WATER and WATER POLLUTION HANDBOOK

Water and Water Pollution Handbook

VOLUME 1

(*in four volumes*)

Edited by LEONARD L. CIACCIO

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Preface

The acceleration of interest in pollution among the general population in the past several years has at last affected that development of our instant communication age, the public opinion poll. This evident and enduring concern has no doubt been responsible for the actions by the legislative and administrative branches of the local and federal governments in pollution abatement.

Many disturbing environmental problems have arisen and they have evoked notable activities. The advent of mercury pollution in Lake Erie and the St. Clair River, first signaled by high content of that metal in fish found by Norvald Nimreite, a graduate student at the University of Western Ontario, has triggered a relatively fast reaction by the Canadian government and its Food and Drug directorate, the State of Michigan, the U.S. Food and Drug Administration, and the FWQA. Although some people see sluggishness on the part of the government, a limit on allowed mercury levels in fish has been set, fishing for sport has been banned, polluting industrial plants have been closed by court order, and an investigation of toxic pollutants has commenced. The solution to problems such as the removal of mercury from bottom sediments and the entrance of mercury and its transmission up the ecological food chain, as well as a comprehensive understanding of the effects of mercury on the health of man, are in need of elucidation. The tragic effects of teratogenicity and neurological damage due to the acute and chronic toxic effects of mercury poisoning in Minamata, Japan and upon the Huckelby family of Alamogordo, New Mexico portray an unpleasant result of our global carelessness.

The Suffolk County, Long Island legislature has banned the use of most existing detergents as of March 1, 1971. Their concern relates to the contamination by undegraded detergents of their drinking water, which is obtained from wells. Since the county's disposal system consists almost exclusively of septic tanks for private homes, the problem is quite serious. Although this is a bold measure, it is a stop-gap action. The installation of a sewer system must eventually be considered in light of

the increasing population in that section of Long Island. All over the world interest has risen because of the pollution of Lake Baikal in Russia, the effect of the Aswan Dam on the ecology of the eastern Mediterranean, the concern about the eutrophication of the Baltic Sea, the rise in pollution of the rivers and lakes in Italy, the international concern about oil pollution in the world's oceans, etc.

The ability of biological organisms to concentrate low levels of dissolved, undesirable substances (e.g., lead, insecticides, mercury, PCB) and their transmission through the biological food chain is a situation for real concern. Although the complete mechanisms of concentration and transmission and their subsequent biological effects are unknown, some mitigating action is necessary. Professor Hutchinson points out that additive changes to the environment require a serious study of their effects on the biosphere. It does not appear to him that their presence would be the "basis for a revolutionary step forward in the evolution of the biosphere." We will have to change our way of living and ultimately, using our science and technology, control the side effects of the production of our goods and services.

The process of eutrophication is threatening our water resources and posing broad ecological changes. The cause and mechanism of this process has led to an important controversy: the respective roles of phosphates and BOD in the cause of algal blooms is being debated. In an attempt to ameliorate the situation, demands to ban the use of phosphates in detergents and cleaning formulations are increasing. Detergents containing lower or no phosphates are being formulated and marketed. The consumer is demanding such products and evidently is recognizing the nature of the problem of pollution. However, the recent response to replacing phosphates with other detergent builders may ultimately be more troublesome. The use of substances such as NTA, whose fate in and effect on the environment is unknown, does not guarantee an improvement over phosphates and may indicate a panic reaction.

It has been estimated that about 26 billion dollars will have to be spent to abate water pollution in the U.S. Since a complete description of ecological effects on the world and regional ecological systems may be many decades in coming, selective guidance from incomplete information will have to be used. One good general principle is to disturb the ecology as little as possible. This principle, however, does not help if limits are not set to the magnitude of "little." Whatever the actions, the task will be extensive and expensive. In his recent editorial in *Science*, Professor Etzioni claims that the elimination of pollution is "the wrong top priority."

His criticism is that the concern about pollution, "... has many features of a fad ..." and that there is much exaggeration about the demise of

the biosphere being circulated in the media to focus on the water and air pollution problems. There is much scientifically based evidence that our environment is changing and not for the better. Some actions are urgent. However, Professor Etzioni casts environmental problems in a more general and logical light. The ugliness and crowding of cities, the deterioration of schools, hunger and malnutrition, racial and sexual inequality, the death of 57,000 Americans in traffic during 1970, are some of the unfashionable human problems that should be given top priority rather than the elimination of water and air pollution. He is referring to the lack of planning for human beings in our society by placing production and consumption of consumer goods as the objective of our society. It is easier, but it is a repudiation of the responsibility of leadership, to solve physical problems, to clean our effluents, or to put a man on the moon, but not to attack the "unfashionable" human problems.

World society will have to face this problem, because the developing countries vis-à-vis the industrial nations will of necessity become polluters as they increase their food production and industrial capabilities. Of course, they are utilizing the systems provided by the industrial nations with their attendant side effect – pollution.

Also important in this whole concept is the size of the world population. More people means more pollution; however, the limitation to population may be the effects of crowding on the sociological and psychological behavior of man. The need for materials and energy by a world population [as opposed to the present where 10 per cent (the U.S.) utilizes a large part of the world's resources] must be solved. This has its implications on pollution levels. Clearly the global manifestations of pollution and their widespread causes cannot be solved solely by bigger and better engineering and more and more money. The objective of society must be human needs, not the production of consumer goods. Until this happens, man in his biosphere will not be preserved biologically, socially, or psychologically.

A number of scholars in the last several years have speculated on the sociological causes for our environmental degradation. There is no universal agreement. Christianity is cited as the cause by White. However, Yi-Fu Tuan points out that the supposed idyllic relationship of ancient man and nature is not unspotted by ecological catastrophies. Moncrief and Goldman point out the effects of industrialization, technology, and the sociological system in exacerbating the pollution problem. With the large population increase since ancient times, the nature of ecological decay can be defined as "the commons problem." Some people are realizing in a practical way that they are the polluters and that individual actions will decide our direction in the battle to save the

environment. Thus, the appeal of low phosphate detergents is gaining among a limited, albeit increasing number of consumers. The youth with their hope and idealism are demanding and working to save the environment not only through Earth Day programs but through positive action: from committees and taxpayer suits to demands in medical schools for courses related to environmental health. They are also concerned with people and eradication of human problems as goals of mankind and no doubt youth will help in changing our priorities as advocated by Professor Etzioni.

The nature of environmental science is somewhat analogous to the medical, nuclear, and space sciences. A number of social and scientific disciplines are necessary to define the complex system or phenomena that are the subjects of these fields. This multidisciplinary effort not only requires the cooperation of groups of scientists representing various disciplines, but demands a multidisciplinary scientist. Trained investigators with broad backgrounds must be supplied by the educational institutions. However, the mode of providing these new scientists can, in an unimaginative way, supply a sweep of courses in a number of the relevant subjects or more creatively provide scientifically integrated subject matter. Thus the educational effort can serve as a real means of providing new courses and programs to bring about an integration of the sciences, and more importantly, to train a different type of scientist. In this context, the link with the social and political sciences and the law can be strengthened. The educational effort of providing knowledge of current advances and new technologies to those in the scientific work force has not been adequately undertaken and could be benefitted by this integration. And more critically, those people, technical and nontechnical, white collar and blue collar, suddenly denied employment because of a recession or economic downturn, have the right to retraining programs resulting in meaningful work for their personal dignity and human necessities as well as the stability, viability, and peaceful future of our nation. Perhaps their reorientation via education toward the sociological and ecological tasks would provide a happy ending to a shocking economic and human event.

This integration, which definitely has a social aspect, may be the factor required to shore up the rapidly fading interest that students and the public have in the contributions of science. Of course, one great hurdle is unfreezing the classical structure of science teaching in the university. The parochialism of various science departments must be overcome so that interdisciplinary areas can be served. However, necessary emphasis in selective areas of the particular science must be preserved. The cause of interdisciplinary sciences can also be advanced, however, through

other means such as publications. This is one of our objectives in the creation of this work.

The organization and preparation of a compendium of this type, focusing on a multidisciplinary area is an enlightening and humbling experience. The breadth of the subject requires the integration of many scientific areas. It is evident from the events in recent years that the chemical, physical, and biological definition of the environment and environmental problems is a most important activity at this time. There is need for specific analysis and identification of these materials in our water environment and their fate and effect on the ecological system, if one considers the nature of the system. Thus the analytical scientist, chemical, biological, and physical, is required for this task. Unfortunately, in many chemistry departments of our universities, analytical chemistry has been de-emphasized, although there are many who do maintain an excellent program. In all fairness, the fault cannot simply be attributed to internecine sniping among chemists, but rather to the failure of many analytical teaching staffs to adapt to the new teaching methods and the restructuring of courses consonant with the new and changing demands, particularly by the multidisciplinary sciences. However, analytical chemists in the universities appear to be responding positively. This is a propitious sign, because the future need for analytical scientists is great and will grow as a result of the increasing emphasis on multidisciplinary sciences.

The water environment can generally be characterized as a dilute, aqueous solution, containing a large variety of organic and inorganic chemical species, dissolved and in suspension, and including a variety of plant and animal life. A knowledge of the qualitative and quantitative composition of these systems is the first step toward revealing the nature of the particular environmental problem. Chemical and biological analyses are first called upon to supply information to the investigators. One may, at the outset, without regard to preventing perturbations in the system, obtain some very general analytical information. However, this type of information is at best only indicative of the identity of the constituents and gives no detailed information of the species present. To obtain knowledge of the specific species present and of their concentrations, the effect of the analytical treatment should in no way change the system with its unique equilibria and components. The analytical results should characterize the original system and not one that is a modification created by the analytical processing. This analytical treatment may cause decomposition or interactions of the components in the sample of the original system. However, analytical treatment can be chosen so that the energy of perturbation is small compared to that energy needed to cause chemical

and physical changes in the system. Still, the disturbing question always remains about the possibilities of induced changes. Results obtained after modifications of the analytical approach along with consideration of the nature of the system should indicate whether induced changes have occurred. Throughout one's consideration of the determination of the composition of the system, it must be noted that most environmental systems are not constant in time; therefore, the effect of time on composition and analytical treatment on kinetics of occurring reactions must be evaluated. These difficult but fascinating considerations must be given thought in elucidating the composition of a system at a given time.

The main theme of these collected volumes was particularly this point, for at this stage in our investigation of the water environment we need good, specific, accurate analytical techniques to define from the static and dynamic states: what happened, what is happening, what may happen, and where it may take us. When we use the word, "analytical," we refer to the numerous disciplines necessary to completely evaluate the environmental situation. Thus we have endeavored to treat chemical, microbiological, viral, bioassay, and mathematical techniques as necessary ingredients in this most important task of defining our multifaceted problems. However, in order to intelligently consider analytical techniques to be utilized in defining the environmental problems, the physical, chemical, and biological characteristics of various parts of the water environment and associated systems are presented. Thus the formal structure of this four volume set consists of two parts: Part I, Environmental Systems and Part II, Chemical, Physical, Bacterial, Viral, Instrumental, and Bioassay Techniques.

The description of environmental systems in Part I includes chapters on the chemical, physical, and biological characteristics of water resources, estuaries, irrigation and soil waters, and wastes and waste effluents and in the areas of water purification, waste treatment, effects of pollution, self-purification, and mathematical modeling. After a definition of the systems, the analyst can utilize Part II effectively. In this main section a wide variety of analytical subjects are covered: Specific tests for BOD, residual chlorine, pesticides, herbicides, minor elements, and radionuclides; instrumental techniques such as infrared and mass spectroscopy, electrochemical, luminescence, gas chromatographic, and automated analyses; biological tests such as bacterial, viral, and bioassay techniques; other analytical subjects such as sampling, organic and inorganic analysis, concentration and separation techniques, insoluble matter, measurement system design, monitoring systems, and other chemical and physical phenomena such as the structure of water and chemical kinetics and dynamics in the water system.

The level of presentation is always a problem in a work such as this.

We must take on a pedagogic role for those who want to enter the field or may be trained only in certain aspects of the field, as well as the multidisciplinary scientist in the environmental field. The audience should represent quite a spectrum, in the both technical and nontechnical areas. Although it may sound as if we are quite ambitious about the group we hope to provide with information and knowledge, we think our book will fulfill this expectation.

Investigations into water pollution are moving rather rapidly, and since this book was assembled over a three-year period, we are bound to have a certain lag with respect to most recent developments. This we acknowledge quite freely, but at the same time we feel the basic information we are bringing forth will be useful for years to come. Our hope is to contribute to and influence the "human biological storage," alluded to by Sir Egerton, from which will spring the progress in this rapidly evolving science of the water environment.

During the generation of this work I have been fortunate to receive help and critical advice from a number of associates and friends. First I want to thank the management of the Research Laboratories of Wallace and Tiernan, Inc. (now Penn Walt, Inc.) and GTE Laboratories Incorporated, of Bayside, New York, for their understanding and generosity in the use of secretarial help in this undertaking. To Miss Virginia Aquino (Wallace & Tiernan Inc.) and Mrs. Lee Epstein (GTE Laboratories Incorporated), who generously contributed their secretarial skills, I am indebted. Dr. Richard Benoit and Mr. Harold Quis responded to my need for "brain storming" with wonderful results, which I appreciate very much. And to those who have been of invaluable aid in critical advice, Dr. Peter Cukor, Dr. Grace Vernon, Klaus Hameyer, Howard Madlin, Robert Rubino, James Cosgrove, and Danny Oblas, I am very grateful.

I would be remiss if I neglected to acknowledge two people who contributed to my professional development. Mr. Tom Grenfell, formerly Quality Control Director of Chas. Pfizer & Co., Inc., exemplified the creative, industrial, analytical, research chemist. Scientific realism and hope was impressed upon me by Professor Rudy Marcus who, while recognizing the complicated nature of basic physical chemical phenomena, labors assiduously in uncovering their characteristics.

To my most intimate human environment, that rare collection of individuals, my family, I must convey my most affectionate appreciation. To our children, Gloria, Luke, Dominic, Imelda and Rita, I acknowledge the lively atmosphere which stimulates, and to my wife, Eva Agostini Ciaccio, the civilizing spirit which keeps all pleasantly in bounds.

LEONARD L. CIACCIO

Glen Rock, New Jersey
December 10, 1970

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PROLOGUE

I will open rivers in the high hills, and
fountains in the midst of the plains.

I will turn the desert into pools of waters,
and the impassable land into streams of waters.

I will plant in the wilderness the cedar, and
the thorn, and the myrtle, and the olive tree.

I will set in the desert the fir tree, the elm,
and the box tree together,

That they may see, and know, and consider, and
understand together that the hand of the Lord
hath done this.

ISAIAH, 41; 18 & 19

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