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Cadmium, lead and tin in the marine environment

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PREFACE

GESAMP, the Joint Group of Experts on the Scientific Aspects of Marine Pollution, was established in 1969 and is today co-sponsored by the International Maritime Organization (IMO), Food and Agriculture Organization of the United Nations (FAO), United Nations Educational, Scientific and Cultural Organization (UNESCO), World Meteorological Organization (WMO), World Health Organization (WHO), International Atomic Energy Agency (IAEA), United Nations and United Nations Environment Programme (UNEP). According to its present terms of reference, the functions of GESAMP are:

- to provide advice relating to the scientific aspects of marine pollution 1/; and

- to prepare periodic reviews of the state of the Marine environment as regards marine pollution and to identify problem areas requiring special attention.

Since its beginning GESAMP involved a large number of experts as members of GESAMP or GESAMP Working Groups and produced, at the request of the sponsoring organizations, numerous reports 2/.

This document reproduces the substantive part of the report of the GESAMP Working Group on Review of Harmful Substances, approved by the fourteenth session of GESAMP (Vienna, 26 - 30 March 1984).

The Working Group was chaired consecutively by Messrs B.H. Ketchum, A. Jernelöv, and L. Friberg. The following experts participated in the preparation of the report: Dr. B.G. Bennett, Prof. L. Friberg, Prof. A. Furtado Rahde, Prof. A. Jernelöv, Mr. R. Lloyd, Dr. L. Magos, Prof. S.P. Meyers, Dr. A. Oskarsson, Dr. P.M. Sivalingam, Prof. G. Tomassi, Dr. H. Galal-Gorchev, Dr. M. Gilbert, Dr. R. Helmer, Dr. J. Parizek, and Dr. G. Vettorazzi.

The Working Group was requested

- to prepare short and referenced reviews on selected substances which include an assessment of the following factors:

  (a) the total amount of the particular substance(s) which reach(es) the marine environment (on a local, regional, and global scale) with particular attention being given to the relative importance of land-based sources;

1/ GESAMP defined marine pollution as "introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea-water, and reduction of amenities."

2/ V. Pravdic: GESAMP, The First Dozen Years. UNEP, 1981.

(b) the fate (transport, distribution, and transformation) of the substance in the marine environment; and

(c) the effects of the substance on the marine environment and adjacent coastal areas, including direct and indirect effects on living resources, human health and amenities;

- to produce a scientific evaluation of the harmful effects of substances released into the marine environment on living resources, human health, aesthetics, and other legitimate uses of the marine environment and adjacent coastal areas.

The activities of the Working Group were organized by WHO, acting as the "lead agency". The Working Group was jointly sponsored by WHO, FAO, and UNEP.

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I. INTRODUCTION

1. Evaluation Mechanisms

From an examination of data profiles by UNEP's International Register of Potentially Toxic Chemicals (IRPTC), other data profiles, and available critical reviews of published data, significant papers were selected by the Working Group for thorough evaluation. These papers, together with recent and pertinent publications, then formed the basis of this review. It is recognized, however, that these papers provide only a partial coverage of the world literature. Information was lacking in several areas essential to an environmental hazard evaluation of cadmium, lead, and zinc, and these areas were identified in the review.

2. Working Procedures of the Group

The method and approaches applied by the Working Group were discussed and agreed upon at a planning session in Stockholm, 24-25 September, 1982. This was attended by the chairmen of GESAMP and of the Working Group, and by international agency representatives.

For each substance, selected experts prepared draft sections of the review. The reviews were then critically examined and revised by the Working Group members (Annex I). The final draft was submitted to GESAMP for consideration, comments, and adoption.

3. Quality of Data Base

3.1 Analytical quality control

Many studies conducted in the various countries aimed at evaluating normal and elevated levels of trace metals in different media. Unfortunately, most published reports lack quality assurance data, and valid comparisons cannot, therefore, be made. Furthermore, results from several inter-laboratory comparisons amplify the need for quality control. A review of such comparison studies, with particular emphasis on lead and cadmium in blood, has recently been published in connection with a UNEP/WHO Biological Monitoring Project on Assessment of Human Exposure to Lead and Cadmium through Biological Monitoring (Vahter, 1982). Various intercalibration exercises with those laboratories engaged in the determination of trace metals in commercially important marine organisms from the North Atlantic were also organized, since 1971, by ICES, the International Council for Exploration of the Sea (Topping, 1983). These reviews clearly show that errors may be large even in "experienced" laboratories. Since 1975, the IAEA's International Laboratory of Marine Radioactivity has also operated a large global analytical quality control programme for metals and chlorinated hydrocarbons in marine organisms and sediments. A similar programme has been run by the Intergovernmental Oceanographic Commission for Seawater Samples.

The introduction of sophisticated and increasingly sensitive analytical techniques has made it possible to measure trace substances in extremely low concentrations. Simultaneously, however, the risks of interference from competing factors has increased considerably. Although the awareness of the need for quality control has also increased during recent years, it is not possible to state, generally, that analyses carried out during the last 5-year period, for example, are always more reliable than earlier analyses.

Analytical problems may occur with any matrix to be examined. Particular problems arise, however, when analysing biological media or matrices which have very low trace metal concentrations (picograms/g). Schaule & Patterson (1980) showed that, for example, the lead concentrations in seawater samples have been overestimated by factors of up to 5000 and, that the lead concentrations reported for marine organisms are, with very few exceptions, several orders of magnitude higher than the actual concentrations present. These high concentrations are caused by the sample becoming contaminated during analysis. The importance of implementing rigid quality assurance programmes was amplified in 2 recent trace metal programmes sponsored by UNEP/WHO. One measured lead and cadmium in blood, and cadmium in kidneys (Vahter, 1982; Friberg & Vahter, 1983).

first programme, it was rare that a laboratory met the criteria for data acceptance throughout the training phase, and gross errors were often recorded. The food study noted that the results of current analytical quality control analyses allowed few conclusions to be drawn concerning the reliability of previously collected data. In addition to the various forms of analytical error, there is the possibility of contaminating biological samples, for example, by use of unsuitable sample collection vials and contaminated chemicals. Furthermore, errors due to adsorption and desorption on the walls of containers may cause inaccurate results.

The various sources of error which are possible make it necessary to exercise great caution when evaluating analytical data. In particular, it is more the exception than the rule that data on quality assurance are presented as part of published studies. Such caution has been exercised in the evaluation carried out by the Working Group, but there is still no guarantee that all the data used in this evaluation are completely valid. If rigid quality assurance criteria had been required, the analytical data available for use in the evaluation would have been extremely limited.

3.2 Ecotoxicological quality aspect

Experiments on marine organisms were carried out using many different procedures and techniques, and the usefulness of the results to the present review was critically examined. In particular, only a few experiments offered analytical confirmation of the concentrations and various forms of a substance that the subject was exposed to. There was little data on proven harmful effects resulting from chronic exposure. Therefore, extrapolations from the limited data base in order to predict whether environmental effects are likely to occur have to be treated with caution. In this respect, there is also a need for reliable analytical data on environmental concentrations for some species of the substances evaluated.

3.3 Quality of human toxicological data base

The quality and quantity of toxicological data show substantial variation from one marine pollutant to another. Ideally, the evaluation of the health hazard presented by a certain pollutant ought to be based on data which include a comprehensive dose-effect relationship. For a selected and preferably critical effect, a reliable dose-response curve should be provided. Equally important is an established correlation between the concentration of the toxic chemical (or one of its metabolites) in an index medium and the effects and responses. Some examples relevant to the substances selected by GESAMP are presented in the following paragraphs.

For one of the most widely studied metals, lead, the relationship between blood lead and the effect of lead on the synthesis of haemoglobin is well established, but the relationship between blood lead and the effect of lead at the lower end of exposure on the development of the Central Nervous System (CNS) in children is a question of controversy. The relationship between oral lead intake and blood lead concentration has not been investigated, and the lack of this information hinders the prediction of blood lead concentration from daily dietary intake and vice versa.

The corresponding correlation between blood cadmium and current exposure has been established. In a condition of changing exposure, however, blood cadmium may not correlate with the renal concentration of cadmium. However, the quality of data that predicts kidney accumulation of cadmium from dietary intake has recently become more reliable.

In many cases, the evaluation is dependent on experimental animal data, especially in experiments which aim to study those quantitative relationships which can be extrapolated to man. Unfortunately, in the cases of tin and particularly of organotins, even the animal data base is not sufficient for extrapolation, and dose-related human data are totally absent.

4. <u>Dietary Intake Considerations</u>

4.1 Basis for total dietary intake estimates

Accurate estimates of dietary intake of food contaminants are difficult to make for contaminant levels and rates of consumption. It is possible, however, to estimate intake from measurements of the concentration of contaminants in specific foods and the amounts of food consumed. Alternatively, measurements may be made with composite samples of the total diet. This approach requires fewer measurements and may reflect actual intake more closely, but it has the disadvantage of disregarding the contribution of single foods to the total dietary intake of contaminants. The calculated dietary intake may be made for representative population exposures, or it may be made with special reference to critical groups, for example, children, pregnant women, high consumers, etc. From contributions of particular food items to the total dietary intake, it is useful to note the "critical" foods to which more attention should be given in surveillance programmes.

Comparisons between calculated dietary intake and tolerable intake limits may indicate safety levels, or the incidence of risk for the exposed population. Due to the large variations in food consumption patterns among countries and to the wide variations in food contaminant concentrations, mean dietary intakes should be calculated and evaluated at the national or even local level.

Finally, the total energy value and composition of the diet should be taken into account in an evaluation of potential risks for population groups. It has been demonstrated that not only total food intake but also components such as fat, calcium, iron, and zinc can influence a subject's susceptibility to toxicity of contaminants by modifying the degree of gastrointestinal absorption.

4.2 Seafood consumption patterns

Seafoods do not represent a significant component of the diet for much of the world's population. Marine foods consumed by man include many trophic levels. Seaweeds are eaten mainly in the Far East, but also in Europe, for example, as laverbread or agar. Phytoplankton and zooplankton are not themselves consumed, but their predators, such as oysters, mussels, clams, scallops, herring, and sardines are. However, krill is used for animal fodder. Higher trophic levels include the carnivorous gastropods, clams, cephalopods, crabs, and shrimp, and foremost, fish. The world (population 4150 million in 1977) average of fish and shellfish protein consumption is 3.8 g per person per day of a total of 68.8 g total protein per person per day (FAO, 1980a). These data can also be converted to and analysed in terms of the fresh weight of marine foods. The world's average daily consumption of 3.8 g protein corresponds to about 20 g edible fish and shellfish per day or 140 g edible tissue, which is equal to about one meal of fish and shellfish, per week. Aquatic plants and seaweeds make up only 4% of the world's harvest of marine and freshwater foods. Of the total catches of aquatic animals, 10% are caught in fresh water and the rest is marine. Seventy-seven percent of the world's landings are marine fish, 7% are molluscs, and 4% are crustaceans, with other marine