CONTAMINATION OF WATER RESOURCES

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Summary

Contamination of water resources by hazardous substances such as organochlorine compounds, agricultural chemicals and heavy metals harms living organisms and ecosystem. There is also the potential to harm human health through bioaccumulation through the food chain, contamination of public water supply, and recreational use of contaminated water resources.

Various problems such as decrease of dissolved oxygen, production of musty odors and toxic substances by cyanobacteria, and problems in waterworks are caused by algal blooms in eutrophic lakes and reservoirs. Throughout the world, many people suffer from water related diseases caused by cyanobacteria, pathogenic protozoa, pathogenic bacteria and pathogenic viruses.

1. Introduction

The environmental contamination of rivers, lakes, reservoirs, and ocean waters can be broadly categorized as contamination caused by organic chemicals, contamination caused by inorganic chemicals, contamination caused by microorganisms, and contamination related to physical conditions. Because these kinds of contamination threaten human health and living environments, the removal or degradation of contaminants and measures to control them are extremely important. This chapter discusses both chemicals and microorganisms causing contamination of water.

2. Contamination by Hazardous Substances

The growth and diversification of industry has been accompanied by wide use of diverse chemicals without adequate evaluation of their effects on the environment and on the human body, resulting in pollution of various kinds contaminating the environment. Examples include the contamination of soil and groundwater by improper treatment of hazardous substances, contamination of water bodies by inflowing wastewater containing hazardous substances, and contamination of soil, groundwater, and water bodies by the seepage of contaminants from landfill sites used to dispose of garbage. Contamination of water resources by hazardous substances harms living organisms and ecosystems at the same time as it harms human health through bioaccumulation, contamination of public water supply, and recreational use of contaminated water resources. The contamination of water and soil can hinder the growth of agricultural products and the contaminants can accumulate in the products. Contamination of lakes, reservoirs, rivers, and ocean waters can affect fish and shellfish. Contamination by hazardous substances seriously harms the agricultural and fishery industries in this way, and exposes people and animals to bioconcentrated contaminants. Table 1 shows a categorization of hazardous substances and typical substances of each kind.

Category	**Typical substance**
Organic compoundss	Dioxins, trichloethylene, PCB, benzene
Agricultural chemicals	Simazine, benthiocarb, thiuram
Heavy metals	Mercury, cadmium, lead, chromium, arsenic, selenium
Inorganic compounds	Nitrate, nitrite, cyanide

Table 1. Toxic substances

Agricultural chemicals is one class of hazardous substances that cause contamination; these are organic chemicals that include organochlorine compounds. They are extremely toxic and when humans are exposed to them, they can suffer from internal and neurological diseases. They include many substances that are suspected of being carcinogens or mutagens. Because people’s health can also be harmed by exposure to these substances through drinking water, they are included in water quality standards for drinking water, environmental standards, and wastewater standards in many countries. In addition to lowland arable land, agricultural chemicals are spread in paddy fields, upland fields, in forests, on golf courses, in parks, and in green belts. They are also used in homes to fight insects. Because agricultural chemicals are generally highly soluble, they contaminate the environment by seeping into the ground with rainwater, while those on the ground’s surface can be transported into river by rainwater. Contamination by organochlorine compounds attracted wide attention in the early 1970s. Typical organochlorine compounds are trichloroethylene (TCE) and tetrachloroethylene (PCE); these are used mainly as solvents or as dry cleaning agents. Many organochlorine compounds have been confirmed to be carcinogens through animal testing, and are suspected of acting as carcinogens on the human body.

Dioxins are now the best known of the organic chemicals. It is reported that 95% of dioxin is produced by incineration plants. Dioxin refers collectively to chemicals known as poly-chlorinated dibenzo-p-dioxin (PCDD) and poly-chlorinated dibenzofuran (PCDF). According to the substitution location and number of their chlorine atoms, there are 75 kinds of PCDD and 135 kinds of PCDF. The toxicity of these substances varies widely, with the most toxic being 2,3,7,8-TCDD, and the concentration of dioxins is often expressed as the total of values converted to the toxicity of 2,3,7,8 TCDD (Toxicity Equivalent: TEQ). As a result of investigation using laboratory animals, dioxins have been reported to be teratogenic, carcinogenic and immunotoxic, and to have toxic effects in reproduction . About half the dioxins discharged into the atmosphere fall to the ground with soot, where they contaminate the soil and water bodies. It is reported that about 90% of dioxin in people's bodies is ingested in their food, and dioxins in the soil and water bodies accumulate in people's bodies through vegetables, shellfish and fish. The WHO has established 4 pg $TEQ•kg^{-1}•day^{-1}$ as the quantity of dioxin that can be ingested without causing harm to people's health, even if they ingest it throughout their lives.

An agreement concerning persistant organic pollutants (Stockholm Convention on Persistant Organic Pollutants) was formally adopted in May 2001 at the United Nations Conference on Environment and Development. The agreement came into force in May 2004. Because Persistent Organic Pollutants (POPs) are chemical substances that resist decomposition in the environment (persistency), are easily concentrated in living organisms through the food chain (high accumulation property), travel long distances to readily accumulate in polar regions etc. (long distance commutation property), and harm human health and ecosystems (toxicity), and because it is reported that POPs cause global scale contamination (for example accumulating in the bodies of Inuit people, and in seals, camels, and other animals), action within an international framework was considered necessary. The substances covered by the Agreement are aldrin (insecticide), dieldrin (insecticide), endrin (insecticide), chlordane (insecticide), heptachlor (insecticide), toxaphene (insecticide), mirex (fire-retardant agent), hexachlorobenzene (insecticide), PCBs (insulating oils, heat transfer medium, etc.), DDT (insecticide), PCDD, PCDF, and fluorocarbons. Under this agreement, international cooperation programs are undertaken to provide technical and financial support to developing countries where measures to deal with these substances have not been implemented.

Inorganic chemicals that cause contamination include cyanide, nitrite, nitrate, and heavy metals such as cadmium, mercury, lead, and arsenic. Heavy metals and cyanide are extremely toxic, and many of these substances are acutely toxic and carcinogenic. In Japan, there have been two well-known cases of contamination by heavy metals. In one case, known as Minamata disease after the city where it occurred, organic mercury accumulated in fish through bioaccumulation, causing central nervous system disorders and fetal poisoning among the people who ate these fish. Another called *itai-itai* disease was an outbreak of osteomalacia and bone deformations among people who ate rice and drank water polluted by cadmium discharged by a mine. Contamination by nitrate and by nitrite in ground water is caused by excessive application of chemical fertilizers, inappropriate control of waste material from animal husbandry, and seepage of domestic wastewater into the ground. It is known that if infants ingest groundwater contaminated by a high concentration of nitrate nitrogen, they contract methaemoglobinaemia. Because the surfaces of soil particles are negatively charged, and negative ions such as nitrite and nitrate are not absorbed by the soil, they seep down to the aquifer, contaminating the groundwater. Another problem caused by nitrite nitrogen and nitrate nitrogen is that it forms N-nitroso compounds in people's stomachs. N-nitroso compounds has been proven to be carcinogenic to laboratory animals. Groundwater flows very slowly and has physical properties which mean that when it is influenced by heavy metals, volatile organochlorine compounds, or nitrate, dilution by further inflow does not normally occur. As a result, once such contamination has occurred, natural recovery is unlikely.

It has recently been discovered that there are chemicals that, when ingested by the bodies of living organisms, influence the hormonal activity that normally occurs in these living organisms. Such substances are called exogenous endocrine disruptors. It has also recently been reported that the mechanism of action of exogenous endocrine disruptors varies, with some acting directly through intranuclear receptors and others affecting the intracellular signal transmission system without acting through receptors.

Examples of chemical substances that act through intranuclear receptors are those that bond with estrogen (female hormone) receptors to act in a way similar to the action of estrogen, and those that bond with androgen (male hormone) receptors to block the activity of androgen. Exogenous endocrine disruptors act in extremely minute quantities, accumulate in people's bodies, and are transmitted from mothers to their children, influencing later generations. They are not acutely toxic, and cause problems that appear after the children have grown up. The effects of these chemicals have also been reported in wildlife such as snails, carp, and alligators.

Selecting chemicals for inclusion in standards, and setting standard values for them, is done by (1) determining if each chemical substance actually effects human health, (2) evaluating the quantitative relationship of exposure to each chemical with its effects on health, (3) evaluating the degree to which people are exposed to each chemical, and (4) estimating the class and degree of risk to people and estimating the probability of health effects appearing in a specified population.

The guideline values in the standards of the WHO have been calculated assuming that an adult weighing 60 kg drinks 2 liters of water a day, a child weighing 10 kg drinks 1 liter of water a day, and a baby weighing 5 kg drinks 0.75 liters of water a day. The guideline values are calculated accounting not only for the direct ingestion of chemical substances by drinking water, but also considering indirect ingestion such as the absorption of volatile substances and absorption through the skin during bathing and showering. Health risk assessments done to calculate the guidelines are based on data obtained by surveys of the effects of chemicals on people and on toxicity testing performed using experimental animals.

This toxicity testing was performed to study acute exposure, short-term exposure, long-term exposure, reproductive toxicity, fetal toxicity, teratism, mutations, and carcinogenicity, etc. Then the NOAEL (no observed adverse effect level) and LOAEL (lowest observed adverse effect level) are obtained from data on each chemical substance. Depending on the chemical substance being considered, there are cases where the NOAEL and LOAEL are obtained using data from surveys of effects on people, and there are cases where they are obtained from toxicity experiments performed using experimental animals. The guidelines are established and calculated based on TDI (tolerable daily intake), i.e. the quantity of a chemical substance that will not endanger a person's health even if the person ingests it in food and water throughout his life.

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Biographical Sketches

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