

Supplement to
Progress in Water Technology

MARINE
POLLUTION
AND MARINE
WASTE
DISPOSAL

Proceedings of the 2nd International Congress,
San Remo, 17-21st December 1973

Edited by
E.A. PEARSON

University of California, USA

and
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Pergamon Press

**MARINE POLLUTION
AND MARINE WASTE DISPOSAL**

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SUPPLEMENT TO
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INTRODUCTION

S. H. JENKINS, Executive Editor *Water Research* and H. F. LUDWIG, Bangkok

INTRODUCTION

The study and control of marine pollution are subjects that lend themselves to international collaboration for the reasons that marine waters recognize no national boundaries, and harmful pollutants may be transported wherever ocean currents may carry them. In recent years a new element has entered into marine pollution consideration. Substances emitted to the atmosphere as gaseous pollutants or volatilized from land are airborne over continents and may descend far from their country of origin. For these reasons alone the problem arising in one country from atmospheric and marine pollution should be the concern of others.

But there are other reasons why the conference heard its opening speakers plead for greater international collaboration. Increased opportunities for scientists, engineers and administrators to meet together to discuss one another's problems help to quicken the development of institutions best suited for the needs of each country to find the most appropriate solution to environmental problems. Countries without experience in the establishment of the administrative and technical organizations needed to deal with pollution can learn painlessly and inexpensively from those countries that, out of sheer necessity, have already had to evolve such institutions because of the doubtful distinction of having been the first to pollute their environments. But above all, the resources of the world must be pooled in order to tackle what is, after all, a world problem so far as marine pollution is concerned. These resources include the sharing of scientific manpower, laboratory facilities, monitoring equipment and techniques and know-how. This present Conference visualizes a degree of international cooperation supplementing and augmenting the activities of official intergovernmental agencies. The International Association on Water Pollution Research (IAWPR) is dedicated to helping to promote and assist in the attainment of international collaboration to the extent of providing a forum where representatives from nations with well-developed control organizations and programs may meet those

from countries where such facilities are in the course of development.

There is no question that the setting of the Conference, at beautiful Sanremo, dramatically illustrates the need for international cooperation to preserve the extraordinary aesthetic values of the Mediterranean Sea. The Mediterranean Sea probably represents the best possible example of this need in that many nations share a unique resource, but due to its geographical position as an essentially inland sea, the Mediterranean is in serious danger of losing much of its beauty unless the countries involved develop an effective co-operative programme in the not too distant future.

The present Conference at San Remo is timely in that the whole problem of evolving rational and effective pollution control methodology and regulations is in an interesting and challenging state of confusion throughout the world. In the USA, for example, where relatively huge expenditures have been made in attempting to improve the management of water-pollution control, mostly by the Environmental Protection Agency (EPA) and its predecessor agencies, the past few years have witnessed a strong tendency for governmental policies on pollution to be set, not by engineers and scientists experienced in pollution-control technology, but by groups responding to great public pressure for immediate action programmes regardless of their cost-effectiveness! As a result, governments are tending to adopt and enforce uniform types of standards requiring high levels of treatment as the minimum permissible, regardless of the need for most effectively protecting the environment. Such policies can hardly be justified on any scientific basis. If enforced, they will lead to huge wastages in money and will compound the energy crisis facing the world today. Hence the picture is bound to change, and somehow the engineers and scientists experienced in pollution control must get back into the decision-making process. It is hoped that the San Remo Conference sponsored jointly by the universities of Milan (Politecnico) and California, by the National Association of Sanitary En-

gineers of Italy (ANDIS), and WHO, as well as by IAWPR, will be a significant contribution in this direction.

WATER-QUALITY CRITERIA AND PROBLEMS

Introduction

The session on Criteria for Marine Waste Disposal included ten papers, supplemented by discussions, on experience in the Mediterranean area and in California, Great Britain, Sweden, USSR and Southeast Asia. Of all these, only California has developed a fairly comprehensive set of numerical limitations, both for effluents and receiving waters, which are now being translated into practice as part of the rigorous regulatory program being generated in California and throughout the USA as a result of pressures from the Federal Government. In the Mediterranean area, while no country has developed any comprehensive criteria, each of the participating countries is now making efforts to establish definite limitations to take the place of the existing regulations, which are mostly of the "do-good" type of non-qualified generalized statements that prohibit any discharge that has harmful effects on any beneficial use. Attention is also now being given to this subject in Southeast Asia.

California Experience

By far the most extensive research and development on marine waste disposal has been carried out, over the past 20 years, in California. As a result, much of the technology developed there, both in regulatory practice and design practice, has been widely applied throughout the world. With respect to water-quality criteria, the regulations and accompanying technical guidelines issued by the California State Water Resources Control Board in October 1972, for control of waste discharges to the marine environment, represent a virtual "bible" or manual on the existing technology on the subject. These releases include listing of all parameters useful for assessing the impact of wastes on marine receiving water values, together with definite numerical limitations, both for effluents and for the receiving waters, all on a statistical basis, i.e. values that are not to be exceeded 50% and 10% of the time. This is believed to be the first comprehensive delineation of criteria for marine waste disposal which incorporates a statistical concept (rather than "absolute limitations"). The California guidelines also present detailed information for monitoring, including the techniques to be used for sampling and analysis and for reporting.

The California regulatory requirements, as prom-

ulgated, while based on the best available scientific information, nevertheless appear to be quite conservative if not overly restrictive, no doubt the result of US Federal Government policy which has evolved in the direction of setting minimum severe treatment removal requirements on a uniform basis regardless of receiving water capabilities. Because of the Federal influence, it now appears that the major marine waste-disposal systems in California, which have generally employed the combination of long ocean outfalls together with primary treatment, and which appear to have provided generally effective protection of environmental values, will have to be upgraded to meet the new EPA standard that all marine waste-disposal systems must employ not less than secondary treatment. The cost of this upgrading, for Southern California alone, is estimated to be of the order of \$750 millions.

Mediterranean Sea and Europe

Reports on the subject of water-quality criteria described situations of widely different kinds. In some countries the information necessary to establish such criteria is still being obtained. In others, it is considered that marine pollution is best controlled by other means. In yet other situations the criteria that have to be met for discharges to the ocean necessitate treatment to very high standards as well as the strict control of potential toxicants. In several countries that discharge non-disinfected effluents or untreated screened sewage to marine waters, such as in the North Sea area, the main criteria that apply to sea water are based on aesthetic considerations. Bacteriological criteria, as evidenced by regular monitoring of the receiving waters, are not regarded as necessary for the maintenance of safe conditions for recreational purposes. Investigations that include calculations of the rate of die-off of coliform bacteria and the dispersion of sewage discharged to western areas of the Mediterranean, where there are as yet no water-quality criteria, have led to proposals that require a minimum initial dilution to be attained on discharge, in addition to a number of other requirements that include a minimum length of outfall, a minimum depth at the point of discharge, and suitable provision for diffusion through multiple ports.

A further stage in the development of water-quality criteria relates to the protection of eastern Mediterranean coastal waters receiving discharges of municipal and industrial waste waters in areas that are extensively used for bathing, fishing and recreational purposes. Based on studies carried out

on the chemical, physical and epidemiological quality of the receiving waters, five uses of sea water and beaches requiring increasingly stringent standards have been drawn up. As a minimum, no material recognizable and definable as waste-borne matter may be present within 50 meters from the lowest tide level. Further safeguards are added to control floatable, settleable, odour-producing and toxic substances. Waters used for bathing and contact purposes require the most stringent methods of control and this is obtained by setting limits for the receiving waters at a distance of 300 meters from low-tide level. These limits apply to pH, floatables, minimum initial dilution, coliform concentrations applicable for either winter or summer conditions, and the frequency of sampling.

Although national and local problems are those most likely to receive priority in the execution of pollution-control programmes in the Mediterranean, these may in the long term prove to be of less importance than the prevention of an overall deterioration in water quality of large areas of water due to the collective inaction of several countries which have not recognized the potential danger. In the northern parts of the Adriatic, where conserving the existing ecology can only be attained by the concerted action of the seaboard and hinterland countries involved, such a situation already exists. At this time the primary attention in local situations is concerned with sewage bacteria and enteroviruses which, however, are likely to be of secondary importance compared to the threat to the ecology of the waters.

Southeast Asia

In Southeast Asia, although most governments have not yet established standards of criteria for control of pollution in coastal waters on any scientific basis, there is interest in the subject and it is anticipated that meaningful programmes of control will be formulated during the current decade. The primary needs for controls are for protecting shallow coastal waters, especially estuarine zones, which are important for fisheries, and for protecting resort areas featuring beach recreation and sport fishing.

For protection of shallow reproduction zones, the best solution is to prevent discharge of wastes into these zones, the collected wastes should bypass the shallow zones and be discharged into deeper waters. For protection of beach resort areas, a submarine outfall (with diffuser system) extending sufficiently far offshore will be the key element, supplemented by treatment to the extent

needed for the particular case. In many cases removal of floatables will be a sufficient level of treatment.

Summary

Generally, at the present time, the coliform index is the only universally used parameter for assessing the quality of marine receiving waters. The standards generally range from the limit of 10/ml in California, which has been widely copied and which is likely conservative, to 100/ml as used in some engineering designs of outfall systems in developing countries. The standards for Italy are even more restrictive than in California. A review of all available information indicates that the California standard (10/ml) is probably quite conservative, and that the "Brazil standard" (100/ml) may prove to be reasonable for use by nations with limited financial resources and enteric disease rates.

While use of the coliform standard appears to provide a sound basis for assuring protection of public health (considering both pathogenic bacteria and viruses), and for assuring a state of cleanliness in the beach and recreational water areas, the more difficult problem will likely prove to be conservation of marine ecology, for which purpose additional parameters of a biological nature will be needed. It is expected that by 1980 most Mediterranean countries will have developed meaningful criteria and moreover will have reached agreement on a common set of figures.

In examining water-quality criteria as to their meaning, it is important to differentiate between criteria or standards that have been officially promulgated but not practised, which is the case in many countries, and standards which must really be met. Most existing criteria have little scientific basis and can be so exorbitantly expensive to achieve that they will not be complied with. In that case they will have little meaning. The objective of current research and development is to achieve numerical limitations which are scientifically based and economically achievable.

BIOLOGICAL PARAMETERS FOR ASSESSING IMPACT ON MARINE ECOLOGY

Introduction

The Conference sessions included presentations on a wide variety of the biological aspects of marine waste disposal. A presentation on behaviour of bacteria discharged with particulates in waste waters showed that most bacteria adhere to particles of less than 20 microns, and hence tend to be

dispersed and stabilized following the fate of these particles after discharge, with few of the particles and adhering bacteria being removed by conventional sedimentation because of the very low removal of small (colloidal) size particles.

Studies of the fate of enteroviruses when discharged to ocean waters indicated that viruses tend to be inactivated due to biological activity, with a disappearance rate of 1 to 3 days ($TL_{90} = 1$ to 3 days), which is much slower than that of coliforms. While the data indicate that viruses may persist for significant periods in marine receiving waters, and hence might pose a hazard not now appreciated, no evidence was produced to show that the existing use of the coliform index as the basis for outfall design does not meet the virus hazard as well as it does the hazard from enteric pathogens.

Studies of effects of waste on marine ecology again point to the extreme complexity of phenomena involved in fish-food chains. A study of physiological effects of toxic materials on fish and other macro-organisms showed a wide range of types of damage to cells, gills, etc., with the indication that the chronic effects of low levels of selected toxicants is likely to be of much more importance in determining the ultimate fate of a species than the readily observable "fish kills" resulting from exposure to acute toxicity.

Eutrophication

It is being increasingly recognized that discharge of nutrients to open coastal waters may be beneficial rather than detrimental to marine biological productivity. This is especially so in the Mediterranean which is a nutrient-deficient sea due to the steady loss of nutrients to the Atlantic ocean. Eutrophication can, of course, be a problem when nutrients are discharged to confined marine waters such as bays and estuaries.

The main effect of nutrients in waste water is to stimulate the growth of phytoplankton. This increase in primary production increases the growth of all members of the food chain and therefore, where the concentration of the biostimulants does not cause local problems, this enrichment may be considered as a means of increasing the fertility of the sea. The concentrations of nutrients that would be required to produce eutrophic conditions in the Mediterranean are approximately four or five times as great as the maximum concentration of nutrients in oligotrophic waters; hence eutrophication of the general sea mass is considered unlikely to arise as a result of sewage discharges.

The Mediterranean Sea is recognized as a very

special problem area because of the extreme clarity and oligotrophic nature of the coastal waters of Dalmatia, the Riviera, etc., which add to the tourist attraction of the area. While it is recognized that nutrient discharges should in general be helpful to the Mediterranean, in enhancing biological productivity, care must be taken not to induce eutrophication, which may impair the clarity of the shallower areas important for recreational purposes.

It is not generally recognized that biological treatment processes (including activated sludge) not only remove little of the bionutrients in wastes but may generate biostimulants having greater eutrophication potentials than the untreated wastes. The design of sewage-treatment systems intended to control eutrophication should consider the use of special measures for removing the biostimulants in the effluents from secondary treatment plants, for example, by use of final stabilization ponds, or physical-chemical methods instead of biological treatment. Even with these precautions, considerable quantities of nutrients will reach the sea from uncontrolled surface runoff, and the extent of this will be sufficient in many areas to negate the effects of nutrient removal in sewage-treatment plants.

Capacity of the Oceans for Receiving Wastes

Significant data were presented, as developed by oceanographic scientists, relating to the capacity of the world's oceans to receive and absorb wastes. The data show that the biological productivity of the oceans is essentially restricted to the shallow belts of water fringing the land masses (90% of the productivity is in 10% of the ocean area), that ocean organisms are far more generalized than comparable land species and possess much less specialized food requirements, and hence are far more capable of withstanding man's effects, and moreover that the open ocean waters are generally barren biologically because of plant nutrient deficiencies. This indicates that, since wastes residuals must be disposed of somewhere, the open ocean represents a much more advantageous repository than the fresh or estuarine waters, or the land, assuming that the objective is to achieve maximum protection of ecology on a global basis within a given total limit of expenditure, and provided that due attention is given to protecting the shallower waters which are much more vulnerable. Large-scale and profound natural fluctuations in the marine environment and its populations, over many time scales, impose real difficulties in establishing base lines of normalcy, but demonstrate the resiliency of oceanic populations.

Assessing Waste Impact on Ecology

It was the consensus that biological methods are the best for assessing the impact of pollution on marine ecology, rather than chemical and physical measurements. The available biological methods include indicator species, indicator communities, species diversity, productivity, diversity-productivity relationships, comprehensive biocoenological and ecosystem analysis, bioassays with standard species and with local species, and fouling tests. Of these, in addition to biocoenological and ecosystem analysis, the most promising approaches are in use of diversity and of bioassays with local species.

The use of indicator species, while long sought by water-pollution research technologists, does not appear promising due to the lack of suitable organisms common to a given set of local conditions, and the wide range of environmental conditions they can withstand. By contrast, species diversity offers the engineer and scientist a fairly reliable numerical tool for assessing improvement of depreciation in environmental quality. Also, acute bioassays, despite their limitations, do appear to yield generally reliable estimates of toxic effects of low levels of pollution, at least for purposes of engineering design. The acute toxicity bioassay remains the best approach for estimating toxicity effects relating to species survival, with a factor of 25 usually applied for transposing acute to tolerable levels. Biological methods of assessing the impact of proposed waste-discharges should be part of the preliminary studies leading to development of the engineering design for all major waste disposal systems.

Research on the fate of chromium discharged to estuarine waters showed that chromium tends to accumulate in the sediments, that phytoplankton concentrate chromium to a higher level than subsequent levels in the food web, with only trace amounts found at the consumer level (benthic feeding fish), and that chromium accumulation above the primary producer level of the food web is directly associated with feeding rather than direct uptake from the water medium. The metals concentrated in the sediments around coastal discharges were not taken up by resident benthic fish, however.

Toxicity from Metals and Oils

The concentrations of some metals that exist in normal sea water may increase as a result of discharges of rivers, discharges of sewage and industrial waste outfalls, and atmospheric pollu-

tion. The increased concentration may have an adverse effect on marine plants and animals and, by concentration through the food chain, endanger human health. In addition, many synthetic organic chemicals reach the oceans by direct run-off from agricultural land, from the atmosphere, by accidental spillage, from sewage effluents, and from the dumping of wastes. A considerable amount of information has been attained on the uptake of various toxicants by primary populations and their concentration in predators, as well as on the inter-relationship between various marine species. By relating this information to the amount of fish eaten by man in different parts of the world, data have been accumulated which permit establishment of maximum safe concentrations of toxicants in fish eaten by man.

In the course of those studies it has been found that tuna fish caught in the Mediterranean contain nearly 2.5 times as much mercury as the same species in the Atlantic. The fact that certain groups such as fishermen may consume ten or twenty times as much fish as other individuals points to the need for preventing the intake of excessive amounts of injurious substances by restricting their access to the oceans.

Based on observations made in the Black Sea and the Caspian Sea it appears that the rate of algae reproduction has been reduced as a result of oil pollution. The effect depends upon the concentration of oil and the species of algae. Some species have been shown experimentally to be adversely affected by a concentration of oil as low as 0.01 mg/l. *Idothea (Isopoda)* cultured in polluted water were shown to have a lower survival rate in emulsions of oil and sea water than those grown in clean sea water. The effect of intermittent oil pollution was found by exposing algae to oil emulsions for short periods. Half an hour's exposure was sufficient to retard the growth of the test algae. The mortality rate of fish spawn was increased and the number of non-viable larvae increased when they were immersed in oil concentrations that ranged from 0.1 to 0.00001 ml/l ($10-10^5$ ppm, v/v).

To carry out experimental work to show the ultimate effect of oil on fisheries would require hundreds of years. Therefore, to obtain information necessary to determine limits for oil in sea water, test organisms with a quick response time are required. Diatoms have been used for this purpose. One species immersed in 10 mg/l oil showed that the effect of oil on the reproduction rate became increasingly serious with each new generation.

ENGINEERING DESIGN OF DISPOSAL SYSTEMS

Introduction

For purposes of illustrating the current status of the design of marine waste-disposal systems, this session included presentations which featured current practice in the USA, particularly in California, together with experience in Italy and Sweden. Also, under WHO sponsorship, a master plan of waste disposal is in preparation for the metropolitan area of Athens (Greece), which hopefully will include detailed oceanographic and ecological surveys as the basis of design.

California Experience

Detailed data were presented comparing the cost effectiveness of the various alternatives available for disposal systems, ranging from systems with long outfalls with minimum treatment, to systems with high levels of treatment with minimum outfalls. Considering all the costs involved, including costs for interceptors as well as treatment plants and ocean outfalls, the data show that much more protection of the environment, for any given level of investment, is obtained when the wastes are transported to bypass the shallow ecological zones and discharged into the deeper ocean waters using a long outfall; that for such solutions only minimum treatment is needed; and that it is fallacious to assume that the best protection of the regional environment will result from investing the money in and placing primary dependence upon treatment. This is the procedure that has been used successfully in the past by all major municipal disposal systems in Southern California, and which is now being followed for new systems being planned or built for many major metropolitan areas throughout the world including Rio de Janeiro, Montevideo, Accra, and Manila. This practice is, of course, now at variance with present US/EPA policy for marine disposal which requires a minimum of secondary treatment and which does not specify any particular minimum length of outfall.

To estimate the overall dilution of waste water achieved by diffusion systems, three dispersion phenomena must be considered, first, the initial dilution from admixing of the discharged waste water with the surrounding receiving water, second by eddy dispersion, and third, "apparent" dilution due to decay or disappearance of non-conservative materials. By diligent design, an initial dilution from about 75 for 10 m depth to 300–400 for 100 m depth can generally be achieved, but higher levels are scarcely feasible due to hydraulic constraints. For

proper design a field programme is essential for evaluating horizontal current speeds and directions, to assess initial dilution transport and eddy diffusion effects and for determining decay or disappearance rates, especially coliform disappearance rates for sanitary discharges (which must be determined *in situ* and cannot be reliably estimated from laboratory testing).

The programme of field work should also include sampling and analysis to characterize the existing environment, using physical, chemical, and biological measurements of both the water column and bottom sediments. This information is essential to permit later assessment of the efficacy of the waste disposal system after it goes into operation. This is important because, if primary dependence is being placed on use of a long outfall rather than primarily on treatment (usually the most economical solution), then it makes sense to proceed with the programme of construction in stages—first to build the outfalls, then to conduct careful monitoring to determine the real treatment needs. All experience throughout the world to date indicates fairly conclusively that the investment in a long outfall will be a sound one, that it is difficult to determine the level of treatment needed for completing the system, and that actual monitoring is the best means for ascertaining the level of treatment really needed.

USA Federal Requirements

The new EPA policy, now being implemented, is not only forcing coastal communities to upgrade their systems to include secondary treatment, but also includes very severe restrictions on effluent quality that probably cannot be met even with the most efficient design and operation of secondary treatment plants—for example, the limitations for some toxic metals are equal to or less than the safe concentration levels of the US Public Health service Drinking Water Standards. Hence, when the upgraded treatment systems become operational, and monitoring shows that all effluent requirements are not being met, it appears probable that the EPA requirements for treatment plants will need to be modified to match efficient plant performance, or EPA will need to implement an exhaustive programme for controlling certain pollutants at their sources.

Italian Practice

Submarine outfalls are used to transport untreated municipal and industrial waste waters to zones where they are diluted and degraded to

harmless or near harmless concentrations. Pretreatment of the waste water and control over the concentration of pollutants permitted to enter the sewer will be necessary in Italy in order to produce acceptable conditions in the receiving waters. Biological treatment will also be required in some cases. The three important components of the design of outfall systems are the environmental considerations, provision for dispersion and dilution of the pollutants, and provisions for protection of the pipeline. The design must meet legal requirements promulgated in July 1973, which define permissible limits for pollutants in the receiving waters under specified conditions in order to produce water safe for bathing and beaches that are aesthetically acceptable.

Industrial Waste Disposal in Sweden

Swedish law requires that within the economic capabilities everything possible must be done to protect the environment of the marine waters which receive pollutants. The Baltic Sea is heavily polluted and much of this is due to industry. A large proportion of the industrial pollution is from the pulp and paper industries which are usually separate from public sewers. Internal improvements in mills have resulted in fibre recovery and reduction in organic pollution load. The older sulphite process usually carried out in small mills is being replaced by the kraft (sulphate) process in larger modern mills which, combined with the prohibition of the discharge of sulphite liquor to receiving waters, has greatly reduced pollution. With the introduction of computer control for pulp manufacture and for operation of washing processes, stoppages that result in losses of effluent and accidental discharges should be minimized.

Until a few years ago one of the most serious sources of mercury emission into the environment came from the manufacture of chlorine using the electrolytic alkali process which resulted in the discharge of 100 grams of mercury per ton of chlorine produced. By using a new process of chlorine manufacture, the loss of mercury has been reduced by ~99% (to ~0.2 g per ton of chlorine). Further improvements have recently been made so that from an industry making 300,000 tons of chlorine annually, less than 200 kg of mercury is discharged in a year or less than 1% of the amount discharged to the environment 5 years ago.

Ocean Dumping by USA

Over 62 million tons of waste materials are dumped annually into marine waters off the US

coastline. Of this 5 million tons are derived from industrial sources and this includes toxic substances. Little is known about the ecological effect of ocean dumping and especially the effect of toxic and non-degradable materials, but it has already been found that the dissolved oxygen content of the water at some dumping zones is falling to a low level and many shell-fish beds are undesirably close to dumping sites. It is known that dumped material may be borne by currents long distances from the dumping sites.

The Marine Protection, Research, and Sanctuaries Act, enacted in April 1973, provides for strict regulation and control of dumping. Dumping may take place only in special areas under controlled conditions related to the amount and composition of the dumped material. The Act makes provision for the phasing out of certain objectionable and toxic substances within a few years, official supervision of the activities of dumpers, and heavy penalties for infringement of the laws. Research work is in progress to study the ecological effects of the materials being dumped to provide guidelines for safe dumping procedures. The urgency with which this program is being conducted should encourage international co-operation in the control of pollution from dumping before insoluble problems and irreversible ecological changes occur.

EXPERIENCE WITH MARINE WASTE-DISPOSAL SYSTEMS

Introduction

The case studies that were the subject of reports covered a very wide range of conditions from coliform counts in sea water around the coast of Britain, where no bacteriological standards exist, to a detailed examination of more than two decades of information on the sanitary and ecological conditions off the coast of Los Angeles.

Great Britain

Investigations were carried out on the effects of comminuted or disintegrated sewage discharged at five different sites around the British coast. The length of the outfalls varied from 20 m to 1400 m and in one case discharges could be made at three different lengths along the outfall. The studies, which were confined mainly to coliform counts, showed considerable variability and the reasons for this were examined. Of the environmental factors that influenced the results one was identified as the tidal cycle but not all sites showed this effect. High seas prevent the settlement of suspended matter associated with coliforms and the high seas

correlated with high coliform counts. Onshore wind was also found to account for high values.

Other extraneous factors influence coliform counts. These are discharges brought in by rivers, which at one site were found to be more significant than sewage-borne coliforms; rainfall, which increases the total coliform load; the discharge from storm overflows; solid matter flushed out from sewers; and seagulls, which at certain periods may greatly increase the coliform count. The mortality rate of coliform bacteria was determined by *in situ* field tests. The die-off rate is increased in bright sunlight; in darkness the die-off rate is insignificant, indicating that sedimentation was not an important factor in the removal of bacteria.

United States

The City of Los Angeles has carried on, for more than two decades, probably the most comprehensive and detailed monitoring programme ever undertaken by a municipal sewerage agency for evaluating the impact of waste discharge on the marine environment. Most of these data relate to the Hyperion Treatment and Disposal System, which discharges several hundred million gallons daily of primary effluent via outfalls reaching from 8 to 11 km out into Santa Monica Bay and therefore furnish a wealth of information on effects of discharge into semi-open coastal waters. This monitoring programme is especially interesting for the San Remo Conference in that the present system comprising primary treatment with long outfalls replaced an earlier system comprising secondary treatment with a short outfall—the changeover was costly and painful but the monitoring data showed that the key to the problem was to discharge the effluent far from shore. The monitoring since then shows the system has satisfactorily met all regulatory criteria and has not resulted in any known impairment of environmental values outside the allocated mixing zone.

Italy

Feasibility studies carried out to arrive at the best solution for the disposal of sewage from the City of Trieste called for an investigation of all important factors such as sea dispersion and self-purification. Although domestic sewage is not regarded as directly toxic to marine life, water polluted with sewage was examined as to its effect on algae, shellfish and test fish. At the discharge point proposed for a marine outfall the diluted sewage should have no effect on these organisms. In these studies the BOD of the waste water was of secondary

importance. Mixing near the shore, as determined by salinity measurements, is limited and from this the conclusion was reached that an ocean outfall would be needed.

Three alternative methods of sea disposal were considered:

1. Offshore disposal of primary settled sewage through a submarine outfall of sufficient length to meet the latest Italian public health standards.
2. Biological treatment of sewage discharged offshore through a shorter pipeline.
3. Biological treatment followed by phosphorus removal and disinfection and discharge through a still shorter pipeline.

The first scheme, primary settlement and offshore discharge, was found to give the most effective solution. In the meantime the discharge of sewage from a small population through a 1-km-long outfall has been shown to produce results that comply with prescribed coliform limits and are aesthetically satisfactory. A valuable suggestion for outfall schemes for the future is that provision should be made for monitoring the results, and facilities should be provided for controlled experiments so as to enable necessary modifications to be made on the basis of scientific data.

Additional studies in Italy, which reviewed the methods available for tracing the flow and dispersion of sewage discharged to marine waters, concluded that silicates meet the requirements of a tracer better than other existing techniques. The advantages include ease of analysis against a background level, continuous determination in a survey vessel, stability, reliability, and presence of silicates in the sewage in concentrations sufficient to make further additions unnecessary. Studies carried out at sea off the City of Maiori confirmed the usefulness of the silicate tracer technique. This method of tracing is not affected by variations in coliform disappearance rates.

Because of the increasing concern about possible health hazards from enteroviruses in marine waters receiving sewage from outfalls, a comprehensive study was made for determining viruses after concentrating them by the use of polyelectrolytes. The sites examined represented a wide variety of conditions, and enteroviruses were detected at most of them. The relationship between the numbers of virus and *E. coli* varied from 1 in 500 to 1 in 40,000. This difference is probably due to the elimination of viruses at a much less rapid rate than *E. coli*. Viruses were also found to be concentrated in or

associated with sand. The fact that viruses may persist for quite long periods draws attention to beach sand as a potential source of infection. The investigation also showed that molluscs were capable of concentrating viruses. This finding justifies the concern about permitting molluscs and shellfish to be used from waters that do not comply with Italian coliform standards.

RESEARCH AND SPECIAL PROBLEMS

Introduction

References to research were included in most of the papers and discussions at every session of the Conference. For example, a discussion on the effects of pollution on plankton describes the use of mathematical models for developing quantitative expressions of the changes in species types and concentration resulting from changes in nutrient levels or from changes in temperature from thermal discharges.

A key point is that governments today throughout the world, in response to public apprehensions on degradation of the environment, must proceed with action programmes to provide guidelines design and operation of marine waste-disposal systems. It is recognized that a great deal of research is needed to establish a much better scientific foundation for design and operation in the future, especially on the question of how best to provide proper protection of the sensitive marine ecology affected by waste discharges. It is being increasingly recognized by governments that the provision of treatment and disposal systems that do protect the environment means very large-scale expenditures for construction and operation of facilities and that the available technology for determining the needed levels and types of treatment, and hence the cost of the facilities, is far from adequate, resulting in a great deal of confusion and wastage of very sizeable financial and energy resources. Accordingly many nations have established sizeable continuing research programs including programmes dealing specifically with marine waste disposal.

Since many marine pollution problems have a direct or indirect bearing on human health and well-being, the World Health Organization conducts, sponsors and supports a variety of research and monitoring programmes dealing with marine pollution. The programmes range in scope from global, through regional and country-wide, to local.

Specific Research Programmes

The presentations included descriptions of the marine waste-disposal research programmes now

under way in France, Sweden, Southern California, and the USA, on control of oil pollution.

The research program in Sweden includes major studies for (1) the Baltic Sea, the world's largest brackish water sea, with primary attention to accumulation of chlorinated hydrocarbons and to effects of oil spills, to the use of benthic fauna communities for the evaluation of effects of industrial effluents and to use of systems analysis and computer simulations of ecosystems, including a mathematical model of the flows of phosphorus and oxygen; (2) the Byfjorden Fiord, to describe quantitatively how the ecology is affected by pollution; and (3) the petrochemical industry, for evaluating effects of plant wastes on fish.

The US Coast Guard has established a comprehensive continuing research programme aimed at reducing oil pollution including studies on systems for prevention of spills, for prompt response action when spills occur, and on practicable enforcement procedures.

The programme of research being carried on by the Southern California Coastal Water Research Project (SCCWRP) over the past several years, one of the most comprehensive investigations ever undertaken for evaluating effects of wastes on marine ecosystems, is studying the entire zone of coastal waters in Southern California from Santa Barbara to the Mexican border and beyond. A great deal of new information has been developed bearing on the basic question of the capability of the ocean for receiving and absorbing wastes and therefore on levels of treatment required for wastes discharged to the marine environment. While the project is still underway, the findings so far indicate clearly that the current Southern California practice of disposing of municipal wastes of the order of $4 \times 10^6 \text{ m}^3/\text{d}$ through use of primary treatment together with long outfalls and diffuser systems, represents an economical and competent method for disposal of residual waste effluents (which cannot be reclaimed for reuse on the land). This method of disposal generally furnishes adequate protection of marine ecology. The research shows that the areas of the ocean which are significantly affected (the water column in the mixing zone and the associated bottom sediments) represent a relatively small effect on the total marine ecology. The research also indicates, however, that the systems of treatment and disposal currently in use, while basically sound in concept, do need refinement and improvement in certain aspects, recognizing that when this system of treatment and disposal was developed in Southern California there was at that time no

suitable technology by which effects of waste effluents on marine ecology could be quantified. One of the surprising findings of the study is that, even though the heavy metal contents of the bottom deposits resulting from waste discharge are orders of magnitude greater than for the unaffected bottom sediments in the vicinity of the discharge (up to 100 times greater for some metals), no increase was found in the heavy metal content in the livers of inhabiting the vicinity despite intensive trawling and examination of many fish samples. Also most important contaminants were dominated by sources other than waste-water discharge.

Aesthetics

Aesthetics, or the beauty of the marine environment, is now being recognized as a key factor in waste-disposal technology, and regulatory agencies are beginning to incorporate into their requirements a number of parameters relating specifically to aesthetics. Previously such regulations have usually contained a qualitative requirement that the waste discharge should not create objectionable conditions, which of course meant that significant impairment of environmental beauty would be permitted so long as gross nuisances were avoided. Now the objective is literally to permit no significant impairment. The most important parameter relating to aesthetics in marine waters is that of floatables, which in turn may be subdivided into two categories, surface films and particulates. Other parameters of value in evaluating the impact of waste on aesthetics include transparency, color, coliforms, species diversity, oil content of beach sands, odours, and fish tainting.

The new State of California regulations for marine waste disposal (1) include definite limitations for grease and oil (hexane extractables) and separately for floating particulates (dry weight), both in the waste effluent and in the receiving water; (2) include limitations on suspended solids in the effluent and on turbidity for both the effluent and receiving water; (3) prohibit visible reduction of transparency outside the mixing zone; (4) require rigorous monitoring including color photography for detection and reporting on visible surface impairment due to floatables, colour, and other causes.

Radioactive Waste Disposal

Studies on wastes from nuclear power plants discharging to the marine environment in Italy developed a methodology for designing discharge systems that afford proper protection of environ-

mental values. This methodology evaluated all significant species of organisms, including humans, affected by the discharges, to be sure the dosages received would be well within limits established for each category. The critical group affected by the discharges was not aquatic organisms but commercial fishermen. The Italian studies included participation in international operations for disposal of concentrated insoluble radioactive materials by containment in concrete and sinking in the Atlantic ocean at 4500-meter depth.

CONCLUSIONS

The Conference at Sanremo developed a number of significant findings and conclusions relating to marine waste disposal, especially in the Mediterranean Sea, which can be summarized as follows:

1. The Mediterranean, despite its confined nature and the discharge to the sea of wastes from many surrounding countries, is still an essentially nutrient-deficient sea with oligotrophic properties in selected areas such as along the Riviera and Dalmatian Coast.

2. It seems unlikely that discharges of waste organic materials from the surrounding countries will be sufficient in the foreseeable future to result in general eutrophication of the Mediterranean, but careful attention must be given to the design and operation of waste-treatment systems to prevent impairment of water clarity and beauty in areas important for recreation, and to prevent the buildup of toxic concentrations of pollutants in the sea which will damage or destroy valuable fisheries or food chains or result in levels of toxicants in fish harmful to human consumers. The latter problem is considerably more serious in the Mediterranean than in the open oceans.

3. To achieve a competent comprehensive waste pollution-control programme for the Mediterranean, it will require a system of international co-operation among the countries involved, especially those bordering on the Mediterranean but also the hinterland countries to some extent, especially for the establishment and enforcement of uniform minimum water-quality criteria. It is expected that an agreement on basic water quality criteria can be achieved by about 1980.

4. To achieve the desired competent and comprehensive waste pollution-control program will also require a great deal of improvement in the scientific understanding of effects of wastes on the ecology and in engineering technology to permit design of treatment and disposal systems that will

in fact achieve the needed protection within the bounds of reasonable costs. The present action programmes in water-pollution control in some parts of the world are characterized by expenditure of large sums of money, allegedly for protection of environment, but not always with firm scientific evidence that the expenditures are justified and meaningful, and considerable evidence that they are not. However, it should be stressed that this argument must not be used to retard the establishment of proper water pollution-control programmes in all those sectors where the scientific basis is relatively solid, especially in restricted sea areas.

5. The Mediterranean countries can obtain the needed new technology both through their own research programmes and through use of research findings from programmes elsewhere especially those in Europe and in the USA. Careful attention should be given to designing the local research programmes to achieve maximum results through avoidance of duplication and through maximum use of research findings developed elsewhere.

6. It is believed the San Remo Conference has made a significant and meaningful contribution in all the problem areas described above.

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1 GENERAL PROBLEMS

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POLLUTION—DESTROYER OF THE USEFULNESS OF THE MARINE ENVIRONMENT

G. J. STANDER†

Our pollution problem was started by Hercules—he cleaned the stables of King Augeas by diverting the River Alpheus. What happened to the poor river or unfortunate ocean which ultimately received the waste is not reported. All we know today is that his method of cleaning the stables of industries and cities has presented us with a Herculean task.

Our oceans are not such simple systems as we are inclined to believe. They harbour a multiplicity of complex and delicately balanced physical, chemical and biological digestive processes which not only convert organic and mineral wastes into substances essential to human, animal and plant life, but also preserve those amenities of our marine environment which are vital to man's mental health and physical wellbeing. However, where our creative endeavours of today centre around the glamour and opportunities of socio-economic progress, we seem to forget this fact and unwittingly abuse nature's gift to man. To preserve this most valuable asset it is vitally essential that a critical examination be made of the key role the marine environment plays in our daily lives in order to rationalize our research and development efforts and decision making.

Apart from their role as oxygen generators through phytoplankton activity, oceans produce a colossal harvest of proteins to satisfy the nutritional requirements of an ever-increasing population in many parts of the world. Its current estimated annual production of some 90 million metric tons of fish represents a mere 20% of its full potential. Coastlines and estuaries are the major spawning grounds for fish, some of which migrate up rivers over long distances. It is also these estuarine zones which offer the greatest potential for the systematic production of fish cultures and increased fish catch.

Coastal waters do not only provide man with much needed protein food. Thousands of kilometres of the world's coastlines serve as the playground of

millions of tourists and billions of dollars are invested in this industry. Swimming, fishing, boating, skin diving and general relaxation on beaches have become major corner-stones in providing outlets for the tensions which modern socio-economic development inflicts upon society. Quite rightly society has become very jealous of these recreational amenities as a special and indispensable health therapy, and as a consequence in many areas of the world investments in these coastal amenities exceed that of secondary industry manifold.

The increasing threat of industrial development and urbanization to the marine environment has precipitated world wide reaction and demands on the part of investors in marine and coastal amenities. Precisely this reaction is today giving rise to a concept extending far beyond the famous words of Coleridge, namely "Water, water everywhere, nor any drop to drink". In fact pressures against marine pollution now demand "Water, water everywhere and not a drop to pollute". These demands by modern society, however unrealistic it may seem, are not entirely without foundation. In many areas domestic sewage and industrial effluents are dumped directly into the sea with minimal or no treatment whatsoever. Rivers polluted with sewage and industrial effluents empty into estuaries and the sea and the pollutants are carried by currents over long distances along coastlines. The deleterious effects which sewage and industrial effluent discharges have on the amenities of the marine environment are adequately described in published records. Similarly the disasters of massive oil leaks and spillages, the discharge and dumping of dangerous wastes and the disposal of sewage and other sludges into the deep sea are common experience and knowledge all over the world. There is no necessity to belabour the obvious.

From the aforementioned considerations, it seems that in our path of progress, we have reached a cross road of destruction and preservation of those beauties and amenities of the coastal and marine environments which we so zealously exploit for our own physical health, mental well-being and our food

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needs in many areas of the world. However unrealistic, disturbing and subjective the environmentalist's call to arms may be, it is for man's own good that he appraises the current situation objectively and critically since the road of self-preservation requires soul-searching, thinking and planning along a critical pathway. One cannot but wonder how it is possible that in this modern age of unprecedented advancement in technology man has failed to recognize along his path of progress the two most important cornerstones for preserving his water environment—keep your own home clean and don't dump your dirt in your neighbour's backyard!! It is worthwhile examining the blinker which socio-economic progress has put over man's eyes.

The vastness of oceans and their inherent self-purification capacity to absorb wastes of nature offered an obvious means and path of least expense and resistance for the disposal of human and industrial wastes for many decades and man enjoyed economic progress at the expense of nature. Slowly but surely these self-cleansing powers of ocean waters used for commercial fishing and pearl production and of ocean waters along coastlines which are the centres of recreation, tourism, holiday making, urbanization and industrial development, have become overtaxed and led to the introduction of primary and secondary purification systems prior to disposal into the sea. It has, however, become abundantly clear that the cleanliness and usefulness of this water environment can no longer be preserved by these tools alone and, as in the case of river pollution, the need for tertiary treatment systems is becoming increasingly essential.

Intensive research and development work in connection with the cumulative adverse effects of pollutants on the amenities of the marine environment, particularly with respect to public health requirements, to aesthetic criteria for surf waters and bathing beaches and to quality requirements for a number of industrial uses of sea water, has exposed notable limitations in the capacity of the marine environment to absorb man-made wastes. In fact in many coastal areas substantial increases in natural pollution loads contributed by stormwater runoff from urban and inland agricultural areas constitute a major threat to marine amenities. From the cumulative data of marine monitoring programmes convincing evidence is forthcoming that long-distance marine outfalls and extensive diffuser systems to exploit dilution and dispersion by sea currents have considerable limitations in offsetting threats to the marine environment and its amenities.

The time has arrived for scientists and engineers

to critically appraise not only the entire technology of marine disposal of wastes, but also the management of industrial and domestic wastes at source. It is imperative that any marine outfall should be designed as an integral part of a whole waste-disposal system and should fit in with all aspects of waste recovery and stabilization before disposal into the ocean. Once the type, quantity and quality of waste after economic recovery of by-products and adequate treatment for disposal are known, the question of the design criteria of the pipeline and diffuser system can be considered.

In spite of the fantastic achievements of modern industrial technology and the development of advanced processes for waste management, it is not generally appreciated that the water environment is a closed ecological system and as such its chemical, biological and physical capacity to absorb man made waste are uncontrollable, limiting and largely unpredictable. Recent work of scientists and engineers leaves no doubt in our minds that the real solution of pollution problems lies in the modernizing of industrial production processes and of urban waste treatment technology. Just as the early techniques of Watts', Stephenson's and Faraday's discoveries had to make way for modernized industrial applications, should the disposal of primary and secondary treated waste products into the water environment be rejected as an obsolete system? One wonders what the impact on the Industrial Revolution would have been if the limitations of early applications of Watts' and Stephenson's discoveries were not overcome. Process modernization for industry's future existence in a competitive market is today an absolute necessity. Surely this also applies to the management of their waste products and the water environment.

We can no longer ignore the writing on the wall—the waste products of future development of industries, concentration of population in urban areas and expansion of agriculture to meet the growing food requirements of man, can no longer be dumped directly into our oceans or indirectly via rivers which ultimately discharge into them. Their use as man's dustbins has become a deadly threat to man's future existence, mental health and physical well being.

This stark staring reality was recognized as a major challenge by a group of scientists and engineers who met in London during the early part of 1961 with the object of fostering international collaboration and exchange of information to protect the usefulness of the water environment against destruction.