Preface

It has been over 30 years since the landmark Brundtland Report introduced sustainability as the obligation of a present generation to deliver to the next a state of affairs in the environment that would allow this to prosper and enjoy a quality of life not hampered by present-day activities aiming at short-term benefits. Fundamental to striving for sustainable development is the advancement and application of environmentally responsible waste and pollution assessment methods, remediation technologies, and management systems. Assessment of pollution in a given medium (air, water, and soil) may be conducted under a wide variety of conditions and at varying scales and levels of sophistication. As a result, assessments can produce a wide range of outcomes. Problem conditions may range from simple settings with almost self-evident identification of one or two key hazards, to highly complex urban and industrial settings with diverse human activities, where the source, location, and inception of pollution can be difficult to identify. This, in many cases, is coupled with complexities in the geological, hydrogeological, geochemical, and biological site conditions, the presence and need for protection of valuable ecosystems, the potential for far-field and/or long-term health implications, and numerous other considerations that render vulnerability assessments very demanding. This broad range of complexity, uncertainty, and needs means that assessments of pollution require a range of sophisticated tools and techniques, from field surveys, say, of major sources of groundwater pollution to detailed surveys of chemical or microbiological pollutant loads, to modeling of, for example, the leaching potential of pesticides used in a catchment. This increased complexity of environmental problems has necessitated the creation of multidisciplinary groups from all fields of science, engineering, public health, economics, and social science, to work together to assess and provide answers to the multifaceted aspects and implications of environmental problems.

This book has attempted to bring together teams of experts from different fields to provide the latest information on the methods and techniques through which pollution is assessed on land, air, and water. Thus the book is divided into the following parts: **Part 1: Pollution Assessment in the Geosphere**, in which we discuss sustainable pollution assessment practices; risk analysis and management; environmental remote sensing; geographic information systems; geophysical methods; site investigation; and subsurface pollutant transport; **Part 2: Pollution Assessment in the Atmosphere**, where we explore indoor and outdoor assessment of air pollutants; modeling of air pollution by atmospheric desert dust; troposphere air pollution; and health economics; **Part 3: Pollution Assessment in the Hydrosphere**, where we review the case study of the Arabian Gulf used to describe a decision support system for ranking desalination processes in the Arabian Gulf countries based on hydrodynamic modeling evaluation of future changes in feed water properties; analytical methods for risk assessment of emerging contaminants in ecosystems; water and sediment quality issues and techniques; brine management; and environmental concerns related to inland desalination; and **Part 4: Emerging Issues in Environmental Pollution Assessment**, where we look at emerging issues with exposés of nanomaterial pollution; noise pollution and its impacts on human health and the environment; radiation pollution from nuclear power plants; the use of artificial intelligence and data analytics for geosciences and remote sensing applications; and finally lifecycle assessment of aquaponics.

Part 1: Pollution Assessment in the Geosphere commences with Chapter 1 and concludes with Chapter 7.

Chapter 1: Sustainable Pollution Assessment Practices, authored by *Mohamed, A.M.O. and Paleologos, E.K.*, focuses on the broad assessment of pollution in the atmosphere, hydrosphere, geosphere, and biosphere within the context of sustainable development. The global environmental problems and the actions toward restoration of the environment are discussed. An overview of the impact from the exploitation and overutilization of natural systems, the deterioration of the environment through the disposal of ever-increasing solid and liquid waste volumes, the pollution of air and water, and the elimination of species, flora, and fauna are summarized with case studies from around the world. Some best-case studies that improve welfare, while not at the cost of environmental degradation or the well-being of current or future generations, are highlighted. The chapter also discusses evidence of global environmental impacts such as: global climate change; pollution of air, land, and water due to accidents during the transportation of oil or other products by ship; plastic debris in rivers and oceans, and effluent discharge into freshwater bodies; growing quantities of waste as a result of chemical product utilization in all human activities, from agriculture to medicine, to energy and industrial and manufacturing processes, to everyday products; and the decreasing species of wildlife. References and excerpts from important national and international conventions and legislation regarding these problems are also provided.

Chapter 2: Risk Analysis and Management, authored by *Paleologos, E.K. and Mohamed, A.M.O.*, presents an introduction to elements of risk analysis and risk management. Decision trees, payoff tables, and criteria to reach optimum decisions are presented, as well as some statistical measures that provide insights into decision-making. Furthermore, an exposition of topics of environmental economics is used to illustrate that, similar to lifecycle analysis, what is considered as the cost of environmental degradation in cost−benefit analyses can influence decisions and lead to less or more environmentally friendly solutions. Subsequently, elements of utility theory are introduced to incorporate the attitude to risk of individuals and corporations into risk analyses. This part, which deals with decision-making analyses, concludes with an elementary exposition of Bayesian decision theory illustrated through a problem of air emissions from waste to energy facilities. The second part of this chapter discusses human health risk assessment for environmental hazards by detailing elements of hazard identification, exposure assessment, toxicity assessment, and risk characterization. Various models of exposure assessment and risk characterization are presented. The steps of risk management programs are described, as well as the role of regulatory agencies and their approaches to risk. Finally, the chapter concludes with a presentation of mitigation measures for pollution in soils that apart from technical and regulatory issues touches upon the efficiency of technological solutions, the economic cost to remediate, the degradation in the function of environmental systems, and the impact to the health of the population.

Chapter 3: Environmental Applications of Remote Sensing, authored by *Mertikas, S.P., Partsinevelos, P., Mavrocordatos, C., and Maximemko, N.*, provides a brief exposition of remote sensing applications in geosciences and engineering disciplines. Remote sensing, the science and technology through which characteristics and properties of targets on Earth can be determined from a distance, has provided systematic, dedicated, and repetitive observations of the planet's surface, which include the atmosphere, water, land, living species, vegetation, pollution, and climate, from global to local scales. Satellite observations have contributed to the spectacular improvement of the accuracy of

weather forecasts over the last few decades. Remote sensing has provided the means for detecting and quantifying the rates of pollution by mapping and monitoring sources of pollution and the degree of remediation for their management. It bears the means to respond and facilitate environmental management and supports making sound and evidence-based decisions in relation to Earth's resources at a global scale and across different continents, nations, and domains. Remote sensing currently supplies essential Earth observations to protect irreplaceable resources and provides support for sustainable economic growth, disaster resilience, management of energy and mineral resources, food and water security, and sustainability. It provides powerful tools for understanding the past and present conditions of Earth systems and components, as well as the interplay between them. Thus remote sensing could assist us to solve environmental problems, address and mitigate risks, and deliver skillful predictions of the future behaviors of Earth systems (natural disasters, state of oceans, atmosphere, land, vegetation, food, public health, etc.). And by translating these Earth observations into decision-making, remote sensing could help mobilize actions to mitigate these effects to the benefit of the human race. A companion chapter to this is Chapter 21 on artificial intelligence and big data, as remote sensing and autonomous airborne systems rely on algorithms for, among others, navigational purposes and data interpretation.

Chapter 4: Geographic Information System: Spatial Data Structures, Models, and Case Studies, authored by *Howari, F.M. and Ghrefat, H.* provides a basic overview and summary of basic concepts of a Geographic Information System (GIS). Initially, the general concepts related to information organization and data structure are briefly described and related to different GIS representations of real-world geographical data. Different perspectives of information organization are discussed, which include various types of GIS spatial relationships together with the underlying information organization structure. Case studies are presented to illustrate the above and to show GIS providing valuable insight into: screening and cleaning geochemical data to reveal patterns between chemical elements and their distribution in the soil; studying land cover and vegetation changes in parts of Saudi Arabia using Landsat TM and ETM+ data for the period 1990−2013; and detecting and mapping copper mineralization zones through the use of multispectral Landsat 8 (Operational Land Imager) data.

Chapter 5: Geophysical Methods, authored by *Mickus, K.*, reviews the use of geophysical methods in the assessment of subsurface pollution within soil, groundwater, sediment, and bedrock. To use any geophysical technique, one is required to understand a few basic steps, which include the theoretical basis and the data collection and interpretation methods. These processes, which are unique to each of the geophysical methods, are discussed and examples of the basic interpretation methods are demonstrated. Specifically, while geophysical methods do not identify the type of pollutant or determine the type of rock, soil, or sediment in the subsurface, they can define the physical properties (e.g., density, electrical resistivity, magnetic susceptibility, seismic velocity) of the subsurface environment, which can be subsequently interpreted to identify a pollutant plume and infer the nature of the soil, sediment, or bedrock. A wide variety of geophysical methods used in pollution studies, such as electrical resistivity, electromagnetics, ground penetrating radar, seismology, gravity, and magnetics, are discussed to demonstrate that depending on a problem's specific conditions, one method may prove to be more appropriate than others. For a wide class of subsurface pollution problems, electrical resistivity, electromagnetics, and ground penetrating radar techniques appear to have an advantage in detecting contaminants within groundwater as they flow through soils, sediments, and

bedrock, while the other methods are useful in determining additional subsurface features (e.g., depth to bedrock, location of cavities) that can be used in estimating the extent and risk of pollution.

Chapter 6: Site Investigation, authored by *Mohamed, A.M.O., Howari, F.M., Ghrefat, H. and Paleologos, E.K.*, explains the various phases in site investigation. Phase 1 investigations are preliminary in nature and are designed to furnish a comprehensive overview of available site information. Phase 2 investigations consist of site characterization and groundwater monitoring wells. Direct methods, such as boreholes, piezometers, and geotechnical analyses of soil samples, are discussed, while indirect methods that include aerial photography, ground penetrating radar, and earth conductivity and resistivity geophysical studies, are detailed. Issues in hydrogeochemical investigations and two case studies are presented, the first related to geoenvironmental investigations at a waste dump site, and the second involving land salinization assessment in arid lands. Field investigations at polluted sites present unique challenges in that they involve, in many cases, heterogeneous, anisotropic environments contaminated by a complex diversity of pollutants. Optimization of the monitoring systems employed involves elements such as network density, spacing, depth, and frequency of sampling, where conflicting priorities may exist in terms of installation and sampling cost, probability of detection, and remediation cost. Thus the highly variable nature of subsurface conditions makes it impossible to define general investigation strategies that would be appropriate in all cases, but careful consideration of site-specific conditions determines cost-effective field campaigns. No proper site remediation plan can be implemented unless the findings of the site and modeling investigations are used in concert with close field supervision during the remediation process. The concept of phased site investigation provides the basis for this approach to avoid remedial cost overruns. Finally, the chapter concludes with a case study that demonstrates that the integration of data at different scales, such as field and remote sensing data, can be used successfully, as in this case, for mapping saline soils.

Chapter 7: Subsurface Pollutant Transport, authored by *Mohamed, A.M.O., Paleologos, E.K., and Maraqa, M.A.*, is concerned with the exposition of pollutant transport models by presenting initially the basic physical mechanisms by which miscible (soluble) and immiscible (nonsoluble) pollutants are transported in the subsurface environment. The physical and chemical interaction mechanisms that govern the transport of organic and inorganic pollutants in the subsurface environment are examined. Single-rate and multirate mass transfer processes for accurate evaluation of pollutant transport, fate, and remedial measures are discussed. For both saturated and unsaturated subsurface materials, the pollutant transport modeling of soluble and nonsoluble pollutants using the second postulate of irreversible thermodynamics is presented. Laboratory experimental methods used to determine sorption characteristics are examined. A variety of analytical models for transport equations are used to elaborate on the level of complexity of the problems under investigation. Over the last 50 years, the heterogeneity of the subsurface environment, which has been exhibited through several orders of variability in the parameters' and variables' measured values, has given rise to a stochastic description of subsurface pollutant transport. In this, the parameters and variables that enter the governing transport equations are treated not as deterministic, but as stochastic variables described by their mean, variance, and covariance function, and other high-order statistical moments. Some basic issues in the stochastic modeling of pollutant transport in soils are highlighted.

Part 2: Pollution Assessment in the Atmosphere commences with Chapter 8 and concludes with Chapter 12.

Chapter 8: Indoor Air Quality: Pollutants, Health Effects, and Regulations, authored by *Paleologos, K.E., Selim, M.Y.E., and Mohamed, A.M.O.*, summarizes some important information that relates to the characteristics, sources, and health effects of some of the most significant "indoor air pollutants," such as volatile organic compounds, formaldehyde, particulate matter, nitrogen dioxide, carbon dioxide, carbon monoxide, radon, ozone, and airborne biological pollutants. Many health studies are presented and discussed in terms of their significance to the general population and to specific segments of it. Subsequently, the chapter presents methods for indoor air sampling, the recommended locations and frequency of sampling, together with the regulatory limits for specific indoor air pollutants, and the principles of active, passive, and whole-air sampling methods. The relation between outdoor and indoor air pollution is discussed and measures to reduce the entry of contaminated exterior air into an indoor environment are explained. Finally, specific building regulations of "indoor air quality" from a number of countries are presented, with the chapter concluding with the important topic of design practices, which moves away from the creation of "sick building syndrome" conditions to the concept of "green building," and by extending the discussion from the health aspects of indoor air quality to a broader perspective of experiencing a "feeling of well-being" inside buildings.

Chapter 9: Outdoor Air Pollutants: Sources, Characteristics, and Impact on Human Health and the Environment, authored by *Mohamed, A.M.O., Maraqa, M.A., Howari, F.M., and Paleologos, E.K.*, presents the sources and characteristics of outdoor air pollutants along with the health and environmental effects of these pollutants. Emphasis is given to monitoring air pollutants by exploring the type of monitoring programs, sampling methods, emission standards, quality assurance aspects, and methods of data analysis and display, and by presenting a case study of air monitoring in a specific country. The chapter further explores the case of climate change by looking into its causes and economic and environmental impacts.

Chapter 10: Modeling Air Pollution by Atmospheric Desert Dust, authored by *Lelieveld, J., Abdelkader, M., Astitha, M., Karydis, V.A., and Klingmüller, K.*, discusses modeling aspects of air pollution by atmospheric desert dust. Modeling challenges include the incorporation and parametrization of small-scale meteorological conditions, such as the mobilization of dust into the atmosphere, and small-scale soil properties and saltation bombardment into the much larger grid size of models. The dust source strength depended on the grid resolution of the models, which required tuning of the parameters in emission submodels. The global ECHAM/MESSy Atmospheric Chemistry (EMAC) atmospheric chemistry−climate model was applied, which included an advanced emission submodel that interactively accounted for meteorological conditions and high-resolution topography data derived from satellite observations. The latter appeared to be critical in representing dust emissions in the Middle East. To account for mineral cation chemistry on the particle surface area, induced by the uptake of anthropogenic pollutants, the dust scheme of the EMAC model incorporated composition data collected over the major deserts of the world.

Chapter 11: Troposphere Air Pollution—Aviation Industry's Case, authored by *Bernabeo, R.A., Paleologos, E.K., and Mohamed, A.M.O.*, discusses the impact of CO_2 emissions from a specific industry, that of aviation, together with the monitoring of CO_2 by airlines, and forward-looking schemes by the aviation industry, such as the EU's Emission Trading Scheme. A technical discussion

is made of how to calculate direct emissions of CO_2 by aircraft and how to represent the contribution of the range of other gases, which include nitrogen oxides, contrails, and water vapor on radiative forcing. The discussion covers calculation issues relating to CO_2 emissions for individual flights and national ones, as well as global inventories. It also reviews the carbon dioxide sources, both natural and anthropogenic, and the carbon cycle to provide the background for discussing the CO_2 emissions from the aviation industry. It further provides some basic background on traditional nondispersive infrared absorption techniques as well as modern spectroscopic instruments such as direct absorption spectroscopy, cavity ring-down spectroscopy, cavity-enhanced off-axis-integrated cavity output spectroscopy, and Fourier transform infrared spectroscopy that are used to quantify CO_2 emissions by aviation, concluding by discussing instruments mounted on satellites for monitoring greenhouse gases.

Chapter 12: Health Economics of Air Pollution, authored by *Siriopoulos, C., Samitas, A., Dimitropoulos, V., Boura, A., and AlBlooshi, D.M.*, reports on the economic cost of public health impacts of ambient and household air pollution, with reference to the countries of the WHO European Region. It also presents a framework that can provide practical guidance on where and how to strengthen policy responses to problems related to air pollution's health impacts. Present-day economics uses a standard method for assessing the cost of mortality at the level of society: the "value of statistical life," as derived from aggregating individuals' willingness to pay to secure a marginal reduction in the risk of premature death. This permits researchers and policymakers to assess the comparative magnitude of the value that societies attach to a given health impact, and of proposals to mitigate it, using money as a common metric. In contrast, a standard and commonly agreed method by which to measure the cost of morbidity is not yet available. Recent practice and available evidence provide a rationale for using an additional 10% of the overall cost of mortality as a best estimate for the additional cost of morbidity. It is estimated that in 44 WHO European Member States the societal costs are equivalent to more than 1% of the respective gross domestic product and in only four of the 48 Member States considered in the analysis do these societal costs amount to less than 1%.

Part 3: Pollution Assessment in the Hydrosphere includes Chapters 13−17.

Chapter 13: A Decision Support System for Ranking Desalination Processes in the Arabian Gulf Countries Based on Hydrodynamic Modeling Evaluation of Future Changes in Feed Water Properties, authored by *Elhakeem, A., Mohamed, A.M.O., and Elshorbagy, W.*, discusses the development of a three-dimensional hydrodynamic model of the Arabian Gulf (AG) using Delft3D-Flow in a fully prognostic baroclinic mode. Water salinity and temperature values were obtained from observations spanning over 73 years until 1996 for the AG, the Strait of Hormuz, and the Gulf of Oman and were used to produce seasonal evaporation and surface density spatial distribution maps for the AG to compare them with available information. The long-term impacts of climate change and coastal effluents on seawater salinity and temperature of the AG were evaluated for two scenarios of the IPCC-AR4 that account for surface warming and emissions of short-lived greenhouse gases and aerosols. Using the current capacity and production rates of coastal desalination, power, and refinery plants, two projection scenarios until the year 2080 with 30-year intervals were developed and indicated an overall increase of the salinity and temperature in the AG and a decrease of precipitation. In addition, long-term hydrodynamic simulation results for the AG response to 10 projection scenarios were

used to evaluate the performance of desalination processes in terms of chemical and electrical operational costs in 2020, 2050, and 2080, considering the combined impact of climate change and coastal effluent. The performance of four desalination processes (multistage flash, multiple-effect distillation, hybrid, and reverse osmosis) were evaluated using seawater salinity and temperature results at coastal desalination plants. The changes in seawater salinity and temperature were applied in a formulated *decision support matrix* (salinity-DSM and temperature-DSM) to produce an adjusted desalination operational cost. The resulting adjusted costs were used to develop future desalination technology rankings based on the *least negatively impacted* desalination process in terms of chemical and electrical operational costs. A total of 32 plants in Kuwait, Saudi Arabia, Qatar, Bahrain, United Arab Emirates, and Iran were evaluated to advise on the most appropriate planning approaches at each location until 2080. The main finding of this study indicated that the impact of future ambient conditions in the Gulf on the operational cost of the considered desalination technologies is most likely to be significant under the considered factors, and considering the proposed approach the *multieffect distillation* technology is expected to be the most economical, robust, and least affected by changes in seawater temperature and salinity.

Chapter 14: Recent Analytical Methods for Risk Assessment of Emerging Contaminants in Ecosystems, authored by *Bataineh, M., Gallampois, C.M.J., and Schymanski, E.L.*, describes recent developments in monitoring and toxicological studies involving emerging contaminants (ECs), which allow regulatory bodies to develop standards to protect human populations and ecosystems. ECs can be found in ecosystems because of their incomplete removal during wastewater treatments and other processes. The analysis of ECs remains challenging because it involves analysis of chemicals with widely varying properties in a broad spectrum of environmental matrices and at very low concentration levels, which require sensitive and selective analytical techniques. The focus in this chapter is on the occurrence and level of detection of five classes of ECs: pharmaceuticals and personal care products, disinfection by-products, perfluorinated compounds, polybrominated diphenyl ethers, and benzotriazoles and dioxane. Sample preparation is an area where new improvements have occurred, aiming at simplification, lower costs, and "greener" procedures. Some novel sampling techniques for the detection of ECs in different environmental matrices are presented, such as: (1) water grab samples from inland and/or offshore; (2) large volume-solid-phase extraction for water samples, (3) passive samplers (POCIS, Chemcatchers, SR, SPMD), (4) sediment grab samples (Van Veen and/or gravity free fall corer), (5) biota grab samples with different trophic levels (sediment microorganisms, mussels, fish, and mammals), and (6) air passive samplers (inland and/or offshore).

Chapter 15: Water Quality at Jebel Ali Harbor, Dubai, UAE, authored by *Maraqa, M.A., Ali, A., Rao, M.V., Hamza, W., Imran, H.D., and Al Awadi, S.*, presents a study of the influence of discharged treated wastewater on harbor water quality in the Jebel Ali Free Zone area of Dubai. An extensive sampling protocol was implemented to identify target pollutants, which covered all discharge locations, several harbor stations, and a reference point in the Arabian Gulf. Water temperature, pH, and total dissolved solids were found to be lower, while total suspended solids and dissolved oxygen were generally higher than minimum objective limits. Ammonia exhibited an increase at deeper depths and the inner and outer basin, while sulfide at several locations was lower than the harbor water objective limit, and phosphorus exceeded the objective limit at the east and west corner of the inner basin. Fe, Zn, and Al were higher than the values at the reference location. Total petroleum hydrocarbon levels exceeded the harbor objective limit by orders of magnitude and as to the organic matter indicators, biochemical oxygen demand and total organic carbon, these were higher near the bottom and

highest in the inner and outer basins. The phytoplankton communities found in the study area matched those known along the coastal area of the Arabian Gulf, although the algae-rich harbor water might be the result of organic discharge and bacterial action. On the other hand, phytoplankton diversity and density drop over time may have resulted from seasonal variations, or the dredging of the harbor bottom's sediments. The presence of high coliform bacteria in marine water, as was the case of the inner basin, was a strong indication of discharge from untreated domestic sources.

Chapter 16: Sediment Quality at Jebel Ali Harbor, Dubai, UAE, authored by *Maraqa, M.A., Ali, A., Rao, M.V., Hamza, W., Imran, H.D., and Khan, N.*, expands the previous chapter's study by presenting the results of sediment analysis at the same harbor to: (1) establish a sediment quality baseline for the ecosystem of the study area, and (2) propose targets for sediment quality that will sustain long-term aquatic ecosystem health. Experimental results showed that sediments at the harbor were characterized by a fine texture containing clay and silt, which was different than what was found at a reference location in the Arabian Gulf. Sulfide, phosphorus, and total petroleum hydrocarbon (TPH) levels were higher in inner and outer basin sediments than in the harbor's main channel. Many metals were at higher levels in the harbor sediments than in those at the reference location. Levels of chromium, copper, and zinc associated with sediments are of environmental concern with all these metals' harbor levels exhibiting serious concerns to aquatic life. Lead was found to potentially represent a biologically adverse effect at parts of the harbor, while TPH and polynuclear aromatic hydrocarbon levels were higher than at the reference station and represented a biological risk in parts of the harbor.

Chapter 17: Inland Desalination: Techniques, Brine Management, and Environmental Concerns, authored by *Khan, Q., Maraqa, M.A., and Mohamed, A.M.O.*, reviews the available desalination techniques, brine management, and environmental impact of land-based desalination plants. The main conventional desalination technologies of multistage flash, multiple-effect distillation, and reverse osmosis are detailed and while dominating the market, there exist some emerging technologies with the potential for full-scale inland desalination. Regardless of the technology used, several environmental concerns associated with inland desalination exist. The reject brine from desalination plants can alter the physical and chemical properties of soils and may also find its way to groundwater, degrading it and making it inappropriate for drinking or irrigation. While there have been some efforts directed for better management of the brine, more work needs to be done from a research and practical point of view. Heavy energy consumption by desalination plants is responsible for greenhouse gas generation, making improvement and optimization of existing processes, or shifting to new technologies that employ renewable energy resources in the desalination process, a necessary condition for the continuation of desalination as a vital source of fresh water in desert regions.

Finally, the last part of this book, **Part 4: Emerging Issues in Environmental Pollution Assessment**, starts with Chapter 18 and concludes with Chapter 22.

Chapter 18: Pollution Assessment of Nanomaterials, authored by *Mohamed, A.M.O., Rodrigues, V.G.S., and Paleologos, K.E.*, summarizes some of the recent scientific information on emerging nanomaterials and highlights the potential and the threat that they pose to human health and the environment. Widespread application of nanotechnology in a variety of industrial applications has spearheaded important developments, but has also created new waste materials of unknown behavior in the environment, which could potentially impact ecosystems and human health. Engineered nanomaterials (ENMs)

enter the environment via different exposure routes, which include solid and liquid waste from domestic sources and industrial activities, accidental spillages, and atmospheric emissions. All these exposure pathways allow ENMs to disperse through the environment. ENM fate and transport in the environment are largely dependent on material properties such as surface chemistry, particle size, and biological and abiotic processes in environmental media. Depending on these properties, ENMs may stay in suspension as individual particles and aggregate, dissolve, or react with other materials. To date, little is known about the behavior of ENMs in the environment and the dominant physical and chemical factors that affect their movement and their toxicological effects once they enter a living organism. They also pose, because of their size and properties, unique challenges in establishing appropriate biomarkers and techniques and instruments to detect and monitor them, etc. Therefore health, safety, and environmental management of nanotechnology are important aspects to mitigate risks, improve the benefits, and transform opportunities into technological development in, among others, medical applications, flexible and communication devices, portable energy, food conservation, agriculture productivity, and pest control.

Chapter 19: Noise Pollution and Its Impact on Human Health and the Environment, authored by *Mohamed, A.M.O., Paleologos, E.K., and Howari, F.M.*, addresses the sources, health impacts, risk assessment, and mitigation measures of noise pollution. Noise pollution is recognized as a major problem for the quality of life in urban areas, especially since its increase as a result of car numbers and an expansion to almost 24-h activities in cities. Economic and population growth has increased the tendency toward noise generation. A major challenge is the quantification of the noise effects on the population. Noise is considered a growing health threat, and if left unchecked it could result to hazardous conditions. The WHO estimates that 10% of the world population is exposed to sound pressure levels that could potentially cause noise-induced hearing loss. In the United States, it is estimated that about 10 million people have already suffered irreversible hearing damage from noise, and 30−50 million people are exposed daily to hazardous noise levels. Epidemiological studies have found that cardiovascular diseases are consistently correlated with exposure to environmental noise. Detailed studies to evaluate the extent of potential health effects of noise exposure are needed that would assist national and local governments to understand the health impacts of environmental noise and help them develop policy and management strategies and action plans for noise control.

Chapter 20: Assessment of Radiation Pollution from Nuclear Power Plants, authored by *Iqbal, J., Howari, F.M., Mohamed, A.M.O., and Paleologos, E.K.*, reviews the challenges that nuclear energy must overcome to remain part of a sustainable energy mix. Different types of radioactive waste pollution from nuclear power plants, environmental and health effects, and nuclear regulations in different countries are discussed. Nuclear power plants raise issues of catastrophic failure, which has met with anxiety from the public, and of an extremely high cost that is not restricted to operation, but expands also to nuclear waste disposal and the need to find and construct appropriate repository sites capable of providing isolation from human populations for thousands of years. Associated with both nuclear plants and repository sites are safety and security measures and costs that extend well into the future. Eventually, given that no absolute guarantee can ever be made about the safety of nuclear power plants or waste repositories, especially for time horizons beyond any meaningful prediction, the use of nuclear energy boils down to a decision by societies of what level of risk is acceptable to them.

Chapter 21: Artificial Intelligence and Data Analytics for Geosciences and Remote Sensing: Theory and Application, authored by *Al-Obeidat, F., Marir, F., Howari, F.M., Mohamed, A.M.O., and*

Banerjee, N., presents two case studies to address the limitation of conventional statistics in dealing with hyperspectral data of satellite and airborne images. The first case study presents the development of an artificial intelligence (AI) and data analytics algorithm capable of classifying hyperspectral data to support remote sensing, and Geographic Information System researchers to understand and predict changes in natural Earth processes. The new classification algorithm is based on a fuzzy approach combining decision tree classifiers with fuzzy multiple-criteria decision analysis classifiers. The second case study presents the development of an AI tool that extracts features from the hyperspectral data to transform a 2D satellite and airborne image into a pseudo-3D image to enhance edge contrast and produce multidirectional sun-shaded images and their edges. Such 3D images are very useful in supporting the discovery and mining of valuable minerals or other geological materials from ores, lodes, veins, seams, and reef or placer deposits, and overall to improve the efficiency and effectiveness of mineral exploration.

Chapter 22: Lifecycle Assessment of Aquaponics, authored by *Kamareddine, L.A. and Maraqa, M.A.*, provides a critical review regarding the environmental, economic, and social impacts of aquaponics, along with evaluating the numerous tools to assess aquaponics, and discussing the challenges that face these systems. The most common method used to assess sustainability is by conducting a lifecycle assessment in which all inputs and outputs are collected, and the cost of each item is provided. Previous studies showed that different geographic locations and climates highly affect the design and operating costs, as well as the environmental and economic sustainability, of aquaponic systems. The authors highlight the need for additional studies under different climate conditions and geographical locations to compare aquaponics with aquaculture, hydroponics, and conventional agriculture.

Environmental problems have entered not only the scientific, but also the daily discourse since the second half of the 20th century. The extent of the problems is such that perhaps the word "pollution" indicates the effects and potential impact of environmental issues. The meaning of the word itself has become so broad as to be capable of being attached and referred to as: air pollution, river pollution, groundwater pollution, marine water pollution, soil pollution, solid waste pollution, liquid waste pollution, noise pollution, and light pollution, among others. Assessing the impact of all these diverse pollution events in every potential medium, air, water, and soil, is a tall task that cannot be met in a comprehensive way by any single book. The editors of this work are aware of these limitations, but hope that this book, which was developed by a select group of scientists and researchers, will provide a view of environmental problems that is not limited to a particular scientific field, and will constitute a valuable demonstration of the multidisciplinary and interdisciplinary nature and need for pollution assessments, which is not realized so broadly, outside the academic community.

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