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WATER POLLUTION WITH SPECIAL REFERENCE TO HUMAN HEALTH

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ABSTRACT

Water quality issues are a major challenge that humanity is facing in the twenty-first century. Here, we review the main groups of aquatic contaminants, their effects on human health, and approaches to mitigate pollution of freshwater resources. Emphasis is placed on chemical pollution, particularly on inorganic and organic micropollutants including toxic metals and metalloids as well as a large variety of synthetic organic chemicals. Some aspects of waterborne diseases and the urgent need for improved sanitation in developing countries are also discussed. The current scientific advances to cope with the great diversity of pollutants. It is organized along the different temporal and spatial scales of global water pollution. Persistent organic pollutants (POPs) have affected water systems on a global scale for more than five decades; during that time geogenic pollutants, mining operations, and hazardous waste sites have been the most relevant sources of long-term regional and local water pollution.

KEYWORDS: Agriculture, pollutants, pesticides, pathogens, wastes.

INTRODUCTION

Many of the major problems that humanity is facing in the twenty-first century are related to water quantity and/or water quality issues.[1] These problems are going to be more aggravated in the future by climate change, resulting in higher water temperatures, melting of glaciers, and an intensification of the water cycle, with potentially more floods and droughts. With respect to human health, the most direct and most severe impact is the lack of improved sanitation, and related to it is the lack of safe drinking water, which currently affects more than a third of the people in the world. Additional threats include, for example, exposure to pathogens or to chemical toxicants via the food chain (e.g., the result of irrigating plants with contaminated water and of bioaccumulation of toxic chemicals by aquatic organisms, including seafood and fish) or during recreation (e.g., swimming in polluted surface water). The sources of micropollutants in natural water are diverse. About 30% of the globally accessible renewable freshwater is used by industry and municipalities[2], generating together an enormous amount of wastewaters containing numerous chemicals in varying concentrations. In many parts of the world, including emerging economies such as China, these wastewaters are still untreated or undergo only treatment that does not effectively remove the majority of the micropollutants present. Other important sources of micropollutants include inputs from agriculture[3], which applies several million tons of pesticides each year; from oil and gasoline spills; and from the human-driven mobilization of naturally occurring geogenic toxic chemicals, such as heavy metals and metalloids. Additional natural micropollutants are biologically produced taste and odor compounds, which are not primarily a toxicological problem but are of great aesthetic concern. There are also the millions of municipal and, particularly, hazardous waste sites, including abandoned industrial and former military sites, from which toxic chemicals may find their way into natural water, especially into groundwater.

Chemical Complexity of Aquatic Pollutants

Considering the large number of structurally diverse pollutants that may undergo numerous interactions with other natural or anthropogenic, dissolved or particulate chemical species and materials (e.g., natural organic matter, mineral surfaces, redox active species), with light, and even with living organisms, exposure assessment of aquatic pollutants is commonly quite a challenging task and requires a broad interdisciplinary approach.[4]

For inorganic pollutants, including heavy metals (e.g., Cr, Ni, Cu, Zn, Cd, Pb, Hg, U, Pu) and metalloids (e.g., Se, As), the main challenge in assessing environmental risks is related to their contrasting behavior under different redox conditions. These elements are not subject to degradation like many of the organic pollutants (see below); the major processes that determine their transport and their bioavailability include oxidation/reduction, complexation, adsorption, and precipitation/dissolution reactions. Most metallic elements exhibit widely different solubility in the presence of oxygen and under reducing conditions. Under toxic conditions, the most abundant redox sensitive metals— iron and manganese—form finely dispersed oxide particles, which strongly adsorb heavy metals and metalloids.[5] When oxygen is depleted, these oxide particles undergo reductive dissolution and release their adsorbed toxic load.[4] The precipitation and dissolution of such reactive particles in the environment are often governed by microorganisms.

Agriculture and Water Quality

Several million tons of chemicals are consumed annually for agricultural production to maintain and increase crop yields by controlling fungi, weeds, insects, and other pests. Pesticides and related agrochemicals are available on the market as tens of thousands of different commercial products that contain approximately hundreds of different active chemical ingredients.[5,6] Owing to the toxicity of these chemicals for biota and humans and their intentional release into the environment, the use of new and established agrochemical products is regulated in detail: Country-specific registration and risk assessment procedures aim at protecting not only soil and water resources/ecosystems but also farmers and consumers. Typical agricultural point sources include pesticide runoff from hard surfaces, mostly from farmyards or storage facilities during the handling of agrochemical products or accidental spills. Depending on connections to sewer systems, pesticides can either infiltrate into the nearby soil or enter aquatic systems via sewage treatment plants. Point sources can cause high-concentration peaks in the outlet of a catchment area, but they do not necessarily constitute a major share of the mass input. Monitoring programs of pesticide occurrence and distribution illustrates that the spectrum of active ingredients can still differ from those used in the developed countries. Especially, the persistent organochlorine pesticides [DDT, hexachlorocyclohexanes (HCHs)] are applied extensively for agriculture and sanitation purposes because they are still comparatively cheap and effective.[2]

Groundwater Contamination by Spills and Hazardous Waste Sites

Contamination of groundwater from municipal solid waste landfills, hazardous waste sites, accidental spills, and abandoned production facilities is a prominent cause of water pollution. Several hundred thousands of sites can be found throughout the world, where 100 million tons of wastes have been and still are discarded. Many of them contain large amounts of hazardous or radioactive material. However, estimates point to an even higher number of unknown, groundwater-contaminating landfills. Even though many of the official contaminated sites are under control, the large majority of them are expected to release chemicals into the environment. In addition, thousands of oil, gasoline, and other chemical spills occur each year on land and in water from a variety of types of incidents, including transportation and facility releases. One of the major scientific challenges and prerequisites for a thorough assessment of groundwater pollution by spills and hazardous waste sites is thus to quantify the site-specific, relevant processes that determine the transport and transformation behavior of a given pollutant and its transformation products.

Waterborne Diseases

The problems related to sanitation, hygiene, and drinking water differ fundamentally between industrialized and developing countries. In high-income countries, maintenance and replacement of the installed sanitation and water supply infrastructure are the predominant tasks during the next 20–30 years. In developing countries, where most of the sewage is discharged without treatment, the improvement of sanitation and access to safe drinking water are of primary importance.[1] However, because most of the population increase will occur in urban areas of developing countries, current estimates predict that 67% of the world's population will still not be connected to public sewerage systems in 2030.[1] Currently, 1.1 billion people lack access to safe water, and 2.6 billion people do not have proper sanitation, primarily in developing countries, and an imbalance exists between rural and urban areas in access to both improved sanitation and safe drinking water supply. Four out of five of the world's inhabitants with no access to safe sources of drinking water live in a rural environment.[4] On a global scale, the restricted access to safe water and to improved sanitation causes 1.6 million deaths per year; more than 99% thereof occur in the developing world. Nine out of ten incidents affect children, and 50% of childhood deaths happen in sub-Saharan Africa.[1] The easily preventable diarrheal diseases caused by unsafe water and lack of sanitation and hygiene contribute to 6.1% of all health-related deaths; one report estimates that unsafe water is responsible for 15% to 30% of gastrointestinal diseases.[7] In addition to cholera, the most proliferate waterborne disease outbreaks were due to (para) typhoid fever (caused by *Salmonella typhi* and *S. paratyphi*, respectively). Also hepatitis A and E viruses, rotaviruses, and the parasitic protozoa *Giardia lamblia* are often found associated with inadequate water supply and hygiene (158). A study in Bangladesh reported that 75% of diarrheal and 44% of the control children were infected with either *Cryptosporidium parvum*, *Campylobacter jejuni*, enterotoxigenic and enteropathogenic *Escherichia coli*, *Shigella* spp., or *Vibrio cholera*.[5,8] In high-income countries, outbreaks caused by pathogenic *E. coli* and cryptosporidiosis are often reported, and *Legionella pneumophila* is increasingly distributed in warm water supplies and airconditioning systems of large buildings, such as hospitals. Outbreaks of typhoid fever occur only sporadically.

Wastewater Treatment and Water Reuse

Mitigation of wastewater streams from households and industry is one of the key components for improving sanitation and maintaining public and ecosystem health. Treatment of municipal wastewater aims at eliminating nutrients (carbon, nitrogen, phosphorous) and pathogenic microbes. Nutrient removal leads to a reduction of the biological oxygen demand (BOD) of effluent water and thus a decrease in eutrophication of inland water bodies and coastal areas. In industrialized countries, connectivity to municipal wastewater treatment plants is in the range of 50% to 95%, whereas more than 80% of the municipal wastewater in low-income countries is discharged without any treatment, polluting rivers, lakes, and coastal areas of the seas.[1] Industrial wastewater is, however, not only a source of BOD but also a point source of chemical pollution of heavy metals and synthetic organic compounds. In industrialized countries, these pollutants have been reduced significantly through implementation of internal water recycling and recovery systems and end-of-pipe treatment using advanced technologies, such as activated carbon, advanced oxidation, or membrane processes. The water efficiency of industrial wastewater treatment (i.e., the product revenues per treated volume of process water) is highly variable, ranging from approximately US$140 per m^3 in Denmark to only US$10 per m^3 in the United States (1) and even less in low-income countries. These numbers depend on the type of industrial activity. To date, a substantial potential exists for water reuse, which would strongly reduce the discharge of potentially polluted water.

CONCLUSION

Tackling global water pollution requires an effective set of policies, technologies, and scientific advances on very different scales. The legacy of persistent priority pollutants, such as Pollution Control Boards, calls for a general phase-out and a regulatory effort on the global scale. Volatile chemicals, such as halogenated compounds or mercury, which are not subject to biodegradation but accumulate in the food chain, should be restricted in their use to applications in strictly closed systems. Human food production systems require rigorous protection against compounds with a potential for bioaccumulation; thus water as the key commodity for agriculture needs the same attention. In addition, the precautionary principle has to be applied in designing potential substitutes for such priority pollutants to make sure that today’s solution will not become tomorrow’s problem.

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