

The Impact of Environmental Pollution on Human Health: A Review of Pathophysiological Mechanisms and Medical Implications

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Annotation: Considering the severe impact of environmental pollution on human health, this essay reviews the relevant studies to elucidate the pathophysiological mechanisms and suggests that addressing environmental pollution would bring broad medical and public health implications. The surroundings of individuals and of the environmental condition in which they live have a significant influence on health. Besides the concern of man and the other elements in the environment, there is the consideration of bacteria, viruses, and chemicals, which may adversely affect health. From a health perspective, morbidity and mortality may result from exposure to various pollutants. The environment can also provide therapeutic benefits, including those from natural settings. Environmental problems may contribute to

physical, mental, behavioral, and social health problems.

Health may be directly influenced by lifestyles, occupations, genetic inheritance, and health care, and it could be indirectly influenced by the environment. A significant contamination in environmental quality requires the dissemination of information, public vigilance and discussion, and activism to recognize its importance in health. Concentrated health threats and pollution, in its different forms and by different paths, could harm health, with implications for the nervous system, endocrine system, reproductive system, cardiovascular system, renal system, immune system, skin, and various other diseases. Since medical studies first investigated the harms and brought health implications into the public sphere, penalties for major contaminations have prevailed. In that sense, public health policies and regulations may address environmental contamination, thereby protecting health by minimizing pollution. Moreover, there is a growing body of evidence revealing the association of substances released into the environment by numerous human activities with major health problems. Based on the data described, it is shown how urgent it is to apply stricter measures to contain the environmental and pollution problem. Thus, this paper elucidates the pathophysiological mechanisms of the impact of environmental pollution on health and suggests broad medical and public health implications.

Keywords: Environmental pollution, human health, pathophysiology, oxidative stress, public health, air pollution, water contamination, soil pollution.

1. Introduction

In the search for vocation, individual activity, and easy money, people keep locked themselves in buildings, cars or offices, feeling the concern of being poisoned by air. They become depressive when polluted mist descends on green meadow or when on waking, instead of the song of a nightingale or lark, they hear choirs of mosquito-fighting helicopters [1]. And they are surprised by the beauty of a piece of land lying between the powerful winds of two oceans or two arms of the sea. Such land is Cape Horn, in the south of Chile, where dies the Latin-American continent,

maimed of folly by the knife of the Panama Canal. Cape Horn reminded us of these forgotten links. So, then, let it be a point of conjunction between that vocation returned to, that individual activity that nourishes us since the first time in history that man tilted in front of a fire, and that despised land easy to conquer. Ample space has been devoted in literature to define the aspects of water and air pollution as well as pollution in a more extended way, like those embodied in the definition of “growing waste of natural resources and consumption of Energy”. These aspects exert mostly interdisciplinary effects that appear evident, striking and already well stigmatized both from the technological and the socio-economic points of view. Man has an attitude, often quite maledicent, to rely on goods and benefits resulting from the over-exploitation of nature, from pollution, from anti-hygienic living conditions. However, what is actually worth attention is by no mean only the effects of the overall ecosystem decline on man’s life, but also a string of less evident, less dramatic aspects, infiltration much more deeply to the very nerves of today’s technological society and questioning its bases in a much more radical way. Economizing, energy saving, fighting waste, up to explore how data banks can be useful in land conservation, gardening and agriculture and curling lifestyles and quality of life so that energy consuming goods can also be dispensed with. The examination of the wider field of effects of pollution on Health shows a remarkable range of the action, with environmental factors contributing significantly to different illness, disease prevalence and possibly morbidity and mortality peculiar aspects of the growth and moving of the populations now live inside technologically advanced and evolved countries. In turn, these effects are evidence to have deep and far reaching impacts on different sides of existent social and economic structures. In these respects many misconceptions exist that seem to be overcome by some effort to a broader multi-disciplinary examination of the Health-Pollution-Development web involved. This contribution is devoted to exploring a wider, more universal and less constrained views on pollution aspects and in part memorable outcomes resulting from a quite vast amount of experience and research in this sector. The wide spectrum of mechanisms at the base of pollution-related Health effects, from individual mechanisms/effects to those of a whole community or urban areas is examined with special reference to the contribution of the Center for Advanced Bio-chemical Sciences in this pattern of research. The standard epidemiological approach is criticized and auxiliary research tending to explore mechanisms and effects, that may be better monitored and predicted is advocated. [2][3]

Literature Review

2. Types and Sources of Environmental Pollution

The environment is increasingly threatened today by various factors, the most dangerous of which is anthropogenic impact. Anthropogenic is determined as an impact that occurs as a result of human activities. For example, the contamination of the environment with various toxic substances is a direct result of such an impact. In addition to humans themselves, there are other sources of pollution, including natural ones. There are three main types of environmental pollution as a whole: air pollution, which is the most common type in the current environmental landscape; water pollution, which is one of the biggest problems in the environmental degradation of water bodies; soil pollution—the existing variety of harmful substances penetrating the soil layers from the surface and strong accumulation in soil and biotic components, thereby causing food contamination and damage to living organisms. The majority of diseases of various vital systems, developing or exacerbating, are directly or indirectly related to environmental pollution. Air, water, and soil pollution are observed to be anthropogenic and, at the same time, closely interconnected. Air pollution, in addition to deteriorating atmospheric conditions, is often a cause of both water and soil pollution. In its turn, water pollution tends to have a bad impact on soil and air quality. In the industrial sphere, for instance, water is used for various purposes, including the chilling of production facilities. Subsequently, used water is drained into water bodies, containing a variety of heavy metals and other toxic substances absorbed from production. Consequently, the risk of soil contamination exists, since various

enterprises have developed near agricultural lands. Thus, environmental pollution often becomes not only an inseparable companion to industrial enterprises but also a component feeding each other. In the agricultural sector, the existing heavy use of a variety of pesticides, herbicides, and other dangerous chemicals is then transferred to soil and groundwater. As a result, not only does soil contamination about these substances occur but also their spread by employment of irrigation water in agriculture. Soil contaminated with harmful chemicals puts an end to the sustainable development of agriculture. It plays an important role in the food chain, with the subsequent risk of entering the human body and causing irreversible adverse effects [1]. Since these three types of contamination are the most significant and directly affect human health, a thorough classification is presented here. [3][4]

2.1. Air Pollution

Air pollution generally refers to the contamination of the environment with hazardous substances that pollute the atmosphere. This is mainly caused by fumes and exhaust gases from vehicles and the extensive operation of industries. The atmosphere is polluted when air is contaminated by harmful substances including particulates, nitrogen oxides, and sulphur dioxide. Particulate matter is a complex mixture of solid and liquid particles suspended in the Earth's atmosphere. It has varying chemical composition and size. Generally, it is classified as fly ash generated by power plants, industrial operations, and vehicular emission; and suspended particulate matter generated from vehicular emissions and industrial processes. Nitrogen oxides are gases consisting of nitric oxide (NO) and nitrogen dioxide (NO₂). Their primary source is from the exhaust of vehicles and the operation of power plants. While, secondary sources include vehicular emissions, industries operations, and photochemical reactions in the atmosphere. Sulfur dioxide (SO₂) is a gas primarily generated from the combustion of coal. Emissions from the industrial sector, and thermal power plants are major sources of sulfur dioxide. [5][3]

Different gases can harm human life and the ecosystem. Prolonged exposure to air pollutants can potentially damage the respiratory system and can cause diseases such as bronchitis, asthma, or an increase in respiratory allergies. Air pollution such as persistent visibility affecting aerosols and an increase in the concentration of gases can affect human health. It can deposit and accumulate pathogens in the respiratory system, leading to a series of pathologies from inflammatory processes through carcinogenesis. Pathogens in the respiratory system can move and generate various diseases. Persistent respiratory diseases such as difficulties in breathing, sneezing, and coughing can be amplified to a level where they may generate permanent diseases like chronic bronchitis or asthma. Moreover, recurrent respiratory infections can occur in children and adults after extended exposure. They can also influence damage caused by air pollutants or long-term pathological deposition. Lower respiratory infections can cause death in children, especially in regions with inadequate treatment, a high concentration of air pollutants, and malnutrition. However, growing concerns about pollutants, especially those related to the respiratory system, are considered the ones that affect many people in a very individual way. Industrial development, urban expansion, dense traffic, and the increase in the number of oil-fired thermal power plants are very unfavorable, as the waste they produce directly affects the environment with major consequences on human life. If a detailed examination is conducted, then it is revealed that emissions, mostly composed of hazardous substances like lead, carbon monoxide, sulphur, nitrogen compounds, aerosols and gases would be in an uncontrolled way. These gradually act on ambient air, soil and water together with the disastrous effects generated [6].

2.2. Water Pollution

The global environment is constantly polluted by various hazardous substances with pathophysiological effects on human health, due to the anthropogenic release of world production and consumption. These substances range from air and drinking water impurities, produced water from the extraction of mineral resources; solid waste from mineral extraction

industries; airborne ashes produced by spontaneous combustion of coal and vehicular traffic; noise from industrial activities, urban traffic, and leisure; pesticide use to contaminated sites and hospital waste. For incorporating this environmental pollution concern, traditional elements and compounds, a model illustrates a human embryo on gauge copper wires symbolizing the placental transfer route from contaminated tap water to human or animal organisms.

Water pollution has major health implications. Contaminated water is used for drinking and domestic purposes by unknowing people. The pollution of safe water sources by a pathogenic population for open defecation allows pathogens to enter water bodies [7]. The presence and growth of pathogens in water sources depend on environmental factors, such as distance from the source of pollution, land usage pattern, soil type, vegetation, population density, leisure activities, animal husbandry, and evidence. Pathogens are introduced into the water body through sewage and waste discharge [8]. They remain there together with humans and infect the other organisms that come in contact. Millions of people suffer from water-borne diseases. In some developing countries, the population has no other choice but to take pathogens unnecessarily, while in other developed countries, it may be due to treatment failure. Water-borne diseases are on the rise, even some under developed nations suffer every year. The World Health Organization estimates that about 80 percent of all diseases spread over water. In developing nations, 90% of water supply is hydrological diseases such as typhoid, cholera, and gastroenteritis. Every year epidemic cholera occurs in many countries through contaminated water. More than 100,000 yearly cholera cases have been reported in a large number of populations in Bangladesh, due to medical waste removal or fearful water samples containing coliforms and fecal bacteria from hospital waste water. The monitoring of microbiological parameters shows that water samples require adequate bacteriological control actions.

2.3. Soil Pollution

Soil is a fundamental component of the life cycle on Earth and is the natural habitat of many organisms. However, since soils have both organic and inorganic constituents, any element or compound present in a surface area may be present on the soil. Risk contaminants are the chemical or physical forms of an element or compounds that are dangerous to organisms. There are major sources of soil pollution in the environment. Industrial activities such as mining and smelting all contribute to the presence of heavy metals in the surrounding area. Use of agricultural chemicals, excessive artificial fertilizations, or irrigation with contaminated water create dangerous levels of pesticides and organic pollutants in the soil. Contaminated waste disposal seeps toxic substances into the soil, and the risk of contact increases when working on agricultural land. Also, since soil waste is often used for the cultivation of fruit and vegetables or in the proximity of water sources for livestock or personal use, humans are open to bacterial-polluted microorganisms, viruses, and a number of parasites. In terms of health effects, contaminants in the soil can cause acute or chronic toxic effects as well as physiological disorders. All of these pollutants, if taken up by soil organisms, can enter the food chain and be taken up by crops. This is particularly the case with heavy metal and persistent organic pollutants, as they have toxic and carcinogenic effects. Especially, these contaminants have the potential for bioaccumulation. When plant uptake of these substances results in a concentration higher than that of the soil, the effects extend beyond the food chain and act on the integration of the entire ecosystem. In addition to these factors, pollution is carried to drinking water when pollutants reach the soil groundwater. Then, drinking contaminated water is the most common way of introducing these dangerous substances into the human body. Groundwater contamination can cause many health effects for both humans and animals, including bacterial, viral, and parasitic diseases, as well as those caused by the presence of anthropogenic chemicals. Long-term exposure to heavy metals of arsenic, lead, chromium or cadmium can cause serious damage to the health of adults and their offspring [8]. Agricultural workers are particularly exposed to contamination, depending on the use of pesticides, fertilizers, and contaminated water during farming. Especially when the contact with contaminated soil is direct, the risk of exposure

increases considerably. The use of protective equipment and the adoption of safe agricultural practices on polluted soil are effective ways of reducing exposure. Sustainable soil management practices can help prevent soil pollution by protecting soil and water resources through the adoption of non-chemical management of agricultural land. The sustainable management of the soil takes all of the fundamental processes taking place in the soil into account, focusing on better soil structure, better organic matter cycling dynamics, and the ecosystem services provided by the soil. Actions in the name of a more productive and healthy soil ensure the regeneration and stability of the soil, safeguarding water reserves and producing high-quality crops. Thus, managerial practices should include the return of organic fertilizers and pesticides to the soil, crop rotation plans, maintaining a neutral pH of the soil, and avoiding water sources in agricultural activities near polluted areas. Since soil health is a prerequisite for ecologically sustainable food production and overall ecosystem and human well-being, it is crucial to address issues related to soil contamination and to promote sustainable soil management techniques for a living and healthy soil. Ultimately, soil pollution is a significant, but frequently neglected threat to public health with circumlocutory widespread impacts on all members of society that necessitate an instant and comprehensive solution approach. [9][10]

Materials

3. Pathophysiological Mechanisms of Environmental Pollutants

A growing body of evidence suggests both air and water pollutants can enter body organs and circulation, disrupting normal physiological processes. The understanding of these pathophysiological responses is critical for clinicians to confront emerging environmental health issues. Further, to tackle health problems caused by environmental pollution, there is an urgent need to decipher the links between pollutant exposure and pathophysiological changes. One of the greatest health challenges of the modern world is exposure to environmental stressors. Representatively, air, water, and soil pollution have a wide range of health risks affecting nearly every function and system in the human body [11]. Either fine particulate matter (PM_{2.5}) or gaseous pollutants, such as nitrogen dioxide (NO₂) and ozone (O₃), can easily infiltrate the circulatory system and then accumulate in other organs, inducing oxidative stress, inflammation, and DNA damage responses.

Groundwater reservoirs contaminated by heavy metals, pesticides, or solvents can endanger human health through the irrigated food chain or direct ingestion [12]. The situation becomes dramatically worse in developing countries, where the implementation and enforcement of strict standards is lacking. Although the exact exposure mechanism may depend on the type of contaminant, evidence indicates both heavy metals and organic pollutants can enter the systemic circulation via the gastrointestinal and pulmonary tracts, especially in the chronic exposure scenario. The organ distribution is largely influenced by blood flow and lymphatics, resulting in bioaccumulation and interaction with other biologically active molecules. In light of the enormous amount of recent evidence, this review attempts to provide a comprehensive analysis of the pathophysiological responses to environmental pollutants. Using practical examples and integrating multiple points of view in a systematic manner, it identifies critical mechanisms governing the impacts of pollutants at both the molecular and cellular level. Given that genetic polymorphisms may directly regulate the response of the environmental stressor, the toxic effects are evaluated in the context of individual genome characteristics.

3.1. Respiratory System

The respiratory system is the most vulnerable in terms of pollution, both indoor and outdoor. The most serious is the exposure of the airways to polluted air. In fact, the problems of polluted air can have serious long-term effects. Air and land pollution have a direct and indirect impact on lung pathology and can exacerbate the existing lung damage. In developed countries, eliminating tobacco, isolating fireplaces, and securing vehicles that run on gases have caused a significant decrease in the incidence of respiratory infections. However, with the expansion of companies

and vehicles that use fossil fuels in developing countries, there has been an increase in respiratory diseases. In addition to industry and transport emissions, increasing traffic jams in major cities are made without studies regarding the consequences of the traffic. Furthermore, the construction of new buildings, when it takes place near the airways of the main city and it consists of scraping the façade of the old building, can also cause air and water pollution. The need for preventive measures such as covering the work, watering the places with water before the work and obliging the crew to wear protective masks is recommended [6]. Incomplete combustion of gasoline produces particles of various sizes suspended in the air. Some are fine enough to reach the alveoli where they can produce considerable irritation. Fine particles are much more dangerous than larger ones, as they spread more easily. Some toxic metals are constituents of particles that are easily retained in the air. Co-particulates also contain irritant hydrocarbons that produce spastic effect on the airways. Furthermore, SO₂ and particulate matter can enhance the effects of allergens on a patient with allergic asthma, and this is a clear proof for those who do not consider air pollution as a factor that exacerbates bronchial asthma. Some suggest as an argument the significant increase in the incidence of this disease in many cities, an increase that was used until recently geographical information indicating the most polluted cities [13].

3.2. Cardiovascular System

The cardiovascular system, a critical area of concern in public health, is impacted by environmental pollutants. There is a strong body of evidence that a wide range of mechanisms are involved in the cardiovascular effects of environmental exposure. Among numerous components of air pollution, there has been a special focus on the role of particulate matter and heavy metals in the pathogenesis of cardiovascular diseases. It is stated that exposure to pollution increases the risk of cardiovascular diseases through inflammation, oxidative stress, acute thrombosis, and neurogenic changes. On the other hand, hypertension and diabetes are recognized complications of environmental exposure. There is a growing line of research that deals more specifically with these mechanisms and with related conditions such as endothelial dysfunction. Increases in both morbidity and mortality from cardiovascular diseases have been strongly linked to air pollution. This can be partially attributed to causal components of air pollution, but it also seems that pollution exposure can alter preexisting risk conditions, and this has been found even at relatively low-level exposure. In developing countries or rapidly industrializing economies, the negative impacts of pollution on the cardiovascular system could be significantly higher because of the confluence of multiple risk factors [14]. Human exposure to environmental pollution is postulated to take a major toll on global health. This can be attributed to the vast range of pollutants, the various pathways of exposure, and the equally wide range of adverse outcomes. There has been a vast amount of work aimed at understanding the pathophysiological and toxicological mechanisms underlying the health impacts of pollutants. However, there is a less extensive (but expanding) body of research that takes a systems approach to the health impacts of environmental pollution noting that no single part of the organism functions in isolation. Growing concern regarding the impact of environmental pollution on public health underscores the importance of understanding the full range of health outcomes from exposure. This is particularly pressing given that the most vulnerable populations are the elderly and those harboring preexisting health conditions. The aim of this review is to provide a general understanding of the mechanisms through which a range of environmental pollutants (water and air) affect human health with a focus on pathophysiological mechanisms and medical implications with a primary interest in comorbidities. Substantial knowledge has been gathered on the adverse health effects of diverse environmental factors, and this review hopes to stimulate focused efforts on the multiple pathways that lead from exposure to health outcomes.

3.3. Neurological System

The neurological system is highly sensitive and can be affected by different types of

environmental contaminants. The range of effects of environmental contaminants on the brain is wide and encompasses acute alterations revealed in behavioral and morphological changes, as well as chronic changes leading to neurodegenerative diseases. Both animal and human studies show that exposure to air pollution can penetrate the brain and lead to inflammation and oxidative stress, with these two effects standing out as a common and fundamental aspect of air pollution damage to the nervous system. Moreover, changes in the central nervous system's (CNS) morphology and behavior are common to different species, with animal studies using mice, rats, and monkeys that are still exposed to air pollution [15]. A variety of behavioral alterations, such as risk-aversion, deficits in memory and learning, as well as changes in some neurotransmitter systems, such as acetylcholine, dopamine, and glutamate, have also been reported. Links have been proposed between air pollution and such diverse neurological effects such as changes in numerical skills, anxiety, depression, autism, an increase in risk of suicide, seizure activity, and schizophrenia [16].

Brain response to air pollution includes increased signaling associated with inflammation and it also includes the manifestation of neurotoxic effects. While neuroinflammation is a common feature of several neurological diseases, the increased signaling of this mechanism in response to air pollution is cause for concern since it appears to be excessively and precociously triggered. Despite evidence of brain effects of air pollution and epidemiological studies linking exposure to increases in morbidity and mortality, measures to reduce emissions, and consequently exposure, have mainly been centered on decreasing exposure to particles polluting the air, but with very slow results. Furthermore, a substantial amount of the pollutants that reach the atmosphere are not easily characterized, so it is crucial that biomedical research provides a better understanding of the effects and mechanisms by which different air pollutants operate in order to hasten the adoption of more effective protocols in curbing both emissions and exposure. [17][18]

Methodology

This study employs a systematic literature review to analyze the impact of environmental pollution on human health, focusing on pathophysiological mechanisms and medical implications. A comprehensive selection of peer-reviewed journal articles, reports, and scientific studies published in reputable databases such as PubMed, ScienceDirect, and Scopus was conducted to gather relevant data. The inclusion criteria prioritized studies published within the last decade that specifically examined air, water, and soil pollution and their physiological effects on human health. To ensure the reliability of sources, only studies with empirical evidence, quantitative data, or strong theoretical frameworks were considered. Data extraction was performed to identify common pollutants, their exposure pathways, and the health conditions they induce, with a focus on respiratory, cardiovascular, neurological, and immune system disorders. A thematic analysis was employed to categorize findings based on pollutant type, health effects, and proposed mitigation strategies. Additionally, comparative studies were examined to highlight variations in pollution-induced health risks across different geographical and socio-economic contexts. The synthesis of results was guided by a multidisciplinary approach, integrating perspectives from environmental science, toxicology, epidemiology, and public health. The methodological rigor was ensured by cross-referencing multiple studies to validate patterns and trends. The analysis aimed to bridge the existing knowledge gap by providing a consolidated understanding of the physiological mechanisms through which pollution affects human health, ultimately supporting the formulation of evidence-based policies and medical interventions to mitigate environmental health risks.

Results and Discussion

4. Medical Implications and Health Outcomes

Environmental pollution poses direct and indirect health risks to humans, with a growing body of scientific evidence addressing the pathophysiological mechanisms by which pollutants can contribute to the onset of a number of conditions [1]. Despite environmental pollution-related

health outcomes being less known by healthcare professionals, it is fundamental for clinical practice to foster greater awareness and to adequately diagnose and manage diseases that might be related to air pollution exposure. In this regard, it is noteworthy that while primary prevention through air pollution reduction remains the mainstay of control, healthcare sectors have a critical role in secondary prevention. Damage from chronic exposures could be attenuated or even reversed by timely interventions once clinical signs appear, requiring early detection and proper management. Targeted analyses exploring the causality between air pollution exposure and health should further underlie the impact of environmental chemicals on humans, ultimately informing potential interventions at the individual level. Recently, with the support of technological advancements, evidence of the harmful effects of air pollution at the individual level is emerging; therefore, this might be the right time to harmonize efforts across physicians, environmental practitioners, public policy, and local communities in shaping a global approach to the management of air pollution exposure. Pollution-related health outcomes are still not well recognized among healthcare workers. Nevertheless, these outcomes are increasingly being documented. The Wuhan Covid-19 disease outbreak of 2019 highlighted the importance for medical professionals to be aware of potential new, and emerging pollution-related health consequences, since a failure to recognize them could expose healthcare systems to a bigger burden than necessary. Thus, a timely and adapted response from medical professionals is required to overcome the specific health challenges arising from air pollution exposure. In addition to fostering awareness regarding air pollution risks among the worldwide public health community, a multidisciplinary approach that simultaneously combines the aforementioned actors could further empower public health initiatives amidst the need for urgent action. Successful intervention strategies traditionally encompass environmental policies and regulations. Case studies that specifically involve an active role of medical professionals for raising the awareness and the health conditions of local communities could further underline the importance of a combined, harmonized effort in mitigating the health consequences of air pollution exposure. [3][5][19]

5. Conclusion and Future Directions

Consideration of different types of environmental pollution and their pathophysiological mechanisms is necessary to identify those populations at higher health risks. Additional in-depth clinical research on pathophysiological mechanisms is important to accelerate the discovery of new treatments or interventions. The earth is our common home. One burning issue of our time and the next generation is to improve the environment and seek sustainable development. Atmospheric and environmental pollution is one of the most significant issues affecting human health. The World Health Organization estimates that 4.2 million deaths each year are caused by exposure to outdoor air pollution, and that air pollution is now the world's largest single environmental health risk. In recent years, a growing body of scientific studies have explored the underlying pathophysiological mechanisms of PM_{2.5}-related diseases. However, how to stop all kinds of pollution and protect our environment remains to be solved. Relevant government departments should establish and perfect clean air action plans and zero growth in soil pollution programs as soon as possible. It is also necessary to strengthen the comprehensive management of air, soil, and water pollution. The wide action of the world will be necessary to reduce manufacture pollution, and to enhance environmental cure is needed to avoid contaminative financial activities. Physicians and health management departments need to pay attention to increasing social concern about the health risks of environmental pollution. The health risks of environmental pollution and measures to protect human health should be promoted continuously. Only by common efforts can people avoid environmental pollution and protect human health. Concerns were raised that only severe bias toward the wider dissemination of outcomes showing positive or statistically significant results risks generating spurious evidence. That methodological research is needed for the development of analytics for countering such bias is also shown.

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