle-income countries where pollution-related health issues are most prevalent. This geographical imbalance not only limits the generalizability of findings but also overlooks unique risk factors faced by populations in developing regions. The review underscores the urgent need for targeted public health interventions aimed at reducing exposure to these toxic substances. Pollutant monitoring, implementation of health-centered regulatory actions and promotion of interdisciplinary collaboration among researchers, policymakers, and public health officials are paramount for developing effective strategies to combat diarrheal diseases linked to environmental contamination. By addressing these critical gaps in knowledge and fostering integrated research efforts, we can work toward sustainable health practices that reduce the global burden of gastrointestinal disorders.

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Author Contributions

Authors contributed equally.

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

Not applicable.

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Data Availability

All data used for this current study are included in the article.

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