CHAPTER 1

INTRODUCTION

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1.1 SCOPE OF THE BOOK

Toxic management of lakes and reservoirs is aimed at the protection of human health and aquatic life from impacts caused by the release of toxic substances to surface waters. Lakes and reservoirs hold important freshwater ecosystems of the globe, in which a great number of species, including human beings, interact with each other. Special care must be taken when releasing toxicants into lakes and reservoirs because of the unique physical and chemical characteristics of confined water. Toxic substances are retained longer in both water and sediments than in flowing surface water, which increases the risk of exposure of toxicants in terms of concentration and duration to both aquatic organisms and humans who depend on drinking water and food from lakes and reservoirs.

This Guideline Book covers basic concepts of aquatic ecotoxicology, case studies of the Great Lakes and practical experiences developed for toxic substances management in the Ruhr River basin, Germany. The three chapters that follow this introductory chapter introduce basic concepts for readers who are not familiar with ecotoxicology. Chapter 2 describes general principles of toxicology which focuses on ecotoxicology on aquatic life with an emphasis on the uniqueness of the ecosystem of lakes and reservoirs. Chapter 3 describes the movement of toxic substances through bioaccumulation and deals with the important chemical factors involved in bioconcentration and bioaccumulation. The ecological structure of biomagnification are also emphasized and the Minamata and Itai-itai diseases are briefly introduced. Chapter 4 focuses on modelling of lake ecotoxicology, relating toxicant movement in lake ecosystems quantitatively so that readers can understand basic concepts of toxic management in terms of mass balance.

The remaining chapters deal with specific groups of toxic substances. Chapter 5 describes heavy metal and other inorganic toxic substances, in which the sources, movement and sinks of representative heavy metals and other inorganic substances are introduced with important points for their management. Chapter 6 describes organic pesticides in aquatic environments -- the Great Lakes studies in which detailed information on pollution from many prominent pesticides is clearly summarized with an emphasis on the importance of atmospheric migration of those pesticides over entire lakes. Chapter 7 describes other organic toxic substances with an overview of various organic pollutants in terms of sources, storage, transportation, use, fate, properties, and prevention policies are presented with an emphasis on common problems faced by developing countries with examples of PAHs, PCBs and chlorinated dioxins. Chapter 8 describes interesting practical experiences for the management of toxic substances in the Ruhr River basin, Germany, where the Ruhr River Association is

responsible for managing the entire basin with respect to the quantity and quality of water of 14 reservoirs as well as the river itself. The experiences of monitoring and surveillance, and mass balance accounts of heavy metals, chlorinated hydrocarbons, AOX, PCBs, pesticides and ammonia are introduced. Control and abatement measures with legal and financial aspects are also described.

1.2 BASIC STAND TO MANAGE TOXIC SUBSTANCES IN AQUATIC ENVIRONMENTS

More than 9 million chemicals are listed on the Chemical Abstract Service's Registry of Chemicals in 1990, and the number of new chemicals is steadily increasing, although only an estimated 76,000 are in daily use. Some estimates of the total global number of species show about 27.7 million in existence (see Table 1.1). A substantial number of these species are aquatic, although often limited in their distribution. When comparing the number of chemicals and these aquatic species for toxics control, it is strikingly obvious that there is insufficient information on the toxicity of chemicals for each species. Moreover, our understanding of the toxicity of chemicals on human health in terms of environmental pollution is still very limited. Readers will understand that the subject of toxic substances management in aquatic ecosystems is both very difficult and complex.

Table 1.1 Summary of Plant and Animal Species Numbers (Kenega, 1987)

Taxonomic groupings	Approximate numbers of species
Plankton kingdom	
Algae, macrophytes (aquatic and terrestrial)	350,000
Animal kingdom	1,200,000
Vertebrates	37,790
Fishes	17,000
Birds	8,600
Reptiles	6,000
Mammals	4,300
Amphibians	1,500
Invertebrates	1,150,000

Toxicology is the study of the adverse effects of chemicals on living organisms by examining the nature of these adverse effects and assessing the probability of their occurrence. Toxicology can be further classified into the following areas; descriptive, mechanistic and regulatory.

Descriptive toxicology is concerned directly with appropriate toxicity tests in which experimental organisms are designed to yield information that can be used to evaluate the risk posed to humans and other species of organisms in the environment by exposure to specific chemicals.

Mechanistic toxicology is concerned with elucidation of the mechanisms by which chemicals exert their toxic effects on living organisms. Results of these studies help to develop more predictive tests useful in obtaining information for risk assessment.

Regulatory toxicology is responsible for deciding whether or not a chemical has a low enough risk to be marketed for its described purposes on the basis of data from descriptive toxicity tests. In general, food and drug administrative agencies are responsible for regulating drugs, cosmetics, food additives and agrochemicals, while environment protection agencies are responsible for regulating most other chemicals in establishing standards for the amount of chemicals permitted in ambient air, water, drinking water and soils. Environmental toxicology can be defined as the toxicology focusing on the study of the adverse effects of target chemicals on the entire ecosystem assessing the risk posed to both humans and other organisms by the chemicals.

Readers who wish to obtain further information on the basic science of toxicology are advised to consult relevant text books (for example, TOXICOLOGY, edited by J. Doul, C.D. Klaassenn and M.O. Amdur, second edition, Macmillan Publishing Co., Inc. New York, 1980). In this book, readers will learn of new ideas and case studies which are more oriented toward environmental toxicology of the ecosystems of lakes and reservoirs. In this book toxic substances are classified by conventional types of chemicals; heavy metals, pesticides, chlorinated organic substances etc., based upon the availability of information on environmental toxicology.

Management of toxic substances in the lake and reservoir environment consists of two parts; (1) risk assessment of target toxic substances in the specific lake and reservoir ecosystem; and (2) development of a control method of target toxic substances based upon the results of the assessment for the ecosystem. Risk assessment of the target chemicals firstly needs collection of basic information on the environmental toxicity provided by governmental agencies, universities and international supporting agencies such as the International Register of Potentially Toxic Chemicals (IRPTC - see Appendix for information on this organization). Commercial international information systems such as the Chemical Information System in the U.S.A. and the Environmental Chemicals Data and Information Network in the EC are also useful. With regard to information on the human cancer risk of chemicals, the International Agency for Research on Cancer (IARC) provides a series of monographs on evaluation of the carcinogenesis risk of chemicals to man.

As a first and simple step towards risk assessment, it can be said that a chemical compound which is likely to be a severe pollutant has the following characteristics; high toxicity potential; high dispersion tendency; persistence in the environment; bioaccumulation tendency; large production volume and large discharge into the environment. Industrial wastes of air, liquid and solid states, often contain toxic substances of the above characteristics so that careful treatment and disposal of toxic substances is essential for polluters to continue their production. Industrial polluters must consider the level of treatment and disposal of target toxic substances to meet the environmental standards set by regulatory agencies. Risk

assessment is conducted to set up the appropriate environmental standards by the regulatory agencies.

Risk assessment of new chemicals, before commercial production, is conducted by the industrialized member countries of the Organization for Economic Cooperation and Development (OECD). One of the environmental activities of the OECD is to provide a guideline on "Chemical Testing Programme" and "Special Programme on the Control of Chemicals" under which new chemicals for the use of industrial purposes (except drugs, food additives and agrochemicals) are evaluated as to whether they are environmentally safe to put into commercial production. The OECD guidelines for the testing of chemicals is discussed in greater detail in Chapter 3.

The regulatory work of risk assessment of drugs, food additives, cosmetics and agrochemicals is traditionally carried out by individual countries. Drugs, food additives and cosmetics are usually only evaluated for risks to human health and not for environmental safety after disposal. Information on the fate of those types of chemicals in the environment is very limited. Further research is necessary to find appropriate methods of environmental risk assessment of drugs, food additives and cosmetics after use.

Pesticides have been regulated by agricultural agencies with traditional methods of risk assessment. However, over use and misuse of pesticides in many developed and developing countries have required the improvement of traditional risk assessment into more stringent methods and with greater orientation toward environmental safety. Problems inherent to agrochemicals are dealt with in Chapters 6 and 8.

The control of toxic substances requires the following stand points; (1) source identification and source control of target toxics; (2) fate and sinks determination for the mass balance of the target toxics; (3) a lake and river basin approach for source control of the target toxics. If toxic substances are discharged from point sources such as industrial wastewaters, municipal wastewaters and solid wastes landfill sites, the source identification is easier for control than other cases of non-point sources. If toxic substances migrate to the lake and reservoir environment through multiple routes including surface water, ground water, rain water and air pollution, the control of toxic substances is very difficult and requires comprehensive measures.

Management of toxic substances requires an institutional approach in which responsible local agencies must accumulate information on target toxics and practice source control of the toxics in the scope of the lake, reservoir or river basin concerned. The cooperation of national and state governments is also crucial in the control of toxic substances. Governments must support the activities of local agencies in order to build an information network and increase the capacity of toxic chemical analysis of local agencies. In order to implement effective source control of target toxics, it is necessary to set regulations by which responsible local agencies can obtain information on toxics inventory from factories, laboratories and hospitals and universities etc., which discharge toxic substances. Developing countries must make great

efforts to increase the capacity of toxic management and they must be helped by developed countries to achieve this.

1.3 BASIC TERMINOLOGY OF AQUATIC TOXICOLOGY

The following key words are basic terms in the field of aquatic toxicology. Definitions of terms are mainly quoted from the Technical Support Document of the US EPA for Water Quality-based Toxics Control (1991).

ACUTE TOXICITY / CHRONIC TOXICITY - Toxic effects may be produced by acute / or chronic exposure to chemical agents. Acute toxicity is defined as toxicity caused by acute exposure including a single exposure or multiple exposure occurring within a short period. In aquatic toxicity tests, a toxic effect observed in 96 hours or less is considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality. Chronic toxicity is defined as toxicity caused by chronic exposure that continues for a relatively long period of time, often one-tenth of the life span or more. Chronic is a relative term depending on the life span of the target organism.

LC/ NOEC/ LOEC/ EC - Lethal concentration is the concentration of a toxicant at which a certain percentage of the test organisms die, e.g. the LC_{10} or LC_{50}. An exposure duration is also included in the endpoint such as 24, 48, 72, or 96 hours (e.g. 96-hour LC_{50}). Commonly used chronic toxicity endpoints are the non observed effect concentration (NOEC), the lowest observed effect concentration (LOEC), and the effective concentration (EC). The NOEC is the highest concentration of toxicant to which the test organisms are exposed that caused no observable adverse effect. The effects measured may include sub-lethality or lethality. Sub-lethality means a stimulus below the level that causes death such as decreases in reproduction, fertilization, growth and abnormality. The effects also include survival from life cycle, partial life cycle, and early life stage tests with aquatic organisms. The LOEC is the lowest concentration of toxicant to which the test organisms are exposed that causes an observed effect. The EC is the toxicant concentration which would cause an adverse effect upon a certain percentage of the test organisms, (e.g. EC_{10} or EC_{50}).

ADDITIVITY / ANTAGONISM / SYNERGISM - Additivity is the characteristic property of a mixture of toxicants that exhibits a total toxic effect equal to the arithmetic sum of the effects of the individual toxicant. Antagonism is the characteristic property of a mixture of toxicants that exhibits a less-than-additive total toxic effect, while synergism is the characteristic property of a mixture of toxicants that exhibits a greater-than-additive total toxic effect.

BIOACCUMULATION / BIOCONCENTRATION - Bioaccumulation is the process by which a substance is taken up by an aquatic organism, both from water and through food, while bioconcentration is the process by which a substance is absorbed from

water through gills or epithelial tissues and is concentrated in the body. Bioconcentration factor (BCF) can be defined as the ratio of a substance's concentration in tissue versus its concentration in water, in situations where the food chain is not exposed or contaminated. Bioaccumulation factor (BAF) can be also defined as the ratio of a substance's concentration in tissue versus its concentration in ambient water, in situations where the organism and the food chain are exposed.

BIOMAGNIFICATION - Biomagnification is the process by which a substance is taken up by an aquatic organism through food chains and thereby exhibits its increasing concentration in the organism related to its trophic status. The term "ecological magnification" is also sometimes used instead of biomagnification.

REFERENCES

Kenega, E.E., Methods for assessing the effects on non-human biota of mixtures of chemicals as applied to specific taxonomic representatives of individual or groups of species, in Vouk, V. B. *et al.*, edition: Methods for assessing the effects of mixtures of chemicals, SCOPE 30, SGOMSEC 3, John Wiley & Sons, 1987.

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