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Environmental Risk Assessment

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FOREWORD

Environmental pollution is a major issue affecting both industrialized and developing countries. According to some recent studies, there are more than five million contaminated sites worldwide. In Europe, there are around 2.5 million potentially contaminated sites and over 340,000 contaminated sites; the management of these sites involves costs of € 6.5 billion per year, covered by private companies, according to the "polluter pays" principle, but also by public funds.

Sources of contamination can be natural, for example, volcanic emissions and eruptions, continental dust transport, and metal-rich rock weathering. The main sources, however, are of anthropogenic origin and include industrial processes and mining, poor waste management, unsustainable farming practices, accidents such as chemical spills, and even armed conflicts.

Those activities generate wastes and emissions that contain toxic substances and, if not properly managed, cause the diffusion and accumulation of pollutants in the soil, subsoil, and groundwater. Their contamination generates significant negative impacts on the ecosystem and human health, causing loss of biodiversity and disabling diseases, which can even lead to the death of people. This also compromises the soil's ability to provide ecosystem services, including the production of safe food. More generally, soil and subsoil pollution hinders the achievement of many of the United Nations Sustainable Development Goals (SDGs), including those related to SDG 1 (poverty elimination), SDG 2 (zero hunger), and SDG 3 (good health and well-being). Soil pollution strikes the most vulnerable people, especially children and women (SDG 5) and the supply of safe drinking water (SDG 6), which is threatened by the leaching of contaminants into groundwater and runoff. Moreover, CO_2 and N_2O emissions from unproperly managed soil cause climate change (SDG 13), and soil pollution contributes to land degradation and loss of terrestrial (SDG 15) and aquatic (SDG 14) biodiversity, and reduces the security and resilience of cities (SDG 11).

The presence of one or more contaminants in the soil and/or the groundwater does not in itself pose a hazard. The state of contamination can be assessed through three different criteria: the comparison with natural background concentrations of pollutants, the comparison with threshold concentrations, the human health risk assessment (HRA) and the ecological risk assessment.

HRA is a method for assessing the possible harm caused by contaminant emissions that affect human health. Its origin dates to the 1950s, but the first concrete applications took place in the United States in the 1980s, after the National Academy of Science published “Risk Assessment in the Federal Government: Managing the Process” in 1983. Later, in 1992, the US Environmental Protection Agency’s “Framework for Ecological Risk Assessment” introduced a simple and flexible structure for conducting and evaluating ecological risk assessment.

Much has come since then, but there is still much to be done. In the European Union, for instance, there is currently neither a univocal definition of "contaminated site" nor a Directive concerning the remediation of contaminated sites. Many Member States have their own legislation and have adopted different definitions, which are not homogeneous. The health and environmental risk assessment often has a key role as it represents a fundamental decision-making tool not only in the assessment of contamination but also in the selection and implementation of the remediation strategies, which can include containment works, remedial actions or monitored natural attenuation approaches.

This book, which depicts a complete and up-to-date picture of the environmental risk assessment, represents a very useful tool for technicians and decision-makers working in the environmental field, who will be guided through the methodologies and procedures that can be used to implement the risk-based approach for contaminated soil management, air and drinking water quality protection, and waste management.

Mentore Vaccari
University of Brescia, Italy

PREFACE

Environmental pollution has been a topic of growing interest all over the world, in both developed and developing countries. At the global level, decision makers are constantly trying to identify sustainable solutions for environmental pollution issues. Multiple international agreements have been adopted to set out a global framework to avoid the dangerous effects of environmental pollution. All these actions also aim to strengthen countries' ability to deal with the impact of environmental pollution and support them in their efforts to mitigate it.

With a rapid increase in population, the demand for energy, food production, machine development, and increasing trends of urbanization has resulted in serious soil, water, and air pollution that affects the surrounding environment and includes human health. According to the World Health Organization (WHO), 24% of all estimated global mortalities are linked to environmental pollution. *Sustainable development* has been defined in many ways, but the most frequently quoted definition is from *Our Common Future*: "*Sustainable development* is a development that meets the needs of the present, without compromising the ability of future generations to meet their own needs". In this context, according to the World Health Organization, every day, approximately 93% of the world's children under the age of 15 years (1.8 billion children) breathe air that is so polluted; it puts their health and development at serious risk. The deaths of 297,000 children aged under 5 years could be avoided each year if risk factors like unsafe drinking water, sanitation, and hand hygiene are addressed.

On the other hand, environmental pollution has led to serious disruptions in natural systems: *e.g.*, snow and ice are melting, hydrological and biological systems are changing, and negative pollution effects are not stopping here. The consequences of environmental pollution for biodiversity and ecosystem conservation have also been observed in the degradation of the benefits that natural ecosystems provide for society, named ecosystem services. Examples of ecosystem services include products such as food, fibres, fuels and water; regulation of air quality and soil fertility; control of floods, soil erosion, crop pollination, and disease outbreaks; and non-material benefits such as recreational, cultural and spiritual benefits in natural areas.

The proposed book has the main aim of a broad vision of the main environmental systems: soil, water, and air. The chapters are focused on a risk-based approach to the environment and a deep dive into risk management implementation, risk considering contaminated sites, air quality, safe drinking water, and the importance of risk analysis in waste management, followed by good practices considering environmental hazards and tools in assessing risks on human's health.

In concordance with the sustainable development definition, the environment must be protected and sustainably managed. This responsibility is ours, together, we should create an educated and correctly informed society regarding environmental protection. Aware of the multiple benefits of a clean environment on human health, our actions as individuals and societies should be only in the environmental protection direction. Stefania Giannini (UNESCO Assistant Director-General for Education) said that "*through education, we could create a peaceful and sustainable world for the survival and prosperity of current and future generations*". In this context, the proposed book represents a guideline for students that study in the environmental engineering fields. The book aims to enable learners to develop knowledge and awareness about environmental risk management and take action to transform society into a more sustainable one. Developing an educated and correctly informed society is

a top priority because it is the foundation on which we build peace and drive sustainable development.

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CHAPTER 1

Environmental Pollution and Health

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Abstract: Both developed and developing nations around the world are becoming increasingly interested in environmental pollution and impact human health. Different factors contribute to environmental pollution, including an increase in population, resulting in demand for energy, which causes toxic pollutants that are released into the *air we breathe*, on the *soil where we grow food*, and in the *water we drink*. These contaminants may be harmful to both the environment and human health.

The influence of environmental pollution on human health and well-being is discussed in detail in the current chapter. There are examples of various environmental problems related to soil, air, and water pollution, as well as evidence of human exposure pathways and the health effects of different environmental pollutants. Specific chemical contaminants present in soil, air and water are also evidenced. So, this chapter introduces the reader to a world where environmental health is synonymous with human health and where how each of us as individuals treats the environment directly affects our well-being.

Keywords: Air pollution, Contaminants, Environmental Risk Assessment, Environmental pollution, Ecological Risk Assessment, Human exposure, Human Health Risk Assessment, Risk-based approach, Soil pollution, Water pollution.

INTRODUCTION

The Environmental or Ecological Risk Assessment study is mainly focused on understanding the potential negative effects of human activities on the ecosystem (plants, animals, lakes, and seas).

This book is focused on key elements of Environmental Risk Assessment, how to manage or to perform such study, in the context of Air, Water or Soil pollution, as the primary source of investigation. The aim of the chapters is to promote a structured approach to Environmental Risk Assessment (ERA), provide high-quality information that is consistent with good practices and, most importantly,

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keep on alert engineering students and decision-makers about the environmental problems for controlling and applying corrective measures to minimise risk and/or to avoid risk occurrence.

ENVIRONMENTAL POLLUTION

The environment is composed of lithosphere (rocks and soil), hydrosphere (water), atmosphere (air) and biosphere (living component of the environment). Environmental Pollution is described as an excessive amount of harmful chemicals in the environment (water, air, and soil), making it dangerous for life. All sources of contaminants, as an initial step, are discharged in one of the environmental components. The contaminants further go through physical and chemical changes, which are lastly incorporated in the medium [1]. For instance, once the pollutants are emitted into the atmosphere, a conversion principle is applied: "*Matter cannot be destroyed; it is merely converted from one form to another*" [2], known as the second law of thermodynamics. In other words, the contaminants that reach the environment are dispersed based on their properties, medium characteristics, and others, and further can be converted (or not) into another type of substance. This type of conversion is applied to the substances/materials which can be replaced or renewed, and these substances/ materials, once in the environmental media, easily are assimilated and do not interfere with the well-being of the environment [1].

To understand the meaning of the pollution, it is important to define the characteristics of the pollutants present in the environment and what effects does it have. Contaminants can occur from diverse sources, natural or man-made. Natural pollution results from different sources such as wildfires, volcanic activity, or seismic activities. In the case of anthropic pollution, this derives from human activity. Examples in this regard are: untreated industrial and municipal wastewater discharge, burning of the fossil fuel, which leads to the atmospheric increase of CO_2 and other greenhouse gases, increasing the global warming and climate change effects at the global level, uncontrolled dumping of waste, excessive applications of chemical fertilizers and pesticides on agricultural soils, or accidental spills of toxic organic substances in the soil (petroleum products, chlorinated solvents). These substances are able to move from one environment system (soil, water, air) towards another through migration processes like: leaching, volatilization, photo-decomposition, runoff, wet and dry deposition, *etc.*, [1]. Common toxic substances found in the environment are illustrated in Table **1.1**:

Table 1.1. Most common chemical contaminants present in the environment [3].

Chemical Classification	Frequency of Occurrence
Gaseous contaminants CO_x (CO, CO_2), NO_x (NO, NO_2, N_2O), SO_x (SO, SO_2, SO_3), NH_3, VOC_s	Very frequent
Gasoline, fuel oil	Very frequent
Alcohols, ketones, esters	Common
Chlorinated organics	Very frequent
Polychlorinated biphenyls (PCB_s)	Infrequent
Nitroaromatics	Common
Metals (Cd, Cr, Cu, Hg, Ni, Pb, Zn)	Common
Nitrate	Common
Phosphate	Common
Ethers	Common

ENVIRONMENTAL POLLUTION AND IMPACT

Air Pollution

Air pollution is one of the biggest issues all around the world in both developed and developing countries, and is mainly caused by heavy traffics, rapid development of the economy, industrialization, exploitation of natural resources and so on. The rapid growth of population and demand for food, energy and materials have driven the emissions of various toxic compounds into the air, impacting human and ecosystem health [4]. Based on the report from World Health Organization, 384 million people suffer from chronic obstructive pulmonary disease, and around 3 million death cases result annually, along with other respiratory health issues caused by air pollution. This issue is leading to the third cause of death worldwide [5].

According to World Health Organization, the cities shall be evaluated considering the air quality based on the average level of particulate matter ($PM_{2.5}$) in the air. Fine particles ($PM_{2.5}$) pose the greatest health risk because these particles have a very small size (particle diameter<2.5 μm) and can get deep into lungs, and some may even get into the bloodstream. Health effects may include cardiovascular effects, such as cardiac arrhythmias and heart attacks, and respiratory effects, such as asthma attacks and bronchitis. Exposure to particle pollution affects especially the population with pre-existing heart or lung diseases, older people, and children. According to Statista Company, the most polluted 10 countries in the world are

CHAPTER 2

Basic Concept of Environmental Risk Assessment

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Abstract: Rapid growth and expansion of the chemical and energy industries have led to an increase in chemical emissions and the potential for accidents, such as fires, explosions, and spills. These potential consequences have caused concern among industries and regulators, leading to an interest in understanding the risks associated with these emissions into the environment and accidents. This knowledge is crucial for complying with laws and regulations as well as for reducing adverse effects on human health and the environment. Consequently, this chapter intends to introduce readers to the Environmental Risk Assessment and the steps that should be accounted for the successful results, representing an important study on understanding the risks and minimizing the negative effects as much as possible. The first part of the chapter is dedicated to presenting specific knowledge on Risk and Hazard, evidencing differences between the two terms. The second section emphasizes the value of human health risk assessment in determining the potential effects of a hazard on the health of an individual, a group of individuals, or a community, while simultaneously outlining the steps that must be taken for the Ecological Risk Assessment.

Keywords: Ecological Risk Assessment, Hazard, Human Health Risk Assessment, Risk Assessment.

INTRODUCTION

The concept of risk assessment first appeared in the 1970s, with its origins in the United States, because of addressing issues related to human health, particularly the approach needed to be more balanced and efficient. In response to the proposal, a more consistent risk assessment program was implemented in the United States in the 1970s and 1980s. As a result, various governments adopted the risk assessment procedure, while also developing different subdivisions of risk assessment, such as environmental risk assessment and human risk assessment [1].

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Due to the high interest in contaminants in relation to ecological processes and effects, the Environmental Protection Agency of the United States began to develop guidelines on ecological risk assessment in the 1980s. In 1983, the US National Research Council formalized the risk assessment model in the "Red Book," and as a result, the terms and procedures of risk assessment and risk management were clearly differentiated [1]. Later, similar documents for assessing ecological risk were developed in Europe, Canada, and Australia.

UNDERSTANDING OF RISK

The four steps of risk assessment are hazard identification, dose-response assessment, exposure assessment, and risk characterization, which serve as the foundation for today's risk assessment research.

Because of the high impact of stressors, risk assessment has recently evolved significantly. Risk assessment methods are now used in a variety of areas, including ecological risk assessment, health risk assessment, life-cycle risk assessment, and others.

Ecological risk assessment, which refers to environmental issues, includes significant information on cumulative risk assessment that was not previously considered. The integration of multiple stressors, management options, and endpoints in the developed conceptual model is referred to as cumulative risk assessment. Aside from that, various countries have developed their own environmental risk assessment software, which has successfully integrated human health risk assessment into the system. Programs can integrate and output information based on the information provided in the data input. Ecological risk assessment has recently been used in the study of genetically modified organisms, generating useful results [2].

i. What is Risk?

According to the Oxford Dictionary, the risk is defined as "an event/situation that involves exposure to danger," and it is also used to describe what is likely to happen (in the future) if the required preventive measures are not carried out in accordance with the standards. In other words, risk was defined by the Royal Society in 1992 as "*the combination of the probability or frequency of occurrence of a defined hazard and the magnitude of the consequence of the occurrence*" [3]. However, there are situations when the danger cannot be predicted or may have a small percentage of circumstance. Herein, the risk assessment study is performed to identify the risk and propose solutions for its elimination.

The risk assessment mechanism is applied in a wide range of domains and academic disciplines. Engineers, for example, use the risk assessment study process to determine the likelihood and effects of component failure while designing a bridge [4]. Engineers were primarily involved in the construction of churches during the Romanesque to Gothic transition stage. Many structures collapsed, and deaths and environmental damage occurred during that time. These events aided society in evolving over the centuries and implementing efficient techniques to reduce the risks of collapses and loss of life. To avoid negative events, engineers and organizations now conduct rigorous risk assessments. Risk assessment has become a popular method for investigating environmental issues and assessing various types of risks [3].

According to the EPA standards, the risk is understood based on the answers to the following questions:

1. **How much of a pollutant exists** in the environmental matrix *(e.g.,* soil, water, air) and who is affected by it?

The answer to this question focuses on identifying potential risks and goods that may be impacted by them (humans, animals, environment, *etc*).

2. **How much contact (exposure)** does an individual or an ecological receptor have with the contaminated medium?

In this case, it is thought to continue with the analysis to determine the causes and potential amount of the asset that was exposed to the stressor/contaminant.

3. **How it affects and what are the consequences** on human health and the ecosystem [5].

It is determined here how the stressor affects the medium of exposure (people, environment), as well as whether the risk has the potential to cause harm or an adverse consequence. In other words, risk is expressed as the result of two factors: the likelihood of exposure and the adverse consequence.

$$Risk = probability\ of\ exposure \times \text{adverse consequence} \quad \textbf{(2.1)}$$

For example, smokers are more likely to develop lung cancer:

"People that smoke cigarettes are 20 times (example) more likely to develop lung cancer than non-smokers".

Risk is expressed as a probability or likelihood of an injury to happen, while the hazard refers to the responsible agent for this cause *(e.g.,* smoking cigarettes) [2].

CHAPTER 3

Risk Management and Principles

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Abstract: The chapter discusses the concept of risks in the economy and how it affects the everyday operations of a company. Risks arising can result in economic losses, damage to facilities and equipment, and, most importantly, workplace accidents. Risk management nowadays has developed in both concept and practice and has become an industry in countries with a functional market economy. The chapter emphasizes that risk management is a crucial aspect of global management that requires information from various fields, such as economic, technical, legal, statistical, and psychological, to maintain the risk at the minimum level. Moreover, effective risk management can lead to sustainable development for humans, the environment, and businesses.

Keywords: Risk Assessment, Risk Management, Risk Control, hazard, Risk evaluation, Risk control, Risk-based management, Risk monitoring, Risk communication.

INTRODUCTION

Facing various situations involving risks, as well as being exposed to hazards, represents daily life for humans in both situations, at work and at home. At the European level, to ensure a healthy and safe workplace, it is an important factor within a fully completed Risk Management.

Environmental Risk Assessment includes two distinct components: Risk Assessment and Risk Management. Risk Assessment, as defined in previous chapters, is the process of assessing the risk posed by substances released into the environment because of anthropic activities, as well as the identification of affected receptors (local, community, and so on), and the assessed risk level.

Risk Assessment may estimate the expected rate of illness among the vulnerable population (population at risk). In the case of Risk Management, however, the results of the Risk Assessment are integrated into various conditions and moni-

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Diana Mariana Cocârță (Ed.)

tored from an economic or legal standpoint. As a result, risk reduction decisions are made to reduce or eliminate the risk completely. Risk Management is the process of deciding what to do about a hazard, the population at risk, or adverse effects, putting the decision into action, and evaluating the results. It also refers to program or authority-level decision making, such as determining which hazards should be managed and in what order. Risk Management can benefit from comparative (or relative) risk analysis and cost-benefit analysis [1].

Some examples of Risk-based Management actions are:

- Decide the amount of a substance to be discharged in the natural habitat;
- Decide which substances are safe to be stored at the hazardous waste disposal facility;
- Decide what strategy to be used for a hazardous contaminated site: actions for cleanup or remediation;
- Set permit levels for waste discharge, storage, and transport;
- Establish national ambient air/noise quality standards and thresholds for the water contamination.

More specific information for a better understanding is presented in (Fig. **3.1**).

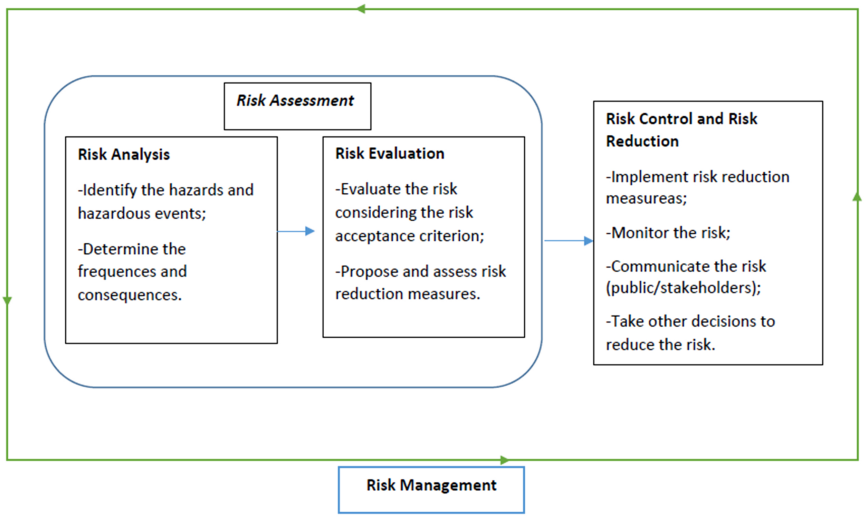

Fig. (3.1). Main elements of Risk Management process (Source [2]).

Risk management is defined as the management process that aims to analyze and assess potential hazards and propose effective risk control measures to reduce or eliminate any potential harm to people or the environment.

Risk Management, in relation to Risk Assessment, is composed of four stages process. The decision-making must be an iterative process. The information gathered between the stages will determine to go back and to revise the scope and principles. (Fig. **3.2**) illustrates the Risk Management stages.

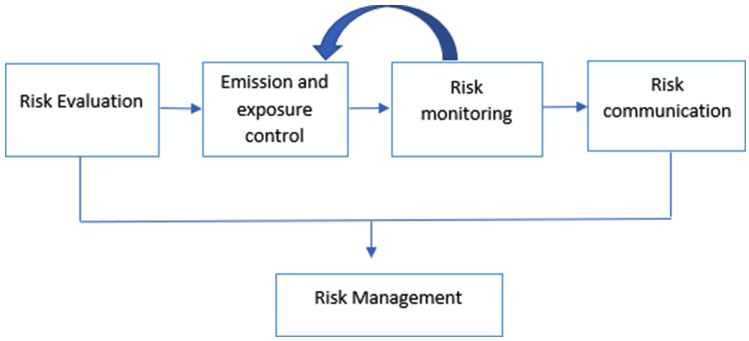

Fig. (3.2). Risk Management - main phases (Source [2]).

REQUIREMENTS OF RISK MANAGEMENT PROGRAM

The Risk Management Program is the formal process used to quantify, classify, and mitigate risks that Environmental Risk Professionals may discover or define in the context of environmental issues. Risk Management is the final process in the Environmental Risk Assessment and must be completed before the decision to mitigate/eliminate the Hazard/Risk can be implemented. In the risk management stage, there are several steps that must be taken into consideration for a positive impact on decision-making. Different phases in the Risk Management stage should be followed in a cycle mode (as shown in Fig. (**3.3**)) to ensure that the established decisions have a positive impact and that continuous improvement occurs throughout the process [3].

Fig. (3.3). Risk management cycle mode (Source [4]).

CHAPTER 4

Risk-Based Approach for Contaminated Soil Management

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Abstract: The current chapter illustrates aspects of sustainable soil management, the basic concepts for site investigation based on the calculation of the risk associated with the various chemicals that affect the structure, quality, and functions of the soil, as well as the highlighting of the most important remedial strategies used to reduce pollution. As a result, the soil can be used for a variety of industrial and civil purposes. Sustainable soil management is a concept based on technical-scientific and economic knowledge. Simultaneously, policy actions are taken to maintain and increase soil productivity, protect biodiversity, reduce risk, and protect natural resource potential by preventing soil quality degradation and supporting ecosystem services. In the decision-making process for Assessing Human Health Risk for contaminated sites, the development of the site's conceptual model is recommended for a better understanding of the evolution of the respective site's situation. The development of a Conceptual Site Model (CSM) is useful for assessing the contamination risks of any site because it identifies the sources of hazards, potential receptors (people, ecology, and infrastructure), and exposure pathways.

Keywords: Soil pollution, Risk assesment, Risk-Based Land Management (RBLM), Heavy metals, Conceptual Site Model (CSM), Remediation technologies, Electrochemical remediation.

INTRODUCTION

Due to pedogenic factors like climate, microorganisms, vegetation, and landforms, the soil has developed from rocks. The rocks have undergone significant transformations over time so that the soil appears to be a natural body distinct from the parent rock. The regeneration time is long, so it takes between 300 and 1000 years to form 3 cm of soil naturally, and 70000 years to form

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20 cm. [1] Soil is the environment on the earth's crust's surface where human life occurs. It is an essential and extremely complex resource composed of mineral particles, organic matter, water, air, and living organisms. Soil is a dynamic system that has many functions and is essential for human activities and ecosystem survival.

Pollution is a consequence of human activity, particularly social and economic activity. From a historical standpoint, environmental pollution appeared at the same time as man, but it has evolved and diversified in response to the evolution of human society, becoming one of the most pressing concerns of scientists and technologists, states and governments, and the entire global population today. This is because the threat posed by pollution has grown and continues to grow, requiring urgent national and international action in the spirit of pollution-fighting ideas.

According to the European Environment Agency (EEA), statistics on the number of decontaminated sites and the number of contaminated and potentially contaminated sites were updated at the European level in 2017 (Fig. **4.1**).

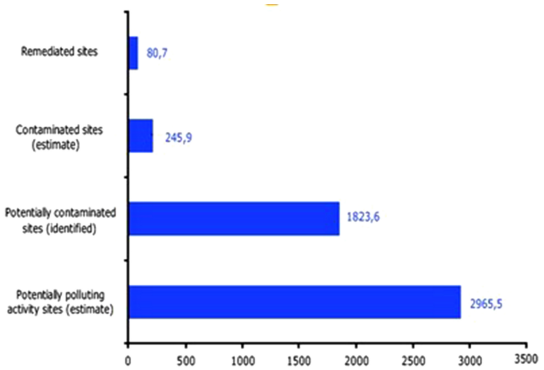

Fig. (4.1). Estimated situation of polluted sites in 2017 in EU countries (number of sites x 1000) [2].

The main economic-industrial activities that caused soil pollution are also represented as a percentage of the number of sites where preliminary investigations were completed, with 2012 as the reference year (Fig. **4.2**).

Prior to the appearance of this concerning context, the general belief was that the soil has an almost limitless capacity for self-purification and resilience. This fact was proven to be false because only the instantaneous reactions of the soil to the various disturbing polluting actions to which it is subjected were quantified. In such cases, nature lacks the ability to correct the negative effects produced in a relatively short period of time, necessitating intervention to limit and eliminate polluting sources of any kind.

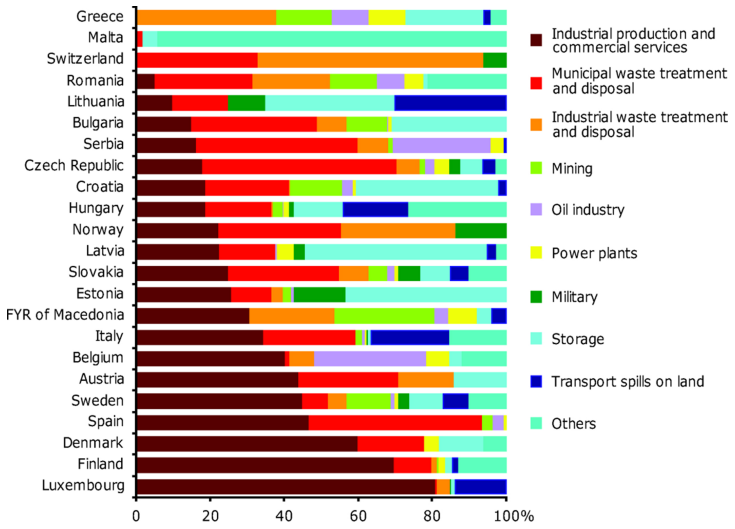

Fig. (4.2). The main industrial and economic sources responsible for environmental and human health pollution [3].

When viewed through the lens of harmful effects on human health, environmental pollution has manifested itself in various types of pollution, as follows:

o **Biological pollution**, the oldest and most well-known type of pollution, is caused by the elimination and spread of microbial germs, mostly pathogens, in the environment by humans and animals. The primary threat posed by biological pollution (bacteriological, viral, and parasitological) is the spread of epidemics.

o **Chemical pollution** is the elimination and spread of various chemical substances in the environment. Chemical pollution is becoming increasingly visible, both by increasing the level of pollution and, more importantly, by diversifying it. The main danger of chemical pollution is the highly toxic potential of these substances, which causes problems with both normal plant growth and human and animal health.

o **Physical pollution** consists primarily of soil erosion caused by environmental factors (the action of wind and rain) and desertification resulting from climatic variations and human impact. Acoustic noises and noise pollution have a significant impact on human societies. The human body was created to tolerate a certain level of noise and vibration; exceeding this threshold can cause illness, embarrassment, or even disruption. Thermal pollution is perhaps the most recent form of physical pollution, with significant effects on the environment, particularly on water and air, as well as indirectly on population health. The cooling systems of conventional and nuclear power plants, the chemical and

CHAPTER 5

Risk–based Approach to Air Quality Management

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Abstract: In the last decades, increased air pollution has been the world's largest environmental health threat, and new causal relationships between it and human diseases have been discovered. To better understand the relationship between air pollution and health risks and to promote the most efficient measures that may reduce the health impact, the chapter sets the context regarding the risk–based approach to air quality management and presents the Health Impact Assessment of Air Pollution, the Health Risk Assessment process and the tools that can be used for assessing it. To support the theoretical information described, several case studies were presented.

Keywords: Air pollution, Health impact assessment, Health risk assessment, Hazard identification, Exposure assessment, Dose-response assessment, Risk characterization, Air quality index, Years of life lost, Disability-adjusted life years, Change in life expectancy, Geographic information system.

INTRODUCTION

Air pollution is defined by the World Health Organisation as the "*contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere*" [1]. Gases (like carbon, sulphur and nitrous oxides, ammonia, methane, and CFCs), particulates (inorganic and organic), and viruses and bacteria are the common pollutants of the air. At the global level, the climate and ecosystems are closely related to air quality. Fossil fuel burning is the main cause of air pollution and contributes to greenhouse gas emissions.

At the local scale, the connections between climate and air pollution are also very important, as they influence each other. The rapid and large-amplitude variations of pollutant concentrations are mostly generated by a series of meteorological phenomena that occur on this scale, such as the thermal inversion layer, sea and

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valley breezes, the canyon effect, *etc*. The local scale pollution primarily affects population health through direct short-term action, but also through longer-term toxicity for certain pathologies.

According to United Nations Economic Commission for Europe (UNECE) and World Health Organization (WHO), air pollution is considered to be "*the world's largest environmental health threat*". The WHO reports that almost 99% of the global population breathe polluted air that exceeds currently set guidelines; population from countries with low and middle income being the ones that suffer from the highest exposures [1]. Also, over 90% of residents in the European region are exposed to yearly levels of outdoor fine particulate matter that exceed WHO and European Environment Agency (EEA) air quality limits, meaning that almost every single person is affected by air pollution [2].

Air pollution from both indoor and outdoor sources contributes significantly to morbidity and mortality by causing allergies, respiratory diseases, and other disorders with both short-term and long-term effects. The effects of air pollution differ from one group of people to another, some individuals, such as children and elderly ones, being more sensitive to pollutants. Also, people with known health problems such as heart and lung disease or asthma may experience exacerbations of these conditions when the air is polluted. The degree to which a person is affected by air pollution is dependent on the exposure time and concentration of harmful substances.

Currently, considering the increased number of experimental and epidemiological studies performed in the last decades on different areas and populations, the health risks related to air pollution are established more accurately, especially for short-term effects. These studies highlight the role of air pollution in the occurrence or exacerbation of a wide range of health effects that can vary from cardio-respiratory diseases to early mortality.

According to data provided by WHO [1], each year, polluted air is responsible for 1.4 million (24%) of all deaths from stroke, 1.8 million (43%) of all deaths from lung disease and lung cancer, as well as for 2.4 million (25%) of all heart disease deaths worldwide.

European environmental protection policy has taken into account the impact on health from the beginning. The leading European and International environmental organizations have stated that, although many environmental and health problems have been ameliorated or solved, important steps remain to be taken, especially regarding the health effects of chronic exposures [3, 4].

The relationships between the environment and health have turned out to be much more complicated than previously thought, being marked by many causal links. In other words, the relationships between exposures and health effects depend on the pollutants present in the air but are also influenced by different factors such as genetic makeup, age, nutrition, lifestyle, and socioeconomic ones.

Due to the increased number of deaths that can be related to air pollution, it is necessary to implement health impact assessments at local scale and to translate the results into local, regional or national policies with the aim of reducing the impact on human health.

HEALTH IMPACT ASSESSMENT OF AIR POLLUTION

Health Impact Assessment (HIA) provides useful information to decision makers about how a policy, programme or project may affect people's health. Because of its ability to influence decision makers and stakeholders, WHO promotes the use of HIA.

HIA has been defined by many different people and organizations. All definitions are almost similar, differing through the emphasis given to particular components of the HIA approach. Some of the most comprehensive definitions are presented below:

o World Health Organization defines Health Impact Assessment, that can also be implemented for air pollution, as a "*practical approach used to judge the potential health effects of a policy, programme or project on a population, particularly on vulnerable or disadvantaged groups*" [5]. To maximize the proposal's beneficial health effects and minimize its negative health impact, recommendations must be made for decision-makers and stakeholders.

o European Centre for Health Policy (ECHP) defines HIA as "*a combination of procedures, methods, and tools by which a policy, program, or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population*" [6].

o According to the United States Environmental Protection Agency (EPA), HIA is "*a tool designed to investigate how a proposed program, project, policy, or plan may impact health and well-being and inform decision-makers of these potential outcomes before the decision is made*" [7].

Health Impact Assessment process consists of 5 steps (Fig. **5.1**):

o **Screening**: an intervention, a policy, or a project for which a health impact assessment would be beneficial is selected. There are three possible outcomes

CHAPTER 6

Risk-based Approach for Safe Drinking Water

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Abstract: The United Nations (UN) recognizes access to safe drinking water as a fundamental human right. However, there are still many people without access to safe drinking water, and diseases caused by contaminated water pose a serious threat to human health. By 2030, progress would need to be made at four times the current rate to achieve UN Sustainable Development Goals related to water. The drinking water system has several points where undesired events could happen, allowing contaminated water to be delivered to the public. The safety and quality of the drinking water that they provide are always the suppliers' responsibility. Risk management is a crucial component in ensuring the supply of safe drinking water. One strategy for supplying consumers with safe drinking water is the "multiple barrier approach". Risk-based methodologies are more effective to identify and manage the hazards in the drinking water system to provide a consistent supply of safe drinking water. To encourage the development and use of risk management methods, the World Health Organization (WHO) has created guidelines for the quality of drinking water. European Drinking Water Directive that was revised and entered into force, which started in January 2021, also includes a risk management system for the "source-to-tap". This chapter presents aspects concerning water contamination and health, an overview of drinking water supply systems, safe drinking water risk management strategies, and the framework for safe drinking water to focus on water safety plan development.

Keywords: Safe drinking water, Water contamination, Drinking water supply system, Multibarrier approach, Risk-based approach, Water safety plan.

INTRODUCTION

Water is a precious resource that sustains life. It is used for various purposes such as domestic use, irrigation, industrial use, commercial use, power generation, aquacultural use or recreational use [1]. Some of these are more important than others. For example, having a minimum of 20 litres of water per person per day [2] is the most important need in contrast with all other needs, like recreational

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use that is the least important in the hierarchy of water requirements [3]. We need water daily for many purposes, like drinking, food preparation, personal hygiene, washing, cleaning, watering plants, *etc.* "Water sustains life, but safe, clean drinking water defines civilization" [4].

There isn't a universally accepted definition of safe drinking water. Safe drinking water is a relative term, which depends on the standards and guidelines of a country. WHO defines safe drinking water as water that does not represent any significant risk to health over a lifetime of consumption [5]. Besides this, the presence of certain amounts of natural minerals and essential elements in safe water intended for human consumption is also important [6].

A continuous supply of safe drinking water is a basic human right that was recognized in 2010 by UN General Assembly resolution A/RES/64/292 [7], and UN 2030 Agenda for Sustainable Development and the associated Sustainable Development Goal 6 - Ensure availability and sustainable management of water and sanitation for all (SDG 6) formulated by United Nations in 2015 [8]. One of the eight targets of SDG 6 is focused on safe and affordable drinking water. Moreover, to accelerate the efforts towards meeting water-related challenges, the period of 2018-2028 was declared an International Decade for Action on "Water for Sustainable Development".

Freshwater represents only 2.5% of the total amount of water on Earth. Out of about 70% of Earth's freshwater, less than 1% is readily available for human use [10], and this is not evenly distributed throughout the world. Despite the efforts of the states that led to increasing proportion of the global population using safely managed drinking water, from 70% in 2015 to 74% in 2020, there are too many people who still lack safe water access, mainly in rural areas [11, 12], Fig. (**6.1**) By 2030, progress would need to be made at four times the current rate to achieve universal coverage [11].

Besides other pandemics during history, the COVID-19 pandemic highlights again the importance of the provision of safe water. Along with adequate sanitation and hygiene, it helps to prevent and protect human health during all infectious disease outbreaks.

WATER CONTAMINATION AND HEALTH

Water Contaminants of Health Significance

Diseases related to contamination of drinking water constitute a major threat to human health. In essence, there are four types of contaminants: inorganic contaminants, organic contaminants, biological contaminants, and radiological

contaminants [13]. Contaminants can be derived from various sources in the urban water cycle. Some contaminants naturally occur in water, but others are the by-products of man-made processes or spread by human or animal wastes. They may cause adverse health effects from single exposures (*e.g.,* microbial pathogens) or long-term exposures (*e.g.,* many chemicals).

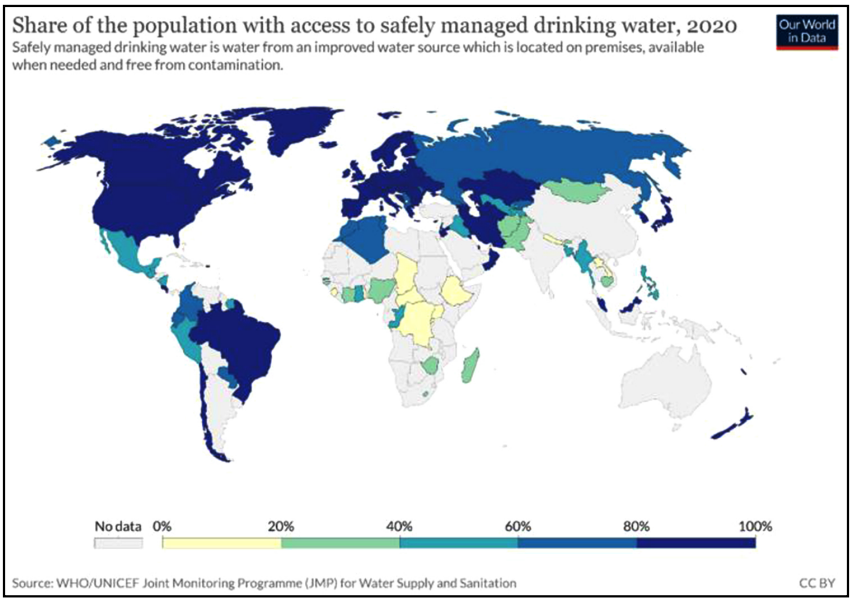

Fig. (6.1). Share of the population with access to safely managed drinking water [9].

Most of water-related health diseases are the result of microbial contamination (bacteriological, viral, protozoan, or other biological) or chemical contamination of drinking water. Microbial risks are associated with ingestion of water contaminated by faeces containing pathogens and by other microbial hazards (helminths, toxic cyanobacteria, and Legionella).

Chemical risks are related to chemicals that may occur in drinking water, such as fluoride, arsenic, uranium, selenium, nitrate, nitrite, and lead. They can cause adverse health effects after prolonged periods of exposure, less for short-term or single exposure [5].

Radionuclides can be naturally presented in water and thus, the risk associated with them should be also considered, although usually it is very small.

Depending on the water involvement in the transmission of diseases, there are four types of diseases ([1, 14]):

CHAPTER 7

Application of Risk Analysis to Waste Technologies

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Abstract: The current chapter presents the main municipal solid waste management processes used worldwide with potentially negative effects on human health: incineration, landfilling and composting by analyzing the defining elements regarding the main pollutants generated by the waste management processes in the form of solid, liquid, and gaseous discharges. Waste production, management and disposal involve more complex activities, with different potentials to affect health directly and indirectly through many pathways and mechanisms. The impact of waste may vary depending on numerous factors, such as the type of waste management processes, characteristics, and habits of the exposed population, duration of exposure, prevention, and mitigation interventions. Improper waste management in terms of health impact could be directly linked, to potential adverse substances, which leads to increased risk of cancer and quality of life decreasing or indirectly, to the environmental impact of the process, such as the contribution to global warming, loss of biodiversity and the depletion of non-renewable resources.

Keywords: Municipal solid waste, Waste management processes, Risk analysis, Risk assessment, Waste technologies, Landfilling, Thermal treatment, Composting.

INTRODUCTION

The three main methods for managing municipal solid waste that may have a negative impact on human health—incineration, landfilling, and composting—are discussed in this chapter. The provided information defines the key pollutants produced by waste management processes in the forms of solid, liquid, and gaseous discharges.

The management of waste has significant implications for environmental preservation and human health and welfare, sustainability, and economy.

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The inappropriate management of municipal solid waste presents some concerns for soil, water, and air pollution, which ultimately impacts the health of the people, as the World Health Organization (WHO) has frequently emphasized.

Municipal Solid Waste (MSW) generation is predicted to increase by up to 3.4 billion tons by 2050 [1], and even if waste management practices tend to improve, this happens from high-income to low-income countries. Due to the continued use of the most potentially hazardous waste management practices, such as open dumping and waste burning, the associated health risks are therefore, higher in low-income nations.

The impact of waste may differ based on a few variables, including the type of waste management methods, the characteristics and behavior of the population exposed, the length of exposure, and measures for prevention and mitigation.

A risk analysis of municipal solid waste begins with hazard identification and exposure assessment [2, 3]. The relationships between municipal solid waste management processes and potential adverse health effects are shown schematically in Fig. (**7.1**). The risks associated with waste management are visible, as are the potential environmental pathways through which the most exposed or vulnerable populations may ingest toxins.

Different waste management techniques lead to the generation of different compounds, as well as to different environmental impacts through exposure and transport. For example, in the direct incineration of waste, air is the first transport route to the environment. Dioxins, benzene pesticides, PCB_s, and other organic chemicals may be generated, and consumption of contaminated food may be an indirect source of exposure [4]. Pollution of groundwater by leaking leachate from the disposal of waste in landfills or open dumps may also affect drinking water [5, 6]. In this case, ingestion of water contaminated with harmful or carcinogenic substances would represent the subsequent exposure [7].

Some suspected effects of landfills and incinerators have been noted in research, such as a higher incidence of cancer and congenital anomalies and malformations in surrounding communities [8].

For the composting processes, in terms of health outcomes, some bioaerosols exposure can be found but with the mention to support a precautionary approach with no increased risks [9].

The Waste Framework Directive - Directive 2008/98/ EC outlines the basic information about the principles of waste management: waste must be managed without posing a risk to human health or the environment, without posing a risk to

water, air, soil, plants, or animals, without causing problems due to noise or odor, and without affecting the landscape or places in the surrounding area [10]. The waste management hierarchy, arranged from top to bottom in Fig. (**7.2**), forms the basis for waste legislation and policy.

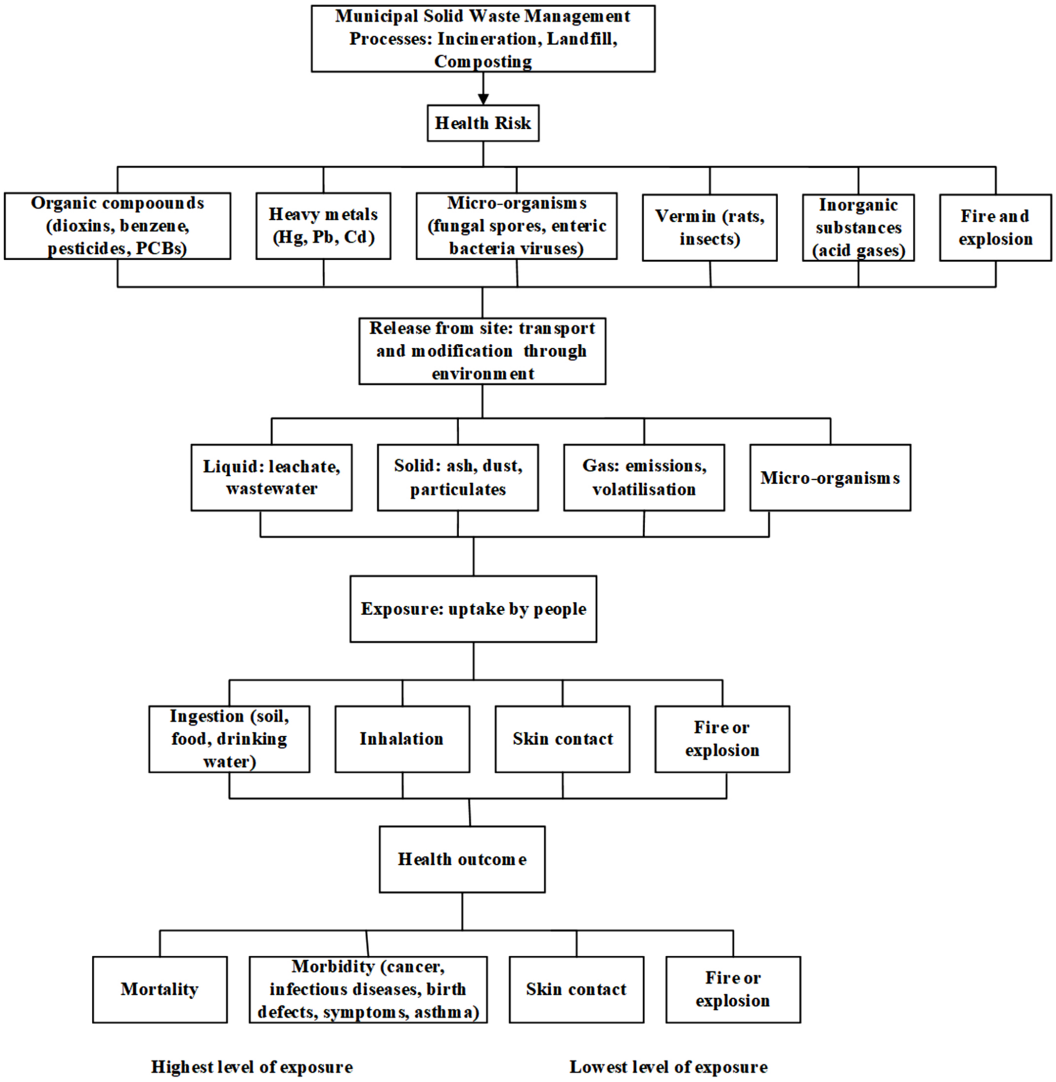

Fig. (7.1). Pathways from health hazards to health impacts of the municipal solid waste management processes.

According to recent studies, inadequate waste management techniques have been associated with a few contamination incidents, raising public concern about the lack of regulations, inadequate legislation, and the impact on the environment and

CHAPTER 8

Concluding Remarks

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Environmental pollution has been a topic of growing interest all over the world in both developed and developing countries. Fast demographic increase in different regions, demand for energy, food production, machine development, and increased trend of urbanization have resulted in serious pollution of soil, water, and air that affects the surrounding environment and human health. According to the World Health Organization (WHO), 24% of all estimated global mortalities are linked to environmental pollution. On the other hand, environmental pollution has led to serious disruptions in natural systems, *e.g.,* snow and ice are melting, hydrological and biological systems are changing, and negative pollution effects are not stopping here.

The main objective of the proposed book is to enlarge the understanding of the three major environmental systems (soil, water, and air) from an environmental issues perspective, and their management. The chapters are centered on a risk-based approach to environmental issues and go in-depth into risk management implementation, human and ecological risk assessment of contaminated sites, risk-based approach for the management of contaminated sites, air quality and assessing the risks from air pollution, risk assessment for protection of drinking water quality, and the importance of risk analysis in waste management. They also provided some good practices while considering environmental risks and instruments for assessing risks to human health and the environment.

The presented theoretical information covers specific terminology on Environmental Pollution Health Impact and Health Risk Assessment.

Within the book content, it is illustrated how to apply the assessment process and how to evaluate the risks at different scales, regardless of whether it is about air pollution, the management of contaminated sites, and the identification of the remedial strategy, safe drinking water, or waste management. The results

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provided by the health risk assessment tools can be transposed into local, regional, or national policies aiming to reduce the air pollution impact on human health.

The current book enables aspiring environmental protection specialists (students) to understand the systems and procedures for assessing the harmful effects of environmental pollution caused by human activities on population health and the environment. This manuscript offers a comprehensive set of procedures to analyze the negative effects of environmental problems by in-field professionals who are actively involved in environmental pollution control. Decision-makers in both public and private sectors should find the volume useful. Implementing the knowledge from the book makes it easier to create environments that are sustainable and healthy.

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