ENVIRONMENTAL HEALTH

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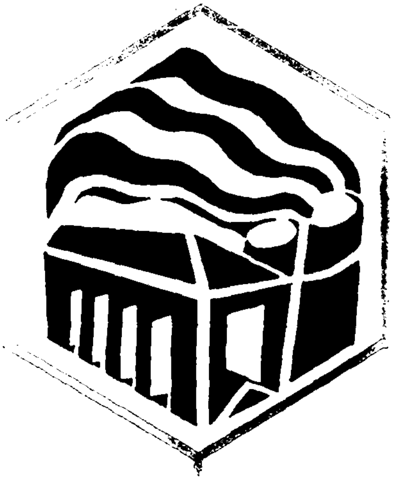

Industrial Wastewater in the Mediterranean Area

WORLD HEALTH ORGANIZATION
Regional Office for Europe
Copenhagen

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TREATMENT AND DISCHARGE OF INDUSTRIAL WASTEWATER IN THE MEDITERRANEAN AREA

Report on a WHO Workshop

Venice
10-14 June 1985

WORLD HEALTH ORGANIZATION
Regional Office for Europe
COPENHAGEN
1986

NOTE

This document has been prepared by the Regional Office for Europe of the World Health Organization for governments of its Member States in the Region. A limited number of copies are available from the Environmental Health Service, WHO Regional Office for Europe, Scherfigsvej 8, DK-2100 Copenhagen Ø, Denmark.

The series is intended to disseminate rapidly information about activities of the WHO European Environmental Health Service and has not received such detailed editorial revision as WHO publications. Parties interested in commenting, receiving more detailed information, or collaborating on specific activities are asked to contact the Director of the Environmental Health Service, at the address given above.

FOREWORD

The World Health Organization has been active in the implementation of the Mediterranean Action Plan since its formal adoption by the coastal states of the Region in 1975 under the overall sponsorship of the United Nations Environment Programme (UNEP). The Plan's scientific component - the Programme of Pollution Monitoring and Research in the Mediterranean Sea (MED POL) - included a pilot project on coastal water quality control (1976-1981). Under this project, 30 national institutions from 14 Mediterranean countries carried out regular monitoring of recreational and shellfish-growing areas. The results laid the foundation for the long-term national sanitary monitoring programmes currently operational in most Mediterranean countries. It also produced the first regional assessment of the state of microbial pollution of the Mediterranean Sea, with environmental quality criteria, part of which have recently been adopted by the countries of the region.

Since 1982, WHO activities within the long-term phase of MED POL have included the organization and evaluation of health-related components of national pollution monitoring programmes. They have also included research activities, mainly epidemiological studies correlating coastal water and seafood quality with health effects, e.g. carcinogenicity and mutagenicity, of marine pollutants and studies on the survival of pathogens in the marine environment.

A cornerstone of the Action Plan is the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources. Adopted by Mediterranean States in 1980 and in force since 1983, the Protocol covers practically every aspect of what is acknowledged to constitute the Mediterranean's greatest pollution problem. WHO played a major role in the preparatory work leading to adoption of the Protocol, including the compilation of a compendium of relevant national legislation in individual countries of the region, and the coordination of an inter-agency pilot project on pollutants from land-based sources in the Mediterranean area.

Implementation of the Protocol, for which a long-term plan of activities has recently been developed, will imply a major re-orientation in the priority areas of the Mediterranean Action Plan. Strong emphasis will now be given to the progressive reduction of marine pollution at source, including the construction of more submarine outfall structures, sewage treatment plants, treated wastewater re-use, and alternative industrial processes.

One of the principal aims of the workshop convened by the WHO Regional Office for Europe in Venice from 10 to 14 June 1985 was to provide a concrete input to the eventual implementation of the protocol. The report of this workshop, which deals with selected aspects of the treatment and discharge of industrial wastewaters in the Mediterranean area, should be of practical use to a range of individuals concerned with the prevention and control of land-based pollution in this region, including legislators, planners and administrators.

J.I. Waddington
Director
Environmental Health Service

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SECTION 1: REPORT ON THE MEETING

Introduction

Liquid industrial waste discharged into the Mediterranean Sea has increased both in volume and complexity during recent decades. In addition, municipal wastewater has changed in composition, not only through the increased amount of household chemicals in use but also through the discharge of varying amounts of industrial waste into public sewers.

Both as part of their own national programmes and in conformity with the terms of international legal instruments they have become parties to, Mediterranean countries are intensifying their efforts to minimize marine pollution by such wastes. In this regard, the major regional legal instrument is the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources, adopted and signed in 1980, which has recently come into force. Under its provisions, Mediterranean countries have undertaken to eliminate progressively pollution by high-risk substances and limit it strictly in the case of others. This action necessitates a complex sequence of programmes and measures at both national and regional levels.

Under its programme of activities dealing with coastal water quality control in the Mediterranean area, and also as part of its chemical safety programme, the WHO Regional Office for Europe convened a Workshop on the Treatment and Discharge of Industrial Wastewater in the Mediterranean Area in Venice from 10 to 14 June 1985. It had three objectives: review relevant international and national legislation, and national administrative provisions relating to treatment and discharge of industrial wastewater, including acceptance of industrial effluents into public sewers and costing and charging policies; discuss recycling and re-use of industrial wastewater and disposal of solid waste and slurry; and discuss requirements for training of personnel. The Workshop was designed to provide relevant information needed to upgrade national control measures, as well as a concrete input into the preparatory work required for implementing the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources.

The Workshop, hosted by the Regional Authority of Veneto, was attended by 16 temporary advisers and 9 other participants from 10 Mediterranean countries, and 2 staff members of the WHO Regional Office for Europe. Participants included environmental engineers, hydrologists, toxicologists, biologists and public administrators (see Annex 1). Mr J.I. Waddington, Director, Environmental Health Service, WHO Regional Office for Europe, addressed the participants on behalf of the World Health Organization. He pointed out that the emphasis in health programmes in modern industrialized society was changing from curative to preventive methods. In this region, personal lifestyle and environment were now two firm pillars in WHO policy that covered a range of governmental activities involving several ministries. This workshop was considered a landmark in WHO's activities in this direction and was concerned with action and practicalities on a regional basis.

Mr G. Cortese, Vice-President of the Regional Authority of Veneto, welcomed participants on behalf of the Authority. He briefly outlined the problems of pollution caused by waste in the region, especially the lagoon of Venice, of which one major factor was the outlet of the Po River into the sea. In addition to a special plan for cleaning the lagoon, considerable funds have been spent on public education to instil environmental awareness and on training of experts and technicians for pollution monitoring.

Professor E. De Fraja Frangipane was elected Chairman, Professor R. Mujeriego Vice-Chairman, and Mr I. Jacovides and Dr A. Adin Co-Rapporteurs.

The technical sessions included the 4 working papers presented in Section 2.

International Legislation

The Mediterranean Sea is a natural resource shared by all its coastal states, and marine pollution control measures have therefore to be based on a common regional framework. Such a framework exists in the form of the Barcelona Convention for the Protection of the Mediterranean Sea against Pollution, adopted and signed by the coastal states of the region in 1976. An estimated 85% of the total pollution load entering the Mediterranean Sea originates from land-based sources, with a significant proportion caused by industrial waste discharge.

The Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources was adopted in 1980 and came into force in June 1983, but the preparations for its implementation have yet to start. To date, the Protocol has been ratified by 9 Mediterranean countries and by the European Economic Community (see page 25 for more details). In December 1985, a meeting of governmental experts is expected to approve a workplan and time-table for the progressive formulation of programmes and measures. The current terms of the Protocol cover liquid waste discharge and make the necessary provision for future coverage of atmospheric pollutants entering the Mediterranean Sea. However, solid waste is not specifically mentioned. Because of the integrated nature of the pollution problem (i.e. the essential relationship among liquid waste treatment and discharge, sludge, slurry and solid waste disposal), the present Protocol will not provide a complete solution, even when fully implemented.

In addition, the articles of the Protocol provide only the basic framework for the progressive development of programmes and measures. The annexes (the "black" and "grey" lists) consist of groups of compounds, not specific ones. Under practically every item in these annexes, lists of substances covered still have to be compiled, and several terms require specific definition to avoid misinterpretation.

Apart from these essential prerequisites in the form of definitions and lists of substances, implementation of the Protocol will require the formulation of emission standards for wastewater discharge in the case of Annex I substances. It also requires the formulation of guidelines concerning authorizations for discharge of (a) Annex II substances and (b) Annex I substances in concentrations below eventually agreed-on limits. Such guidelines will have to be sufficiently flexible to ensure a common regional baseline while at the same time allowing for specific local circumstances and requirements. Finally, environmental quality criteria will need to be developed to cover the particular uses to which the receiving water (or any other part of the marine environment affected by such discharge) are put.

The development of both environmental quality criteria and emission standards has to be worked out within the framework of an overall regional strategy. In view of the heterogeneity in socioeconomic and technological development among Mediterranean countries, such a strategy should allow for phased progressive implementation, based both on regional priority needs and the capabilities of individual countries. As with all the programmes and measures covered by the Protocol, the practical implementation of emission standards and environmental quality criteria will eventually incorporate joint common regional standards and criteria into national legislative and administrative measures. Regional measures will therefore have to be adjusted to suit what can be termed the minimum common denominator, leaving countries free, as is normally the case, to apply stricter measures at the national level if circumstances so require. Common minimum standards could be made progressively stricter, given time, as infrastructure improves and technology develops.

Practical difficulties in eventual implementation of the Protocol may be encountered by countries already party to agreements with, or having to comply with directives from, other international bodies including partial coverage of the Mediterranean coastline, whether or not such agreements or directives also cover non-Mediterranean areas. From the viewpoint of actual numerical standards and criteria, this problem is more apparent than real. First, compliance with the stricter of any two different standards involves automatic compliance with the other. Second, there would be every justification for applying different standards at national level to coastlines bordering on different seas, especially if the prevailing circumstances regarding each differ. The problem arises mainly in the mechanism of compliance, rather than with the standards and/or criteria themselves. Therefore, while the overall requirements of the Mediterranean region should be accorded the highest priority in the development of programmes and measures for implementing of the Protocol, full account should be taken of existing mechanisms in the region, especially with regard to parameters, matrices and standard methods of determination, to avoid or at least minimize unnecessary duplication of work.

During 1976-1977, as part of the scientific component of its Mediterranean Action Plan - the Coordinated Mediterranean Pollution Monitoring and Research Programme (MED POL), WHO was responsible for the technical coordination of a pilot project on pollutants from land-based sources in the Mediterranean, in which the following international organizations also participate: Economic Commission of Europe (ECE), Food and Agriculture Organization of the United Nations (FAO), International Atomic Energy Agency (IAEA), United Nations International Development Organization (UNIDO), United Nations Educational, Scientific and Cultural Organization (UNESCO) and the United Nations Environment Programme (UNEP). Although most of the data had to be obtained indirectly, the estimates made were considered to be reasonably accurate. A more thorough repetition of this exercise would enable an evaluation of the impact of improvements in national legislative and other pollution control measures over the intervening period. It would also go a long way towards providing an updated assessment of the actual situation with a view to pinpointing priority areas for the development of programmes and measures under the terms of the Protocol.

National Legislative and Administrative Measures

In 1976, WHO and UNEP jointly carried out a survey of national legislation on the control of pollution from land-based sources in Mediterranean states. It showed that relevant measures existed in a number of countries, but that most were fragmentary in nature. Since then, a trend towards more coordination has become generally evident.

Various approaches can be used to control marine pollution by industrial wastewater. In some countries, legal measures provide for different approaches, using a comprehensive policy aimed at controlling wastewater pollution in general, and therefore covering the different situations giving rise to such pollution. This total approach, requiring a considerable technical and administrative infrastructure, is not a common one within the Mediterranean region.

In a number of countries, legislation requires environmental impact assessments with regard to the installation of industrial and related plants potentially affecting environmental quality. Often, this covers air as well as wastewater pollution. In some cases, the studies are fairly comprehensive and are subject to official control right along the line. In other countries, environmental impact assessment reports are prepared by potential or actual polluters themselves, who also assess the problems they may create and decide on proposals for their solution. This "self-regulation" is not always conducive to objective results, especially where the authorities do not practise regular control.

Regulations and administrative measures regarding effluent discharge exist in most Mediterranean countries. In some instances, emission standards for various substances are laid down in the law itself. In others, standards are provided for but not yet strictly defined. Two approaches are evident here. The first, considered to be the simpler and more enforceable, is the imposition of upper limits for various parameters in the industrial effluent itself, either in the form of pollutant concentration or total pollutant load per specified period. While enabling standardization of control, this method does not allow for differences in, for example, the receiving capacity of the various parts of the marine environment where the waste is discharged. The second approach is the laying down of environmental quality criteria with regard to the receiving water body, depending on the various uses it may be put to. While such an approach has long been used with regard to microbial concentrations in bathing and seafood culture areas, its application to pollutants originating from industrial effluents is as yet rarely practised.

In several cases, treatment for recovery of industrial pollutants prior to discharge is laid down by law. This also applies to discharge of industrial wastewater into public sewers, to which standards apply in a number of countries, covering a varying range of physical, chemical and biological parameters. In this respect, industrial effluents not complying with prescribed limitations have to undergo treatment, at the expense of the industry discharging this waste, to ensure such conformity. The procedure is still not widely practised in the Mediterranean region and is difficult to enforce in the case of many relatively small industries located in urban areas.

Various approaches are used to determine standards. In a few countries, these are based on environmental impact assessment studies and/or the establishment of environmental quality criteria for the receiving or affected water. In other cases, international or "foreign" standards are applied, with varying degrees of adaptation to specific conditions. However, very few countries have standards covering what are considered to be the most important pollutant parameters, especially in the case of chemicals requiring relatively sophisticated analytical procedures for detection at low levels.

Control measures existing within the region also include regulations for zoning and siting of new industries and for annual permit systems, whereby operating licences may be revoked in cases of noncompliance either with prescribed procedures or with more general conditions laid down from time to time at the discretion of national or municipal authorities. In certain countries, penalties for pollution by industrial wastewater discharges are higher than the equivalent cost of treatment. For most measures, one particular problem affecting many countries is that of enforcement. Thus, while the legislative and administrative infrastructure may appear to be adequate in theory, it is often not so in practice, either through insufficient coverage at the regulatory and/or administrative level or through insufficient operational control.

In general terms, the success of any pollution control programme, including programmes backed by legal and administrative provisions, depends to a considerable extent on three factors: the particular environmental management scheme adopted, the capability of planners to derive effective and enforceable programmes within its overall framework, and the ability of the parties to implement these programmes. Enforcement constraints are closely linked with the degree of sophistication of measures adopted. Under certain conditions, especially in developing countries, varying degrees of limitation exist in the ability of authorities to enforce measures, of industry to implement such measures, and of the national economy to bear the cost. There is therefore a ceiling, in every country, to the complexity of optimally effective measures at any given time.

One solution to this problem is the establishment of priorities, initially involving the largest pollution sources. Such a programme would involve the application of strict treatment requirements on selected large industries. With eventual improvement of the national or local organizational system, it could be progressively extended to cover smaller sources of pollution. However, enforcement of waste treatment on numerous small sources in any given area, characteristic of developing countries, may prove both impractical and uneconomical. In this event, the situation could be tolerated, provided the combined impact of such small sources does not exceed a significant level from the overall viewpoint. Otherwise, consideration could be given to relocation of some or all of the industries in question.

Acceptability of discharge of industrial effluents into municipal sewerage systems constitutes another problem. Combined treatment of industrial and domestic wastes offers distinct advantages, including lower costs due to the economics of large-scale application, increased reliability of treatment and much-reduced monitoring and enforcement requirements. This approach, however, assumes compatibility of the different effluents in many respects, including volume and composition. Moreover, the composition and/or irregular discharge patterns of industrial effluents often disturb the operation of treatment plants. A number of hazardous substances may either pass through the treatment plant, polluting the receiving water, or may accumulate in the treatment plant sludge. Depending on their nature, industrial wastes may also affect the integrity and safety of the sewerage system.

One of the first considerations in the development of waste management schemes is the adoption of national standards for the quality of wastewater prior to its discharge into a sewerage system. In principle, such standards should reflect the minimum pretreatment requirements, thus placing only a reasonable burden on the national economy and on monitoring and enforcement capabilities. When conditions and requirements so demand, such national standards would have to be supplemented by more stringent local standards.

Legislative and administrative approaches to the problem of industrial wastewater pollution control vary between the different Mediterranean countries. Legislation is moving from a fragmentary to a more comprehensive pattern. In a number of instances, dependence on subsidiary legislation and administrative practice is increased because these are more flexible and easier to update and modify than legal acts. Such practices are often encountered in those countries which rely mainly on standards prevailing abroad, and which are likely to result in more frequent local modification.

If overall Mediterranean standards and requirements are to be met, a common framework policy must be established at the regional level. This policy, however, would have to be flexible enough to cover the particular circumstances prevailing within each country, especially during the initial period of establishment and operation of programmes.

Recycling and Re-use of Industrial Wastewater

The development of industry in many Mediterranean countries has significantly increased water consumption. In some countries, the demand for industrial consumption is expected to exceed that for domestic purposes. A number of Mediterranean countries with insufficient freshwater supplies to meet consumption demands use desalinated seawater. The recycling and re-use of industrial wastewater wherever feasible would not only alleviate the pollution problem but create a new water resource. Industrial processes and, to a certain extent, agriculture do not require water of the same or of the highest quality.

The re-use of industrial wastewater for agricultural purposes depends on the origin of the wastewater or on the type of the industrial process. Wastewater discharges containing pollutants similar to those found in domestic wastewater, or those which are biodegradable, are generally compatible. These primarily originate from food-processing plants and a number of other industries using organic matter in the production process. Industrial wastewater discharges containing pollutants which may disturb biological degradation or which are intrinsically toxic are generally incompatible, as are those with extreme pH values. These discharges are usually from metallurgical or chemical industries. In principle, the experience gained from the use of domestic wastewater may be useful in assessing the potential re-use of compatible industrial wastewater discharges for agricultural purposes.

Re-use of industrial wastewater for industrial purposes is most frequently carried out by in-plant recycling processes. Treated industrial wastewater is used primarily in cooling processes. Besides cooling, certain industries re-use treated wastewater for washing raw materials, for transport of materials, and for other requirements such as steam production for technological processes or energy. Re-use of industrial wastewater is necessarily connected with the re-use of waste matter extracted from it. In many cases, water re-use becomes economically viable if extracted waste matter is also re-used.

Treatment of industrial wastewater before re-use is a necessity, the degree depending on a number of factors, especially the origin and composition of the wastewater and its intended use. Quality requirements of treated water used in agriculture are not the same as those applying to industrial use. In the former, the quality depends on three categories of use: non-edible crops, crops consumed cooked and crops consumed raw. In the latter, the quality depends on the intended use of the water: cooling, steam production, washing and rinsing operations, or processing operations.

A decision on industrial wastewater re-use requires consideration of a number of factors including the quantity of fresh water available for use and the costs involved in its acquisition, the cost of treatment and disposal of wastewater, the possibility of modifying industrial processes for reducing waste, the costs of preparing wastewater for in-plant recycling or re-use, and the costs of preparing and disposing of treatment concentrates, including the possibility of their recovery.

Re-used industrial wastewater can be considered a new water resource in the Mediterranean region and should be accorded due consideration.

Disposal of Solid Waste and Sludge

Solid waste and sludge have a particularly important place among the many types of waste generated by industrial activities. This importance has increased as a result of legislation providing directives for a cleaner and safer environment through more stringent limitations on the discharge of liquid effluents, which has made treatment of solid waste more difficult and costly. In addition, higher levels of liquid waste treatment produce an increased mass and volume of sludge to be managed, so that solid waste treatment systems must not only handle more material but also be operated much more effectively.

Solid waste and sludge are difficult to subdivide more specifically. Sludge from wastewater treatment facilities of industrial installations is conventionally divided into biological sludge and physical/chemical sludge. Biological sludge is to some extent similar to its counterpart generated by domestic plants. However, biological treatment units must be supported by necessary physical/chemical pretreatment units if the industrial wastewater contains elements adversely affecting biological degradation. This aspect makes the quantity and quality of physical/chemical sludge from industries considerably different from those of primary sludge from domestic plants, and there are several industry-specific sludges.

In the Mediterranean region, considering the necessary link between solid waste disposal and the envisaged common measures for regulating industrial wastewater discharge, a re-classification of industrial solid waste and sludge into hazardous and nonhazardous waste should be considered. One approach to identifying hazardous waste is to list wastes that present no short-term handling problems and no long-term environmental hazards, and to define hazardous waste by exclusion. The more widely adopted approach is to establish inclusive lists indicating hazardous waste from specific industries, containing specific compounds or specific waste streams.

Despite their variety, relatively few ways are available for disposing of industrial solid waste and sludge. In most cases, they need to be treated to a degree suitable for the particular method of disposal employed. The disposal options defined for municipal solid waste are also applicable to nonhazardous solid waste of industrial origin. Similarly, disposal of nonhazardous industrial sludge is generally evaluated along the same concepts. However, because of the high water content and potential environmental incompatibility of this type of industrial sludge, a totally different sequence of appropriate treatment methods has to be used before final disposal.

Apart from the potential energy recovery existing from gas produced during anaerobic stabilization, pyrolysis or burning of sludge, sludge itself can also be used as a fertilizer or in land reclamation. In addition, a number of recovery methods are currently feasible to enable use of the recovered materials as waste treatment chemicals, landfill toppings, industrial raw materials, animal feed, and construction materials.

Special care should be taken when dealing with hazardous waste because of the potential consequences arising from disposal operations. Comprehensive hazardous waste disposal plans covering all relevant aspects have to be prepared. In this context, the programmes and measures to be developed in the Mediterranean region to control liquid wastewater discharges should be accompanied by complementary measures dealing with the treatment and disposal of solid (especially hazardous) waste, mainly arising as a result of the primary measures themselves. Such plans should also take into account the main economic issue, i.e. the maintenance of necessary, and at times delicate, balance between the needs of environmental protection and economic development.

Training and Use of Personnel

Training and use of personnel form an integral part of a successful waste management policy. Pertinent training and education should consist of a mosaic of different but equally essential factors. The relevance, and consequently the practical results, of such educational programmes depend largely on the consideration of all aspects at different levels.

Within this context, important issues include diffusion of information to the public to instil a sense of awareness of the need for environmental protection and a concomitant understanding that environmental programmes are aimed at protecting people; and education of decision-makers on both the regulatory and the potentially polluting sides.

Considerable importance is being increasingly attached to adequate academic programmes at all levels in environmental engineering, in recognition of the fact that these are the key elements in the technical solution of environmental problems. Similarly, as environmental issues always necessitate an interdisciplinary input, environmental topics are now being introduced into the education and training programmes of other related disciplines. At an intermediate level, adequate industrial waste control programmes demand many licensed operators and technicians of good quality.

Educational and training programmes should also be backed by the design and implementation of quality assurance programmes which are essential for performance monitoring and evaluation.

The present level of trained personnel (in type, numbers and quality) varies among Mediterranean countries. In many cases, such variation is directly related to differences in the degree both of industrialization and of enforcement of pollution control programmes. Implementation of the programmes and measures to be progressively developed for the control of land-based pollution in the region will demand more trained personnel at all levels, especially in industrial waste control. Development of a basic regional framework for relevant programmes, taking into account those already existing both within and outside the region, would go a long way towards ensuring a unified approach.

REPORT ON A WHO WORKSHOP

Conclusions and Recommendations

Implementation of international legislation

1. The only international legal instrument covering the control of industrial wastewater pollution which applies to the whole of the Mediterranean region is the 1980 Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources.

2. The Protocol does not specify the programmes and measures to control such pollution but only provides the framework for their development. Therefore, implementation of the Protocol as it now stands will only partially solve the problem.

3. In developing common regional programmes and measures under the Mediterranean Action Plan, due account should be taken of existing commitments of countries at the international level.

4. Establishment of common regional quality criteria should take into account the environmental quality requirements of the Mediterranean region as a whole. Emission standards should take into account the prevailing technological capacity and socioeconomic conditions in the various countries.

5. A detailed evaluation of the present level of waste discharge from land-based sources into the Mediterranean Sea should be conducted with three objectives: to establish an overall picture of the present situation, to determine the extent and effectiveness of corrective measures adopted since 1977, and to establish priorities for action in the near future. This evaluation should be continued through regular monitoring of the direct and indirect sources of pollution.

6. A regional code of practice for control of industrial wastewater discharge should preferably be an integral part of an overall framework for control of land-based pollution. The latter should in particular cover the control of potentially hazardous substances.

7. Common standards for control of pollution by industrial waste should be adopted by Mediterranean countries. In this regard, recognition should be paid to the fact that in the early stages, countries may have to adopt different approaches for attaining international goals, depending on their state of development.

8. Some countries have not reached the ultimate goal of deriving local plus individual effluent emission standards from ambient quality criteria. Therefore, because of the urgency of reducing

existing pollution, an immediate practical measure would be to define interim effluent standards based on pollutant concentration or possibly on pollution load per unit product until ambient standards are achieved.

National and municipal legislative and administrative measures

Legislation

9. The present legislative and administrative measures in force in several Mediterranean countries to control industrial wastewater discharge and other forms of land-based pollution require considerable improvement, coordination and consolidation.

10. Legislation and related administrative action should be directed at (a) preventive measures applied to new industries at the planning stage, and (b) remedial measures for existing industries.

11. It is important that national legislative and administrative measures should be enforceable.

12. Promulgation of new national legislative measures should be made in accordance with current international agreements.

13. National legislation should include clear definitions of technical terms and expressions.

14. National legislation should identify and incorporate the basic elements of a management policy or programme on industrial waste treatment and disposal.

15. National legislation should facilitate definition of enforceable local and individual effluent emission standards based on ambient quality criteria, depending on intended use.

Planning

16. Accepting that only measures of limited complexity can be effectively implemented at a given time, especially in the early phases of pollution control programmes, the most cost-effective and enforceable pollution abatement programme can be achieved only by the systematic giving of priority to such measures on selected heavy-pollution-load industries.

17. Considering the difficult issues which may arise in relocating industrial plants in the event of severe pollution problems, a relocation policy should be developed as part of a wider national policy.

18. To enable the successful implementation of complex industrial pollution control measures, national strategies should address these on a priority basis ranked according to their complexity and gradually attempting the more difficult ones.

19. Environmental assessment should be performed during the planning stage.

Quality criteria

20. For effective management of industrial effluent discharge into receiving water, water quality criteria must be established, adapted to local conditions and periodically reviewed on the basis of feedback from monitoring and experience.

Treatment and disposal

21. Combined treatment of industrial wastewater, pre-treated to the extent necessary, with municipal wastewater is desirable when the two effluents are compatible in volume and composition.

22. All relevant aspects should be considered when issuing standards for the discharge of industrial wastewater to public sewers, including:

- protection of the municipal sewerage system;
- protection of the biological treatment process in the municipal treatment plant;
- acceptability of final water quality with respect to re-use for agricultural irrigation or any other purpose;
- protection of groundwater, surface water and marine waters, including the open sea; and
- hygiene of workers.

23. Establishment of new industries or expansion of existing ones should not be allowed unless proper wastewater treatment and disposal can be ensured.

24. Environmental impact assessment studies should be carried out as a basis for authorizing discharge of industrial waste.

25. Disposal of sludge from industrial wastewater installations should be considered in parallel with the wastewater treatment strategies.

Costing and charging

26. It is considered advisable that the responsible public authority charges industries that discharge to a municipal system on the basis of defined parameters (e.g. volume, rate of discharge) and specific physical and chemical parameters defining the nature and composition of the waste.

Recycling and re-use of industrial waste

27. Water re-use is of high priority among wastewater disposal alternatives, including possible recovery of waste material through treatment.

28. Wastewater with potential for re-use should be considered as a new water resource, and it should fall under the same jurisdiction as other water resources.

29. Treatment, disposal and recycling methods for industrial solid waste and sludge need to be developed.

30. Waste recycling should be considered first in-plant and then for other purposes (e.g. agriculture, other industrial usage, street cleaning and public gardens).

31. Waste quality requirements should be defined according to the final use. When wastewater is re-used for agricultural purposes, the appropriate quality distinctions should be observed according to the type of crop and mode of application. When re-used for industrial purposes, the distinction should be made between water used for cooling, steam production, washing, rinsing and processing operations.

32. The possibility of energy recovery from sludge (e.g. anaerobic digestion and incineration) should be examined and adopted whenever possible.

Education and training of personnel

33. Effective use of personnel assumes proper graduate and continuing training in the multi- and interrelated disciplines involved in environmental health projects.

34. Environmental engineering academic curricula should include industrial wastewater treatment and management. The educational programmes of other related disciplines should emphasize environmental topics and their interdisciplinary nature.

35. Industrial environmental health inspectors should participate in techno-economic studies dealing with alternative wastewater control possibilities and the derivation of national and local standards. If necessary, they should be sent abroad for in-job training with competent pollution control authorities.

36. Each industrial environmental health inspector should preferably concentrate on a limited number of industrial processes so that he or she can acquire the level of detailed knowledge required.

37. The education of decision-makers, administrators and industrialists should be undertaken to increase their awareness of current issues and to ensure a correct evaluation of the technical and economic problems involved.

38. The public should be kept informed on relevant industrial pollution issues.

Industrial design and process

39. Industrial processes should be designed to minimize the amount of waste materials.

40. Treatment, disposal and re-use systems should be considered as a part of the industrial process design.

41. Industrial hygiene measures, including awareness by the users, should be applied.

42. Because of the chemical complexity of industrial wastewater, purpose-specific tests, such as bio-assays and corrosivity, should be performed on the actual effluent itself.

Recommended action by WHO

43. WHO should coordinate technical strategies and management philosophies at national and regional levels, including choice of methodologies, recommendations on training strategies and subjects to be studied, training quality and efficiency, and preparation of appropriate manuals.

44. WHO should consider the possibility of setting up a scientific working group to discuss aspects of industrial waste re-use in Mediterranean countries and make appropriate recommendations.

45. WHO should consider the possibility of organizing working groups and/or related activities on pollution profiles for the fol-

lowing major industrial activities; basic framework and documentation for training courses for operators, industrial operators and technicians; analytical quality control procedures; and intercalibration programmes for performance evaluation.

46. Studies on individual cases and experiences within the region should be disseminated and exchanged in order to enhance solutions of industrial waste problems at both international and national (local) levels. WHO could act as a coordinating centre in this respect.

Annex 1

PARTICIPANTS

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SECTION 2: WORKING PAPERS

INTERNATIONAL LEGISLATION FOR THE CONTROL OF INDUSTRIAL WASTE DISCHARGE RELEVANT TO THE MEDITERRANEAN AREA

by

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Introduction

The first comprehensive review of the state of pollution of the Mediterranean Sea was produced by the General Fisheries Council for the Mediterranean (GFCM) of the Food and Agriculture Organization of the United Nations (FAO) in 1972 [1]. The review was based on questionnaires completed by the various countries of the region. Although the responses provided an approximate indication of the situation, they could not be considered as completely accurate or exhaustive. Nevertheless, the conclusion was reached that the state of pollution of inshore waters had reached a critical level, mainly due to the high quantities of untreated or insufficiently treated domestic sewage discharged into the sea through rivers, outlets and pipelines. Also contributing were the organic load of industrial effluents and the almost total absence of control over their toxic components and solid substances. It was similarly concluded that the state of pollution in at least parts of the open water of the Mediterranean Sea must be considered severe, the result of highly developed industries situated along the coastline that discharged their wastes through pipelines and/or dumping at sea. Another important contribution to the overall pollution load was considered to be the appreciable quantities of pesticide blown out to sea from inland agricultural areas.

Although no accurate figures exist, approximately 80-85% of the overall Mediterranean pollution load is generally considered attributable to land-based sources. Though domestic sewage is an important source of pollution, and is perhaps more readily obvious owing to the proximity of outfalls to coastal recreational areas, industrial waster forms the major part of pollution. Evaluation of the situation is complicated because, apart from pollutants contained in industrial wastewater proper, municipal sewage often contains water from various industries (some of them reasonably large), waste from small establishments, and chemical products used in households.

INTERNATIONAL LEGISLATION

At the time of the 1972 FAO report, no international legal instrument on the control of land-based pollution in the Mediterranean Sea existed. Various relevant national legislative and administrative provisions covering certain aspects of marine pollution control existed in many countries of the region, but these were mainly designed to attain other objectives. The composite mosaic of legislation evident at the time was fragmentary and uncoordinated at best.

Following the adoption of the UNEP-sponsored Mediterranean Action Plan by the coastal states of the region in Barcelona in 1975, the scientific component of the Plan, called the Joint Coordinated Mediterranean Pollution Monitoring and Research Programme (MED POL Phase I) was initiated during the same year. Organized jointly by the United Nations Environment Programme (UNEP) and the relevant specialized United Nations agencies, the programme was to provide as much information as possible on the state of pollution of the Mediterranean Sea, in order to facilitate both the updating of national legislation and the development of *ad hoc* regional legal instruments. Following the adoption and signature in 1976 in Barcelona of the Convention for the Protection of the Mediterranean Sea against Pollution, a special project on pollutants from land-based sources in the Mediterranean Sea (MED X) was developed within the framework of MED POL Phase I and implemented during 1976 and 1977. The project was coordinated by WHO and jointly executed together with the Economic Commission of Europe (ECE), FAO, International Atomic Energy Agency (IAEA), United Nations International Development Organization (UNIDO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). The specific tasks to be undertaken were:

- preparation of an inventory of all major sources of pollutants in the coastal area;

- assessment of the nature and quantity of selected pollutants entering the Mediterranean Sea from such sources;

- assessment of the nature and quantity of selected pollutants entering the Mediterranean Sea through major rivers; and

- review of current waste disposal and management practices.

The 1976 Convention [2] provided the legal framework for Contracting Parties to adopt protocols or to take measures of equivalent value covering the various aspects of marine pollution control in the region. It was decided at an early stage to develop a specific protocol concerning land-based sources of pollution, and preparatory work on this commenced soon after signature of the Convention itself. The time schedule for the project on pollutants from land-based sources in the Mediterranean Sea (MED X) was therefore closely linked to the preparation and negotiation of the draft protocol, which entered its critical phase in late 1977. This time limit therefore allowed only for an overall assessment of relevant pollution sources. The project report [3] included detailed estimations of the annual pollution loads of the Mediterranean Sea from major land-based sources, as well as the locations of major industrial areas along its coastline. The conclusions reached included the following three.

First, most of the various sectorial studies revealed the limited availability of relevant data, particularly in the case of hazardous pollutants. Second, industrial waste discharges were responsible for considerable amounts of organic matter and suspended solids. Various industrial processes also resulted in releases of phenol and metals. Third, major rivers and drains transported an integrated load of domestic, industrial and agricultural pollutants from the entire drainage basin into the sea. Their contribution in suspended solids, nutrients, metals and organic matter was therefore very high.

In its review of waste management and disposal practices, the project report indicated that emphasis had been placed largely on the legislative basis of waste management, though the situation had also been considered with regard to particularly hazardous pollutants.

The report also included a country-by-country review. An analysis of the situation still showed a wide and diverse mosaic of practices, both legal and administrative, in the various countries.

This mosaic had already been evident in a comprehensive survey of national legislation on the control of marine pollution from land-based sources, produced jointly by WHO and UNEP in 1976 [4]. A revised, updated version of this publication is in preparation. Since 1976, progress has been achieved, either by improving the majority of existing legislation or through the enactment of new comprehensive legal instruments which approach the problem of land-based pollution control in a more comprehensive and coordinated manner.

The Legal Framework for Industrial Waste Discharge Control

Article 8 of the 1976 Convention for the Protection of the Mediterranean Sea against Pollution binds the Contracting Parties to take all appropriate measures to prevent, abate and combat pollution of the Mediterranean Sea caused by discharges from rivers, coastal establishments or outfalls, or emanating from any other land-based sources within their territories. The terms of this article do not therefore strictly bind the Parties to take joint regional measures. The formulation and development of a specific protocol were decided on in view of the facts that land-based pollution constituted by far the greatest problem and that the best way to ensure maximum harmonization of national legislation was to achieve a common regional baseline.

The draft Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources was first discussed at an intergovernmental consultation in Athens in February 1977 [5], followed by a second consultation in Venice in October of the same year. In the intervening 8-month period, the MED x project was finalized and discussed at a special expert meeting in Geneva in September 1977 [6]. The Venice consultation in 1977 [7] brought several divergent views to light, some of them of a fundamental nature. The status of the draft Protocol was reviewed at an intergovernmental review meeting in Monaco on the Mediterranean Action Plan in January 1978 [8]. It resulted in action being temporarily shelved pending further study of the matter by national authorities and the seeking of a compromise solution based on the various national views eventually obtained.

Considerable progress towards this solution resulted from two meetings of legal [9] and technical [10] experts, held in parallel in Geneva in June 1979, to discuss the new text of the draft Protocol and the technical annexes, respectively. This progress, however, was achieved mainly by postponing discussion on a number of controversial issues, in many cases involving practical measures to be undertaken, from the pre-signature to the post-ratification phase. The final version of the Protocol [11] was adopted and signed in Athens in May 1980, and came into force in June 1983, following the deposit of the sixth instrument of ratification. Its present status is shown in Table 1.

Although the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources is the only international legal instrument controlling industrial waste discharge at the regional level, a number of bilateral and multilateral agreements contain relevant provisions.

1. An agreement between Italy and Yugoslavia on collaboration in safeguarding the water of the Adriatic Sea and the coastal zones from pollution was signed in 1972 and came into force in 1976. This is an agreement on cooperation rather than actual control, though one of the functions of the joint commission created is to advise the two governments on programmes and measures concerning pollution assessment and control.

2. An agreement between France, Italy and Monaco on the protection of Mediterranean coastal waters, covering the northwestern basin, was signed in 1976 and came into force in 1981. The agreement establishes a tripartite commission to undertake

administrative and scientific functions, most of them related to pollution through waste discharge.

3. An Agreement between Greece and Italy for the protection of the Ionian Sea was signed in 1979. As in the case of the Italian-Yugoslav agreement on the Adriatic Sea, this is a cooperation agreement, establishing a joint commission to advise on joint programmes of research and control measures.

In addition, several directives by the European Economic Community (EEC) afford a partial coverage of the Mediterranean Sea through their application by the three EEC Member States in the region (France, Greece and Italy).

Directive No.76/464/EEC covers pollution caused by certain dangerous substances discharged into the aquatic environment of the EEC [12]. It is very similar to the operative articles of the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources, and in certain instances lays down specific measures to be undertaken.

Two Council directives deal with waste from the titanium chloride industry. Council Directive No. 78/176/EEC aims to reduce progressively, with a view to eliminating, pollution caused by waste from this industry [13]. Council Directive No. 82/883/EEC lays down the procedures for the surveillance and monitoring of the effects on the environment of the discharge and other forms of disposal of waste from the titanium dioxide industry [14].

Council Directive No.82/176/EEC establishes limit values and quality objectives for mercury discharges by the chloralkali electrolysis industry [15]. This directive lays down limit values for emission standards for mercury in discharges by defined industrial plants, quality objectives for mercury in the aquatic environment, time limits for compliance with the conditions of authorizations granted by competent national authorities in the case of existing discharges, reference methods for determination of the mercury in discharges, and monitoring procedures.

In addition, the Barcelona Convention of 1976 on the Protection of the Mediterranean Sea against Pollution, and its different protocols, were concluded according to Council Decisions No. 77/585/EEC and No. 81/420/EEC.

Various proposals for council directives have also been made to limit values for discharge of aldrin, endrin, and dieldrin into the aquatic environment [16]; quality objectives required for the aquatic environment into which aldrin, dieldrin and endrin are discharged [17]; and limit values for discharges of cadmium into the aquatic environment [18]. There is, as well, a communication to the Council on dangerous substances which might be included in List I of Council Directive No.76/464/EEC. A recent (1984) Commission communication to the Council on the protection of the environment in

Table 1. Status of protocol

Country	Signature	Ratification	Accession	Approval
Albania	-	-	-	-
Algeria	-	-	2 May 1983	-
Cyprus	17 May 1980	-	-	-
EEC	17 May 1980	-	-	7 Oct 1983
Egypt	-	-	18 May 1983	-
France	17 May 1980	-	-	13 July 1982
Greece	17 May 1980	-	-	-
Israel	17 May 1980	-	-	-
Italy	17 May 1980	4 July 1985	-	-
Lebanon	17 May 1980	-	-	-
Libya	17 May 1980	-	-	-
Malta	17 May 1980	-	-	-
Monaco	17 May 1980	12 Jan 1983	-	-
Morocco	17 May 1980	-	-	-
Spain	17 May 1980	6 June 1984	-	-
Syria	-	-	-	-
Tunisia	17 May 1980	29 Oct 1981	-	-
Turkey	-	-	21 Feb 1983	-
Yugoslavia	-	-	-	-

the Mediterranean basin [19] proposes a strategy and plan of action with specific targets, including waste management practices.

The legal regime of the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources has been comprehensively described by Kuwabara [20]. The book deals with the general legal bases of cooperation, regional legal norms governing the control of land-based pollution in the Mediterranean Sea, enforcement requirements and national legislation, and liability and compensation for transboundary, land-based pollution damage. The main part of the book is an exposé of the legal implications of the Protocol, and a comparison with similar texts existing at global level or in other regions.

Implications of the Protocol

Article 1 of the Protocol binds the Contracting Parties to take all appropriate measures to prevent, abate, combat and control pollution of the Mediterranean Sea area caused by discharges from rivers, coastal establishments or outfalls, or emanating from any other land-based sources within their territories. Article 4 further specifies that the Protocol shall apply to pollution discharges reaching the Protocol area from land-based sources within the territories of the Parties, in particular (a) directly, from outfalls discharging into the sea or through coastal disposal, and (b) indirectly, through rivers, canals or other watercourses, including underground watercourses, or through run-off. Therefore, any discharge of industrial (or other) waste containing pollutants that eventually reaches the sea is subject to the terms of the Protocol wherever the point of discharge and whatever route it takes.

The annexes go further. Annex II, which lists less-toxic substances, includes (item 13) all those which though nontoxic, may become harmful to the marine environment or may interfere with any legitimate use of the sea owing to the quantities in which they are discharged. This, together with Annex III which lists the factors to be taken into account by national authorities in issuing authorizations, means that all discharges, irrespective of their composition or content, are subject to qualitative and/or quantitative control.

Articles 5 and 6 of the Protocol are linked with Annexes I and II (the so-called "black" and "grey" lists), respectively. Article 5 binds the Parties to "eliminate" pollution of the Protocol area by Annex I substances, and to this end, to elaborate and implement programmes and measures which include, in particular, common emission standards and standards for use. In line with the realization that implementation of standards for all substances would constitute a gradual process, the article also provides for the establishment of appropriate timetables. Article 6 binds the Parties to "strictly limit" pollution by Annex II substances, and to elaborate and implement suitable programmes and measures to this end. The operative part of this article is that discharges shall be strictly subject to the issue, by the competent national authorities, of an authorization taking due account of the factors listed in Annex III to the Protocol.

As Annex I specifies that its provisions do not apply to discharges containing substances below the limits to be defined by the Parties, discharges of such substances above such limits would be prohibited. All other discharges, irrespective of substance, would be subject to a formal authorization by national authorities.

The progressive implementation of Articles 5 and 6 will therefore require the following steps to be taken.

1. Lists must be made of what specific compounds fall within the purview of each of the two annexes. In several instances, the lists simply describe groups of substances and, moreover, exclude (unspecified) compounds within the groups which are

biologically harmless. A comprehensive list of compounds to which the annexes apply has therefore to be drawn up.

2. To enable progressive implementation, a list of priorities, based on both regional needs and the capacity of individual states to apply the necessary measures, needs to be established.

3. Common emission standards need to be formulated for Annex I substances. Such common emission standards cannot be general but would have to vary according to the specific industries they apply to, especially if they are eventually formulated in terms of pollutant concentration within the overall discharge volume. Particular attention must be taken in the case of municipal effluents that include industrial wastes containing Annex I substances. Although their overall concentration in the effluent might be relatively small, their quantities, in absolute terms, could be significant. This factor is covered by Article 7 of the Protocol. One particular item binds the Parties to formulate and adopt progressively common guidelines, standards or criteria dealing with specific requirements concerning the quantities of the substances listed in Annexes I and II discharged, their concentration in effluents, and methods of discharging them.

4. Common general guidelines need to be progressively developed that enable national authorities to harmonize their methods of evaluating applications for discharge authorizations.

5. In view of the relationship of environmental quality criteria to emission standards, such criteria, based on agreed-upon priorities, need to be progressively developed.

The eventual development of both environmental quality criteria and emission standards would have to be worked out within the framework of an overall regional strategy. In view of the heterogeneity between Mediterranean states and the obvious impossibility of achieving realistic common standards at the outset, such a strategy could be phased. The initial phase, based on what could be termed the least common denominator, could consist of relatively mild (i.e. the minimum feasible) standards on a common basis, with the proviso that any individual state whose circumstances required stricter measures would be (morally, if not legally) bound to enforce the latter, if not already doing so. This interim phase would be followed by a long-term one designed to improve the capacity of the lesser-developed Parties to develop and implement stricter standards, which would eventually become common regional ones. An alternative mode of implementation could be a two-tier system with a double set of standards: mandatory and desirable. This is the case with some of the EEC standards for coastal water quality.

Implementation of Article 6 is essentially based on the issue of official authorizations by competent national authorities. All discharges containing Annex I substances in concentrations and/or quantities below the limits to be eventually defined, and all other discharges, whether they contain Annex II substances or not, would come under the terms of this article. The only stipulation is that authorizations should take into account the factors listed in Annex III. These factors include all relevant aspects to be considered: characteristics and composition of the waste, particularly in regard to harmfulness; characteristics of the discharge site and the receiving marine environment; availability of waste technologies; and the potential impairment of marine ecosystems and seawater uses. The national authorities have the discretion to issue or not to issue an authorization, based on evaluation of the data. However, no general guidelines are available for such evaluation, and as stated earlier, these would be essential to ensure a reasonably homogeneous decision-making process throughout the region.

Article 7 of the Protocol is specifically devoted to the progressive formulation and adoption of common guidelines, standards and criteria. These deal, in particular, with the following:

- length, depth and position of pipelines for coastal outfalls, particularly taking into account the methods used for pre-treatment of effluents;

- special requirements for effluents necessitating separate treatment;

- quality of seawater used for specific purposes that is necessary for the protection of human health, living resources and ecosystems; and

- control and progressive replacement of products, installations and industrial and other processes causing significant pollution of the marine environment.

All the above are directly related to the discharge of industrial wastewater and are closely linked to the formulation of emission standards and other measures.

The third item is of particular significance. Development of emission standards for a specific pollutant would have two broad goals. The first is to reduce to the greatest extent possible the total load of the pollutant reaching the Mediterranean Sea. The second, and perhaps more immediately important is to ensure that the amount of pollutant discharged does not affect a specified seawater use in areas relatively near to the discharge point. This goal implies that emission standards would have to be based on, or at the very least take due account of, environmental quality criteria established for seawater use.

In the case of coastal recreational and shellfish-growing areas, seawater quality is of paramount importance, and discharges (including emission standards) have to be regulated to satisfy quality criteria. Other areas of the sea, such as fish-breeding grounds and marine parks and nature reserves, would have the same requirements. As recreational areas (bathing beaches) would be primarily affected by the microbiological content of municipal sewage, quality criteria for such areas are generally confined to these parameters. On the other hand, both the condition of the living resources of the sea and the risks to human health through consumption of contaminated species are mainly linked to chemical pollutants from industrial wastewater discharges, which may cause deleterious effects in areas relatively far from the point of discharge.

In summary, practical compliance with the terms of the Protocol would have several implications regarding industrial wastewater discharges. The concentrations and/or quantities of specific pollutants (i.e. substances listed in Annex I) would have to be below common (as yet unspecified) limits. Furthermore, in a number of instances, the limits themselves would be linked with compliance with environmental quality criteria to be established for specific categories of sea-use areas. Control of discharges would therefore ultimately depend on such criteria. Firstly, discharges containing Annex I substances below the limits, and/or any other substances, would need to comply with terms to be developed for the granting of authorizations by the national authorities.

The regulatory strategy envisaged by the Protocol is therefore threefold: effluent standard regulations, receiving water quality standards, and licenses and permits. This strategy does not in itself preclude any Contracting Party from taking other measures, such as effluent charges and/or tax incentives, 'ccording to its own particular circumstances.

In the formulation of specific measures, due account would have to be taken of any international activities of a similar nature in the region. This refers particularly to the EEC directives with which three Mediterranean countries (France, Greece and Italy) have to comply. These three countries cover a substantial part of the industrialized northern seaboard of the Mediterranean Sea. It would not be easy for any country to comply simultaneously with two separate sets of norms, particularly if these rely on different programmes and measures for such compliance.

Disposal of Solid Waste

The Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources is concerned only with pollutants reaching the marine environment by discharge and via the atmosphere. The term "discharge" is not defined, but by implication it would appear to exclude solid waste. Any waste (solid or liquid) disposed of at sea by a vessel (ship or aircraft) comes under the terms of the 1976 Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircrafts [21].

A study of the 1976 Protocol, together with the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources, leads to the conclusion that no provision appears to have been made for control of pollution by solid waste disposed of directly from the coast into the sea, unless such waste is contained within a liquid discharge. Regulation of the disposal of solid (or liquid) waste on land falls outside the coverage of the land-based sources protocol unless the material can reach the sea in a dissolved or suspended form.

Conclusions

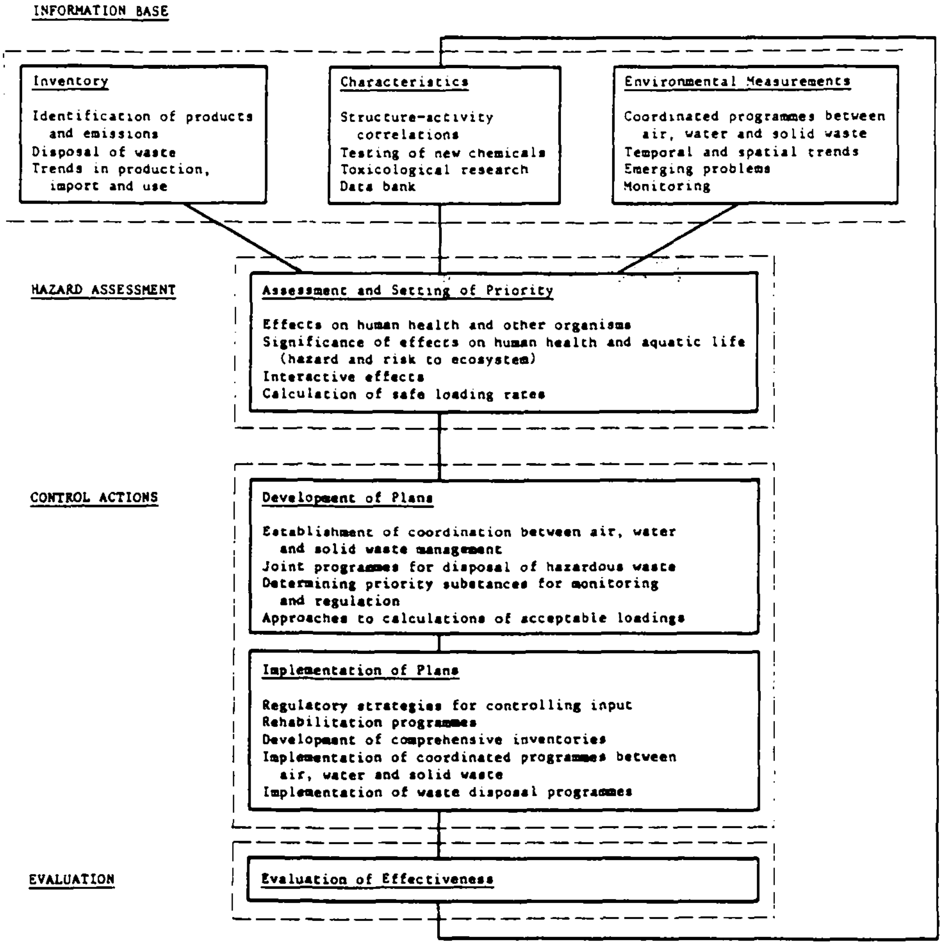
International legislation currently in force in the Mediterranean region, in particular the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources, provides an adequate legal framework for the establishment of programmes and measures at both national and overall regional levels for the control of pollution by industrial wastewater discharges. Implementation of the necessary measures is essentially a long-term problem, especially where technical measures are subject to the influence of heterogeneous socioeconomic considerations.

Normally, a code of practice for control of industrial wastewater discharges would be expected to form part of an overall framework for control of pollution from land-based sources to the marine environment in general, and for the control of potentially harmful substances in particular. An example of a toxic substances control framework, developed in Canada and quoted by the ad hoc Working Group of Experts on the Protection of the Marine Environment against Pollution from Land-based Sources [22], demonstrates the steps required for the development of such a framework (Fig. 1).

One of the main features of this framework is its necessary dependence on coordinated programmes between air, water and solid waste. Effective implementation in the Mediterranean area would be rendered difficult as the current regional legal framework for pollution control (a) does not include pollution of the sea through the atmosphere as a problem calling for immediate action, but postpones the issue to an indefinite future date, and (b) does not cover solid waste management.

A general set of principles, methodologies and guidelines for the protection of the marine environment against pollution from land-based sources has recently been developed jointly by the Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) [23] and the UNEP *Ad Hoc* Working Group of Experts on the Protection of the Marine Environment against Pollution from Land-based Sources [24]. The report of this working group includes the following: strategies for protecting, preserving and enhancing the quality of the marine environment; classification of substances, monitoring and data management; and methodologies and guidelines to assess the impact of pollutants on the marine environment. These principles could be applied, both generally and in a number of aspects specifically, to the planning and progressive implementation of the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources. In particular, within this overall framework, adequate control could eventually be achieved over industrial waste discharge within the region.

Fig.1 Development of a toxic substances control framework [22]



(Lines are drawn without arrows to indicate feedback or interaction in both directions between various components)

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NATIONAL STRATEGIES FOR INDUSTRIAL WASTEWATER POLLUTION CONTROL

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Introduction

The industrial revolution, with its associated massive use of manpower for the production and distribution of goods, and the improvement and mechanization of agricultural methods have contributed considerably to the vast growth of cities. This phenomenon, well developed during the end of the eighteenth century in England and during the nineteenth century in most countries of Western and Central Europe [1], has since affected most parts of the world with increasing intensity.

Indeed, in 1950 only 70 cities in the world had a million or more inhabitants. Twenty-five years later, there were 158 such cities, 84 in developed and 74 in developing countries. By the year 2000, 276 such cities are expected in the developing world alone.

The rapid growth of cities and the concentration of industries within or around them have created severe strains on the environment in terms of air, water and land pollution. Those countries that participated early in the industrial revolution were forced to tackle their pollution problems a long time ago, and by now have developed the organization and skill to cope effectively with them. However, most developing countries have made little or no progress in this direction, and now these countries often have to face alarming problems with limited resources.

In their initial efforts to abate pollution, most countries have had disappointingly little success, with considerable expenditures yielding minimal impact and with long time delays. As the environmental problems accumulate, a time is inevitably reached when further industrial development is jeopardized because the associated pollution problems have made it unattractive to the population. For example, over 50% of the industrial activity of Greece has been concentrated in the Greater Athens Area. In the past decade, on environmental grounds, industries found expansion increasingly difficult. Some were relocated and others, including a large and relatively new power plant, were forced to shut down - all this, presumably, at a considerable cost. Thus, successful pollution control is not only imperative for human health, for preservation of valuable resources (e.g. fresh-water supplies), and for perpetuation of the marine ecosystems, but also as a means of allowing further social and economic progress through continuing industrialization.

The success of pollution control efforts undoubtedly depends on the environmental management scheme adopted, on the capability of the environmental planners to derive effective and enforceable action programmes within it, and on the ability of the parties involved to have these programmes implemented. In most countries, even after years of combatting pollution, clearly defined management schemes do not exist, action programmes are not given priority or enforced, and the whole exercise appears to lack cohesion and targets. The objective of this paper is to address these serious problems and propose a flexible approach which can be of particular benefit to nations in an early stage of their pollution abatement efforts.

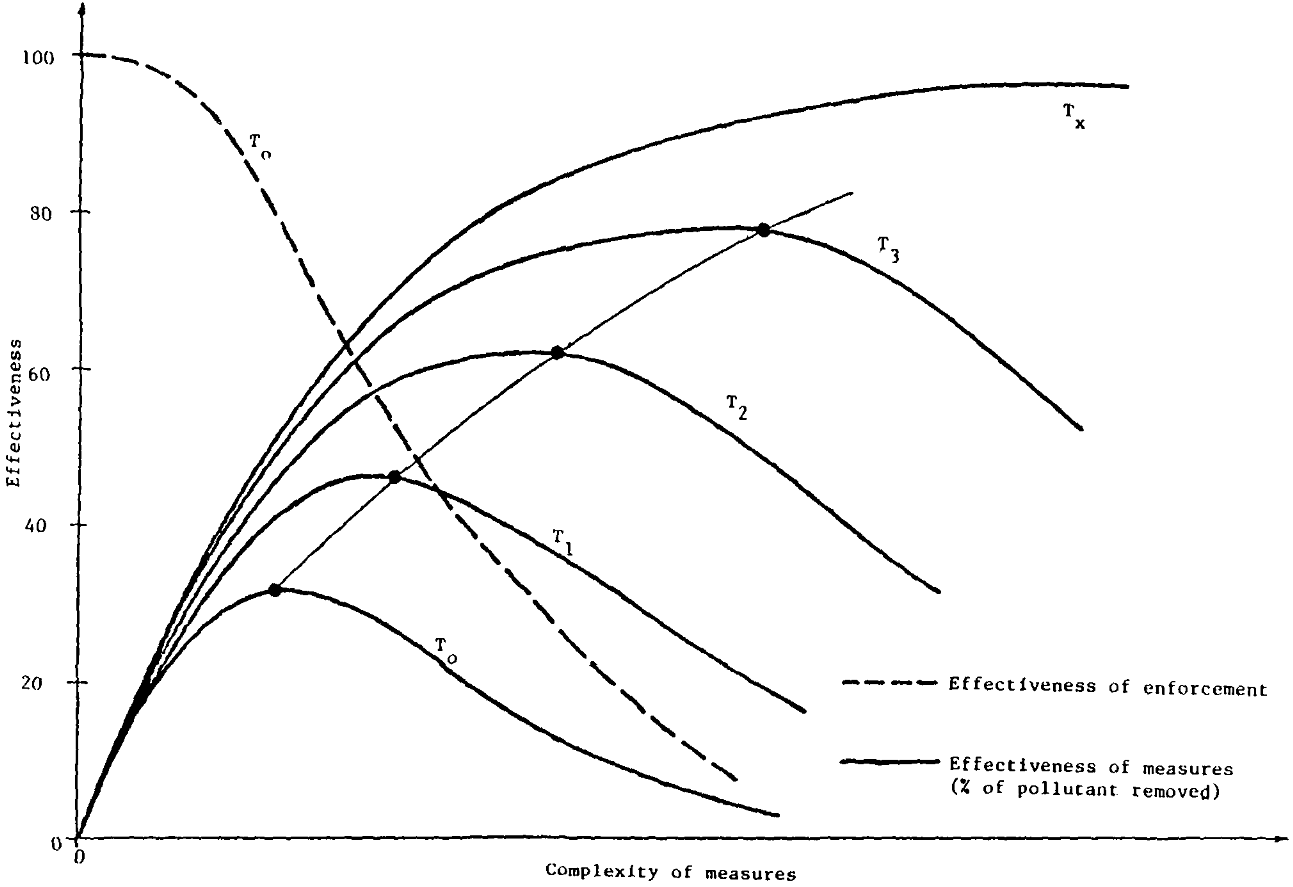
Enforcement Constraints

Figure 1 shows how the ideal effectiveness (of measures) for a given complexity of measures, solid curve T_x, can be attenuated considerably under present conditions, solid curve T_o, due to ineffectiveness of the enforcement, dotted line T_o. Indeed, it could be expected that the stricter and more sophisticated the measures, the more effective the pollution control programme would be. In reality, however, for any given area and time there is a limited ability of the pollution control authorities to enforce the measures, of the industry to implement them, and of the national economy to bear the costs. The combined effect of the above factors shapes the dotted curve T_o. This in turn reduces the real effectiveness of measures which could have been expected under ideal enforcement conditions.

As illustrated in Figure 1, based on the organizational, technical, financial and other constraints present in a given area at a given time, there is an optimum point in the complexity of the pollution control action programme for maximum results. There is also a definite ceiling on what can be achieved at this stage. With time, it may be possible to improve the organization, develop better technical skills, etc. so that more complex measures can be better enforced. This progressively pushes the real measure effectiveness curve at time T_1, T_2, T_3..., etc. closer and closer to the ideal curve T_x.

Clearly, the measure effectiveness curve for most developing nations resembles the situation depicted by curve T_o in Figure 1, while that in developed countries approaches curve T_x. Because developing nations lack the capability of formulating their own effective action programmes, they are often tempted to copy effluent standards and measures from those applicable in the industrialized world. Such measures are generally too complex for their situation,

Fig. 1 Evolution of optimum measure complexity



causing, as could be expected from Figure 1, disappointing results. Other factors, such as the much smaller size of industries generally encountered in developing nations, along with differences in processes and operation, add considerably to the difficulties of straightforward transplantation of action programmes and standards from developed countries [2]. It is thus crucial for the success of any pollution abatement programme to develop a local national strategy which addresses on a priority basis the existing problems, considers carefully the existing constraints, and lays down the plans for the progressive relaxation of these constraints so as to enable the eventual implementation of measures with a sufficient degree of complexity.

High Priority Measures and related Legal Considerations

The limited complexity of measures which can be effectively promulgated at any given time, especially in the early pollution abatement stages, makes imperative the systematic screening of such measures, selecting the simplest and the most cost effective among all possible alternatives for the given situation.

Such priority setting is of key importance, for it can greatly enhance the impact of the action programme while simultaneously reducing the time and costs required to achieve noticeable results.

As a rule, strict setting of priorities leads to action programmes involving the largest pollution sources [2]. Indeed, this condition tends to offer the best cost effectiveness through large-scale wastewater treatment and also the minimum enforcement requirements in view of the limited number of sources involved. Moreoever, this condition offers high effectiveness since, in most cases, a small number of such key industries (e.g. 5% of the plants operating in a given area) are responsible for the bulk (e.g. 80%) of the total industrial pollution loads generated.

It is thus possible to develop a highly effective and enforceable pollution abatement programme, even when faced with tight organizational, technical and financial constraints. However, such programmes often involve the application of strict treatment requirements on a small number of selected industries, and the question is whether this practice should be acceptable and justified. This question could be of academic interest only in cases where charges are levied for the discharge of waste, in proportion to their volume and strength. Big polluters who have to treat their effluents would thus be compensated through lower charges of this nature.

When effluent discharge charges do not exist, the imposition of effluent treatment on selected industries should be documented so as to be impartial. At any rate, the transient nature of the optimum measure complexity, as illustrated by Figure 1, would make possible the progressive imposition of waste treatment in smaller and smaller sources. Thus, in principle the problem is temporary. However, it may be found uneconomical and impractical to enforce any treatment on numerous small sources, characteristic of developing economies, that may exist in given areas. There are indeed few practical alternatives to dealing with this source of waste and, as long as their combined impact is small, this situation could be tolerated.

Management of the Industrial Effluents Discharged into Sewerage Systems

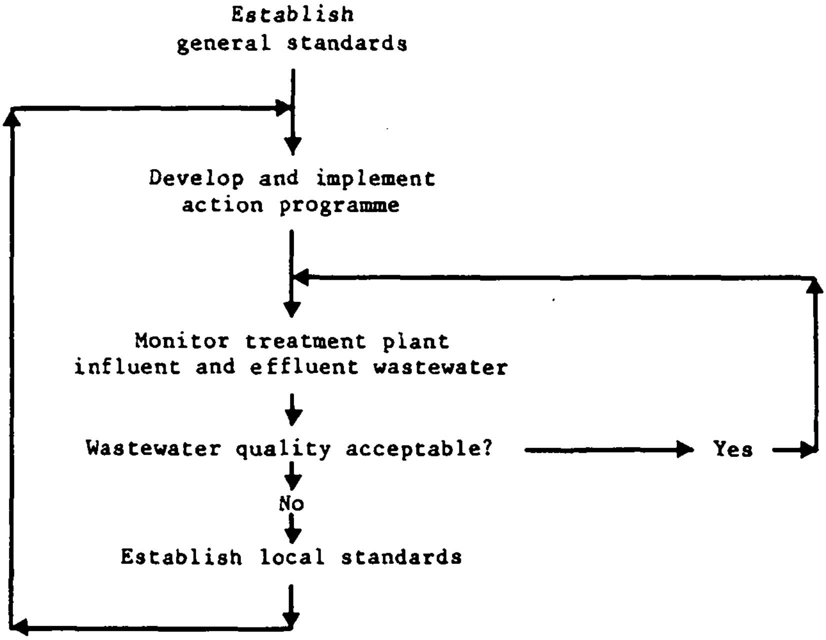
Combined treatment of industrial waste and domestic waste offers distinct advantages, such as lower cost due to the economics of large-scale treatment, increased reliability of treatment, better handling and disposal of sludge and greatly reduced monitoring and enforcement requirements. For these reasons, combined treatment is, and should be, promoted when industries are within a reasonable distance from the sewerage system and their effluents are compatible with the domestic ones.

However, industrial waste often disturbs the operation of the treatment plants because of the substances contained or the irregular discharge patterns. Moreover, some of the hazardous substances may pass through the treatment plants, polluting the receiving water, or may be accumulated in the sludge of the treatment plant, generating sludge treatment and disposal problems. Finally, industrial wastes, depending on their nature, may affect the integrity and safety of the sewerage system. To cope with the above problems, controls at the source are normally required and thus, an industrial waste management scheme, such as that illustrated in Figure 2, becomes necessary.

Among the first tools used to develop the management scheme is the adoption of national standards for the quality of industrial wastewater prior to discharge into a sewerage system. A basic purpose of these standards should be to protect the health of people involved in the maintenance and operation of the system, to prevent explosions and to maintain the hydraulic capacity of the sewer lines. Such standards would thus reflect an acceptable use of the sewerage system. A further purpose of the national standards should be to reduce toxic substances that may inhibit the function of the treatment works or cause pollution of the receiving water. Such standards should in principle reflect the minimum pretreatment requirements and should affect only a relatively small number of key sources, placing only a reasonable burden on the economy and on existing enforcement and monitoring capabilities.

The large bibliography [3,4] on industrial pretreatment requirements reflects a very extensive experience on the subject. While such experience can provide a valuable input into the formu-

Fig. 2 Management scheme for joint industrial wastewater treatment



lation of the national standards, it should be adapted to reflect the local conditions so as to be effective by addressing priority areas and enforceable by not being excessively complex.

On the basis of the adopted national standards, local sewerage authorities can proceed (Fig. 2) to derive, as well as to implement, their comprehensive action programme. Well-balanced national standards can greatly simplify the implementation and enhance the effectiveness of these steps.

As mentioned above, national standards are generally not very strict for economic and enforcement reasons. Such standards will have to be supplemented in certain cases by more stringent local standards: for example, when the concentrations of toxic substances are still high, the quantities of conventional pollutants, or the effluent volumes from large sources cause extensive loading on the sewers lines, pumps and/or treatment works, or spills or intermittent batch discharges from significant sources affect the sewerage system or the treatment works. Monitoring of the treatment plant influent and effluent wastewater, along with source inventory information about the nature and size of the industrial discharges into the sewerage system, provide the basic input required for the formulation of the most appropriate local standards.

Again, as in the case of national standards, action should be initially limited to key sources, in line with both the maximum cost effectiveness and minimum enforcement requirement principles.

The nature of the management scheme of Figure 2 safeguards against the possibility of too-relaxed standards, as in time they can become progressively lighter to include smaller sources as required. It also provides the necessary feedback from the impact of the changing industrial activities with time.

The most difficult problem is the derivation of local standards and action programmes to control effectively the level of toxic substances. For this purpose, wastewater monitoring data can provide information on the concentration of toxic substances, which can be compared against the limiting concentration levels listed in Table 1 [4] and selected on the basis of the type of biological process employed. Toxic substances present in inhibitory levels for the treatment works can thus be detected and should constitute the priority target for the pollution control action. Screening studies considering the largest sources for these substances, their discharge levels and available control alternatives will have to be carried out to derive the most appropriate local standards and action programmes for this purpose.

Management of Industrial Effluents Discharged into Receiving Water

There are many concepts on how a country should go about developing its pollution abatement strategies [5]. Some of these

Table 1. Concentration of compounds inhibiting biological treatment processes

Compound	Aerobic processes ppm	Anaerobic digestion ppm	Nitrification ppm
Copper	1	1	0.5
Zinc	5	5	0.5
Chromium hexavalent	2	5	2
Chromium trivalent	2	2000	
Total chromium	5	5	
Nickel	1	2	0.5
Lead	0.1		0.5
Boron	1		
Cadmium		0.02	
Silver	0.03		
Vanadium	10		
Sulfides (S^{--})		100	
Sulfates (SO_4^{--})		500	
Ammonia		1500	
Sodium		3500	
Potassium		2500	
Calcium		2500	
Magnesium		1000	
Acrylonitrile		5	
Benzene		50	
Carbon tetrachloride		10	
Chloroform	18	0.1	
Methylene dichloride		1	
Pentrachlorophenol		0.4	
1,1,1-Trichloroethane		1	
Trichlorofluoromethane		0.7	
Trichlorotrifluoroethane	5.0		
Cyanide		1	
Total oil (petroleum origin)	50	50	50

concepts are deceptively simple, such as those centering on the uniform (or zero) effluent discharge standards principle. Others, such as those based on the load-allocation principle, are far too sophisticated for the existing infrastructure in most countries.

If one accepts the notion that the eventual goal cannot be reached with the first trial, one can employ a management scheme

(Fig. 3). This scheme is equipped with feedback loops continuously providing the experience from the effectiveness of past action programmes, so as to plan better the required follow-up actions. According to the management scheme described in Figure 3, water quality criteria must be established to provide the basis for determining whether or not a water receiver is polluted in relation to its intended use.

In deriving such criteria, considerable information can be obtained from international bibliographies [6-8], but data must generally be adapted to local conditions.

A systematic classification of the types of receiving water according to their intended present and future use is also required in the early stages of the pollution abatement programme. Indeed, collection of available monitoring data and comparison with the water quality targets for each receiver quickly reveals, at an early stage, high priority areas on which action programmes must be focused. This is the first key step in the procedure for giving priority to the development of a truly rational strategy on a national level.

Organization of a systematic receiver and effluent water monitoring programme and the derivation of a rational action programme in accordance with the priorities derived above are the next steps in any management scheme. These steps control to a large extent the impact and success of the entire programme for the first few years, and hence are critically important. Guidelines for developing these steps have been given elsewhere [2].

As in the case of industrial effluents discharged into sewerage systems, national standards express a minimum level of treatment requirements. Generally, these standards would have to be very strict if the most sensitive wastewater receivers were to be adequately protected. As this is not the case, national standards would normally have to be supplemented by stricter local standards, as required. A combination of national and local standards offers a cost-effective approach without sacrificing the quality of the receiving water. National and local standards will have to be periodically supplemented and updated (Fig. 3).

Derivation of the most appropriate effluent standards and the associated action programmes is a highly complex exercise. In view of the costs involved, it would really pay to base their derivation on detailed techno-economic analysis of the control alternatives involved. However, if this degree of sophistication does not exist or the time available is too short, existing source inventory data can be supplemented by rapid pollution assessments [9, 10]. This information, through intuition and engineering judgement, can lead into the development of a rational and enforceable strategy, at least in the early pollution abatement stages [2].

Clearly, in deriving such strategies, the higher the uncertainties about the potential cost impact of the measures considered, the more cautious the steps to be taken should be. It is through sharply focused targets, strict setting of priority and steady, cautious, successive steps that one can hope to develop, within a reasonable time, a cost-effective pollution abatement programme with sufficient enforcement capabilities and adequate complexity of measures.

Relocation of Industries

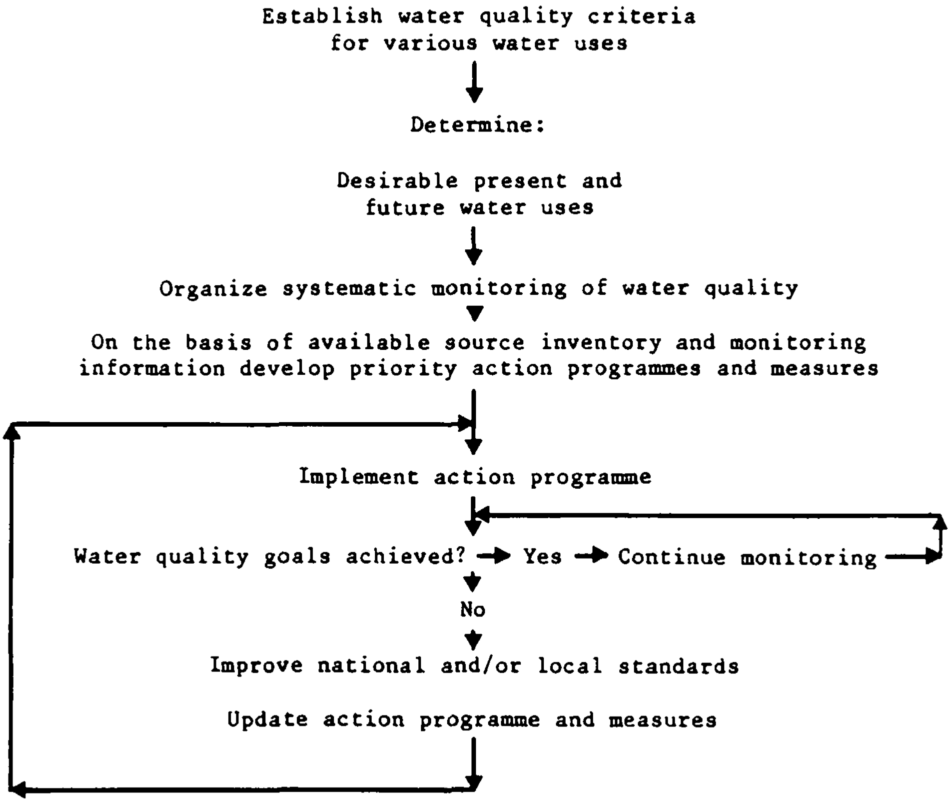
A satisfactory control programme is often impractical to implement when pollution problems originate from small industries because their small size make it uneconomical and their large number make it unenforceable. Thus, depending on the severity of the problem, the possibility of relocating some types of smaller plant should not be excluded.

Formulation of a rational policy for the relocation of certain types of plant is a complex issue. It may involve not only relocation and treatment cost assessments but also, for example, consideration of possible simultaneous modernization of technologies, marketing and transportation of products, and transfering of workers. In view of the above, and of the potential financial impacts, a proper relocation policy should be long-term and developed as part of a wider, long-range planning policy. The former can help to relieve some difficult existing problems while the latter is a prerequisite to effective national water pollution control.

Relatively simple yet often important is the control of toxic waste from small plants, such as electroplating shops, tanneries and acid battery manufacturing plants, which operate within a city. The smaller of these plants cannot economically pretreat their waste, yet they are often responsible for the bulk of toxic substances reaching the treatment works. For such industries with compatible effluents, the creation of industrial parks in strategic locations within the city can be considered. Using proper incentives, these areas could attract all new plants, and as the market and infrastructure develop, also most of the existing plants. Satisfactory pretreatment of the combined wastes becomes thus less expensive and more enforceable.

In rural areas, unplanned scattering of industry can potentially lead to widespread pollution problems which are very difficult to control. Creation of industrial zones with good infrastructure so as to accommodate in an orderly way all new industries, as well as to attract progressively most of the existing ones, could certainly yield much better possibilities for effective controls through combined waste pretreatment and treatment installations.

Fig. 3 Management scheme for direct wastewater discharges into receiving water



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RECYCLING AND RE-USE OF INDUSTRIAL WASTEWATER IN THE MEDITERRANEAN AREA

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Introduction

In comparison with the oceans, the Mediterranean Sea is a semi-enclosed body. With an annual water mass brought in by rivers and rain that is smaller than the evaporation rate, it is also a concentration basin. The exchange of water between the Atlantic Ocean and the Mediterranean Sea is carried out through the Straits of Gibraltar, and the exchange of the total water mass takes about 80 years.

The total population of the 18 countries along the Mediterranean shore is 100 million, of which 44 million inhabit the coastal zone. About 100 million tourists visit the Mediterranean coast every year, making it one of the leading tourist areas in the world.

The Mediterranean Sea receives wastewater from settlements, tourist resorts, industry and agricultural run-off. The rivers which flow into the Mediterranean Sea carry additional loads of organic and inorganic waste matter. An estimation of the annual pollution load of industrial wastewater, and total waste matter including the loads carried by the rivers in the Mediterranean zone [1] is shown in Table 1. According to these data, the load of industrial wastewater in the Mediterranean Sea is significant: out of the total mass of the annual waste matter carried in, 30 % comes from the organic and inorganic matter in industrial wastewater.

The Adriatic Sea is an especially enclosed part of the Mediterranean Sea. The annual load of industrial wastewater in the Adriatic Sea coming both from Italy and Yugoslavia is shown in Table 2 [2]. These data should be taken cautiously since Provini & Pacchetti [3] report that the average input of total phosphorus from the rivers Po and Adige is 12 826 t/a while from the total load from the Adriatic Sea of 30 000 t/a (Table 2) the contribution from the Italian rivers is estimated at 6750 t/a. Marchetti [4] estimates the average load of phosphorus in the Po River at 11 000 t/a or depending on the flow, at between 7000 and 19 000 t/a. For other streamflows in the Emilia-Romagna region, he gives the value of 3000 t/a of phosphorus which is carried into the Adriatic Sea. The data in Table 2 also appear to underestimate the quantity of lead from

Table 1. Annual pollution of the Mediterranean Sea from industrial sources [1]

Pollutant	Industrial wastewater of coastal zone (t/a)	Total load (t/a)	Ratio of industrial/total (%)
Volume total discharge x 10^9	6	430	1.40
Organic matter			
BOD[1] x 10^3	900	3300	27.27
COD[2] x 10^3	2400	8600	27.91
Nutrients			
Phosphorus x 10^3	5	360	1.39
Nitrogen x 10^3	25	1000	2.50
Specific organics			
Phenols x 10^3	11	12	91.67
Mineral oils x 10^3	120	(insufficient data)	
Metals			
Mercury	7	130	5.38
Lead	1400	4800	29.17
Chromium	950	2800	33.93
Zinc	5000	25 000	20.00
Suspended matter x 10^6	2.8	350	0.80

[1] BOD = Biochemical oxygen demand.
[2] COD = Chemical oxygen demand.

the Rivers Po and Adige which is carried by rivers (15 t/a from the Italian territory), as Provini & Pacchetti [3] give the average load of lead in the Adriatic Sea as being 881 t/a.

The more heavily polluting industries in the Mediterranean region are leather tanning and finishing facilities, iron works and basic steel industries, petroleum refineries and oil terminals, and chemical production (organic and inorganic) plants. In addition, textile manufacturing, food processing and canning, and pulp and paper factories contribute significant amounts of pollution.

Petroleum refineries and oil terminals add to the Mediterranean load of mineral oils, already high as a result of heavy tanker traffic. With an estimated 23% of global oil transport is carried out through the Mediterranean, this sea is the most oil polluted in the world [5].

Table 2. Annual pollution load in tons (t/a) of the Adriatic Sea from Italy and Yugoslavia from industrial wastewater [2]

Pollutant	Industrial wastewater of coastal zone (t/a)	Total load (t/a)	Ratio of industrial/ total (%)
Volume total discharge x 10^9	2	111	1.80
Organic matter			
BOD x 10^3	240	1354	17.73
COD x 10^3	520	2825	18.41
Nutrients			
Phosphorus x 10^3	4	30	13.33
Nitrogen x 10^3	34	343	9.91
Specific organics			
Detergents x 10^3	2.4	10.54	22.77
Mineral oils x 10^3	8	84.65	9.45
Metals			
Mercury	2	6	33.33
Lead	340	413	82.32
Cadmium	4	11	36.36
Zinc	300	852	35.21
Suspended matter x 10^6	0.23	2.08	11.06

Although the impact of industrial wastewater on the pollution of the Mediterranean Sea as a whole is still unquantified, the discharge of untreated industrial wastewater causes local disturbances in coastal areas. Such discharge often contains heavy metals which may prove dangerous because of their toxicity and bioaccumulation. In this regard, mercury, cadmium and their compounds are especially dangerous. Mercury is most frequently found in wastewater from plants producing chloralkali, electrical equipment, paints and fungicides. Cadmium can be found in wastewater from plants manufacturing paints, inks and plastics. Mineral oils and hydrocarbons may be toxic to marine organisms, depending on the origin and composition of the oil and hydrocarbons, concentration at the time of biotic intake and type of organisms exposed. An estimated 1 million t/a are discharged into the Mediterranean Sea [6].

Uses of Industrial Wastewater

The demand for water

Population growth and improvement of living standards contribute to the increased demand for water, one of the fundamental conditions for life. With the development of industry in many countries, water consumption has largely increased. Some 300 - 600 liters per person per day are reached, with a tendency towards further increase [7]. The trend towards urbanization and coastline development with an increased tourist catering industry in some countries, has caused shortages in the fresh-water supply for the local population, tourists, industry and agriculture. A survey of water consumption (Table 3), broken down according to consumer groups, for the three continents surrounding the Mediterranean Sea shows the increased demand for water in this century (with the presumed consumption in 1985 and 2000) [8].

Table 3. Water consumption by consumer groups in km^3/a [8]

Continent	Consumer	Year					
		1900	1940	1950	1970	1985	2000
Europe	Population	9	13	14	29	55	77
	Industry	9	31	43	160	240	320
	Agriculture	23	47	60	125	240	320
Asia	Population	7	12	19	40	100	200
	Industry	2	6	12	60	200	500
	Agriculture	260	440	550	1400	1700	2400
Africa	Population	1	1.5	2	4	15	40
	Industry	0.5	1	1.5	3	20	50
	Agriculture	30	50	60	80	140	220

Table 3 shows an increased water demand for industry. In some countries, the demand for industrial consumption will greatly overtake water supply for the population. The increased water consumption is accompanied by increased surface and underground water pollution. Wastewater is one of the main pollution sources of natural water. Industrial wastewater plays a major part in this, especially when coming from chemical industries.

To protect fresh water, wastewater must be treated before final discharge. This procedure also applies to natural fresh water, with regard to required water quality criteria, for use by the population and industry since totally clean surface water and underground water hardly exist.

Treated wastewater is discharged into natural water and, after dilution and additional self-purifying processes, is re-used for the same or similar purposes. The process of indirect re-use of water is familiar and is applied by all consumers in a certain watershed. Wastewater is re-used in the indirect way once or more than once, depending on the configuration of the watershed. An exception is in the coastal areas where water used once is discharged into the sea. In the total water balance, this way of using water is wasteful and increases the water deficit.

Mediterranean countries that do not have enough fresh water available for all their water-supply needs (Cyprus, Israel and Malta) make use of desalinated sea water. The term desalination is understood to mean the removal of about 3.5% of dissolved salts and considerable amounts of organic matter. Municipal wastewater contains between 0.1 - 0.2% of pollutant, and it would be only normal to enquire why the processes of direct re-use of wastewater are not adopted in coastal areas. Some industrial wastewaters contain more waste matter than others. Some industries also require large quantities of water of which only part is used in the production process, the rest being used as cooling water or for steam production.

The percentages of water use in the United States [9] are given in Table 4.

Table 4. The percentages of water use in industry in the United States of America [9]

Industry	Production process	Cooling	Steam production
Chemicals and allied	15	80	5
Basic metallurgic	22	74	4
Petroleum	6	87	7
Paper	64	30	6
Total industry	26	67	7

Re-use of Wastewater

Not only does wastewater from certain types of industry carry different waste matter loads, but industrial processes do not require water of the same or of the highest quality. For direct re-use of water, it is most important to carry out the classification of water according to the purpose as this will lower the expenses of the treatment of wastewater and make re-use economically viable. In this regard, the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources mentions the re-use of wastewater as one of the ways to decrease coastal sea pollution.

The indirect and direct re-use of wastewater enables improvement in the water balance of certain areas; the re-use of lower quality water allows more natural fresh water to be used for purposes which require higher quality water. Re-use will also decrease the quantity of discharged wastewater, thus helping to protect fresh water from pollution. According to the WHO [10] definition:

- indirect re-use of wastewater occurs when water already used one or more times for domestic or industrial purposes is discharged into fresh surface or underground water and used again in its diluted form; and

- direct re-use is the planned and deliberate use of treated wastewater for some beneficial purpose, such as irrigation, recreation, industry, the charging of underground aquifers and drinking.

In-plant water recycling is a special case of re-use of water. Industrial wastewater is treated, improving its quality, and subsequently re-used in the same plant for conservation and pollution control purposes. Cecil [11] considers that recycling is not synonymous with re-use.

Re-use for agriculture

Generally speaking, industrial wastewater may be re-used for agriculture and/or industry. The re-use of wastewater for agricultural purposes is an old and well-known method, especially for municipal wastewater. The re-use of industrial wastewater in agriculture depends on the origin of wastewater or on the type of industrial process. Wastewaters which contain pollutants similar to those in domestic wastewaters or those which can be biologically degraded are called compatible. These are primarily from food-processing plants and some other industries using organic matter in the production process. Incompatible industrial waters contain pollutants which may disturb biological degradation or contain toxic and dangerous materials such as cyanides and heavy metals, or have extreme pH values. These usually come from metallurgic or chemical industries.

In principle, the experience gained from the use of domestic wastewater may be helpful in assessing the potential re-use of compatible industrial wastewaters for agricultural purposes. In this regard, the re-use of industrial wastewater to irrigate public gardens, golf courses and similar surfaces may be considered an agricultural purpose.

Mediterranean countries have gained a certain amount of experience concerning the re-use of wastewater in agriculture and for irrigation of green surfaces. Cyprus has to conserve its limited fresh-water supply for the needs of the local population and tourists. Treated wastewater from tourist resorts is used to irrigate parks and greenery. The re-use of wastewater for agricultural purposes in Cyprus is very efficient as it enhances the development of intensive agriculture. At present, re-used water is applied only to plants which are not used as food. According to research reports, a special problem in the re-use of wastewater is boron which is found in detergents [12].

Shelef [13] reports that Israel is making use of more than 90% of "conventional" water resources (surface and underground). Re-use of wastewater represents an additional water resource for this country. Among all the available water resources, used wastewater contributed 3.1% in 1974, and an increase to 15.7% has been estimated for 1985 excluding recycled wastewater used in industrial plants [13]. In this estimation, industrial wastewater made up 16.1% of the total quantity of re-used wastewater.

The major part of re-used water goes to agriculture. Treated wastewater is used according to specific criteria for the production of plants which are industrially processed, for fruit and for some products which are eaten raw. For more than two decades, re-used wastewater has been used for agricultural purposes in Tunisia [14]. There are two ways of using such wastewater: by direct irrigation of the agricultural surfaces or by infiltration into the groundwater from where it is pumped according to demand. Infiltration into the groundwater has the effect of third-degree (tertiary) treatment. This groundwater may be used for agricultural purposes, but pumping is not allowed to supply water to populations near the locations where treated water has been infiltrated [14].

In Turkey, wastewater from some refineries is used for irrigation of plants processed before consumption [15].

In Algeria, the development plan foresees the construction of water treatment plants for each settlement of more than 50 000 inhabitants with re-use of water for agriculture and industry [10].

Re-use for industry

Re-use of industrial wastewater for industrial purposes is most frequently carried out by an in-plant recycling process. Treated industrial wastewater is used primarily in cooling processes. Besides cooling, certain industries re-use treated wastewater as part of the industrial process, washing raw materials, transport of materials and for other needs such as steam production for technological processes or energy. Wastewater may be re-used especially in the following industries: automobile, chemical, distilling, machinery, meat, petroleum, photographic, pulp and paper, soap and detergent, steel, sugar, tannery and leather, and textiles.

It is important to mention that re-use of industrial wastewater is connected with the re-use of waste matter removed from wastewater. This means that industrial waste matter is not necessarily worthless. On the contrary, industrial waste matter may be recycled in industrial plants or used as raw material in some other process. In many cases, re-use of industrial wastewater becomes economically viable if the removed waste matter is also used.

Besides wastewater recycling, the steel industry also re-uses dust and slag, which are waste matter [16,17]. In the petroleum industry, large quantities of cooling water are recycled and the condensed steam is re-used. Where the re-use of oil in the technological process is not economical, waste oil is used as fuel [18]. Re-use of silver occurs in the photographic industry, and removal of nickel may prove economical in metal-plating plants. Both cases conform to the principle of economic use of natural resources and pollution control [19]. Waste matter from the food-processing industry may be used for the production of stock feed [20]. Re-use of waste matter and water or recycling in the technological process is applied in such industries as pulp and paper, leather and textile.

Requirements for re-use

Before re-use, industrial wastewater must undergo treatment. The degree of such treatment depends on several factors, especially on the origin of the wastewater and its intended re-use purpose.

Re-use of wastewater must not endanger public health or the life of other organisms (plants and animals). Industrial wastewater contains microorganisms and substances which by their nature or quantity may endanger organisms and cause disease, abnormal behaviour, carcinogenic, mutagenic and teratogenic effects, physiological complaints, physical deformation or death. The effect of toxic substances may not be immediate but delayed, and the outcome may not appear until much later. The risk involved in re-using wastewater is higher in the case of direct contact with wastewater or when eating food which is produced by using treated wastewater. Microbiological pollution, characteristic of municipal wastewater, may also occur in industrial wastewater.

The decrease of bacteriological pollution after a complete biological treatment is within limits of 90 - 95%, but the treatment is not equally efficient with regard to virus decrease. Viruses survive in biologically treated water after disinfection with chloride in which coliform content was considerably lowered [7]. Microorganisms from excreta from humans and animals die out in the new environment owing to such factors as temperature, solar irradiation, mineral salts and predators. In spite of all the factors having an unfavourable impact on microorganisms, some of them survive in the soil or in plants. Table 5 shows survival periods for some microorganisms [21].

Chemical pollution of wastewater is characteristic for industry. When water is re-used, it is impossible to work out standards for tens of thousand of chemical compounds contained in industrial wastewater. Many toxicologists, however, agree that the

Table 5. Survival of microorganisms [21]

Organism	Supporter	Survival time (days)
Coliforms	Soil surface	38
	Vegetable	35
	Grass	6-34
Salmonella	Soil	15-280
	Fruit and vegetable	3-49
Salmonella typhosa	Soil	1-120
	Fruit and vegetable	1-68
Shigella	Grass	42
	Vegetable	2-10
	Treated water	160
Mycobacterium	Soil	180
tuberculosis	Grass	10-49
Entamoeba histolytica	Soil	6-8
	Vegetable	1-3
Cysts	Water	8-40
Enterovirus	Soil	8
	Vegetable	4-6
Eggs of *Ascaris*	Soil	more than 7 years
	Fruit and vegetable	27-35

most harmful substances in industrial wastewater are heavy metals, cyanides and fluorides, organosilicon compounds, biocides, crude oils and hydrocarbons.

However, some metals are necessary in small quantities as micronutrients (Table 6) but may become toxic in higher concentrations [22].

Factors indicating the impact of chemical pollution on organisms are persistence, toxicity, accumulation in biological materials and biochemical transformation producing harmful substances. The problem of waste matter in industrial wastewater is complicated by possible synergism of toxic and nontoxic matter.

Quality standards

Advanced treatment of industrial wastewater offers the possibility of purification to a high degree of quality, but for economic reasons only the partial control of waste matter necessary for re-use for a definite purpose is generally carried out. Quality requirements of treated waters used in agriculture are not the same as those when they are re-used in industry. When re-used for agricultural purposes the quality distinctions for treated wastewater are made for fodder, fibre and seed crops (not for direct human consumption), crops eaten cooked and crops eaten raw. When re-used for industrial purposes, water quality will depend on whether it is used for cooling, steam production, washing and rinsing operations, or processing operations.

Some countries have defined the standards for water to be re-used for agricultural purposes. Table 7 shows the standards in California [23,24].

Table 6. Essential and toxic elements for plants and animals [22]

Element	Essential		Toxic	
	Plants	Animals	Plants	Animals
Cadmium	No	No	Medium	Strong (bioaccumulation)
Chromium	No	No	Weak	Weak
Copper	Yes	Yes	Strong	Medium
Lead	No	No	Weak	Strong (bioaccumulation)
Mercury	No	No	Weak	Strong (bioaccumulation)
Nickel	No	Yes	Strong	Medium
Zinc	Yes	Yes	Medium	Weak

Table 7. Standards for the safe direct use of reclaimed wastewater of irrigation and recreational impoundments [23,24]

Use of reclaimed water	Minimum required wastewater characteristic			
	Primary (not more than 1.0 ml/l/h settleable solids	Secondary and disinfected	Secondary, coagulated, filtered and disinfected (Not more than 10 JTUs)	Coliform median MPN/ 100 ml (daily sampling)[1]
Irrigation				
Fodder crops	X			No requirement
Fibre crops	X			No requirement
Seed crops	X			No requirement
Produce eaten raw, surface irrigated		X		2.2
Produce eaten raw, spray irrigated			X	2.2
Processed produce, surface irrigated	X			No requirement
Processed produce, spray irrigated		X		23
Landscapes, parks, etc.		X		23
Creation of impoundments				
Lakes (aesthetic enjoyment only)		X		23
Restricted recreational lakes		X		2.2
Non-restricted recreational lakes			X	2.2

[1] MPN = Most probable number.

These standards emphasize health protection against microbiological pollution. The possibility of exposure of agricultural workers to pollutants when spray irrigation is adopted has been taken into consideration. Crook [24] reports about the possibility of infection from inhalation of contaminated aerosols. Aerosols with high bacteriological pollution were carried a distance of 300 to 400 meters at a wind speed of 18 km/h and 1000 m when winds were stronger [24].

Owing to this problem, the standards in Israel require that when spray irrigation with treated water is applied, the minimal distance between sprinklers and the nearest residential areas should be 400 m [13].

When wastewater is re-used for industrial purposes, water quality requirements depend on the final use. Generally speaking, the requirements for re-use of wastewater may demand the degree of treatment which will prevent the development of algae (low biological oxygen demand (BOD) and restricted phosphates), corrosion (low ammonia), health risk (low concentration of coliforms) [13].

In Japan, general standards for industrial water supply may be applied for the re-use of wastewater in industry [25]. These water quality criteria are: turbidity, 20 mg/l; ph, 6.5-8.0; alkalinity, 75 mg/l; hardness, 120 mg/l; total solids, 250 mg/l; chloride, 80 mg/l; iron, 0.3 mg/l; and manganese, 0.2 mg/l. In Tokyo, treated wastewater is re-used for cooling and washing, and the standard (Table 8) is adapted for the above-mentioned purposes [25].

A group of WHO experts has prepared a set of recommendations for treatment processes of wastewater to be re-used [7]. The following are the recommendations for the re-use of water for agricultural and industrial purposes. Table 9 indicates the

Table 8. Water quality criteria industrial water supply in Tokyo

Characteristic	Criterion
Temperature (°C)	less than 27
Turbidity (mg/l)	less than 15
pH	5.8-8.6
Chloride (mg/l)	less than 1500
Iron (mg/l)	less than 0.7

treatment processes to meet given health criteria for wastewater re-use. The health criteria are the following:

A - Freedom from gross solids, significant removal of parasite eggs;
B - As A, plus significant removal of bacteria;
C - As A, plus more effective removal of bacteria, plus some removal of viruses;

Table 9. Suggested treatment processes to meet the given health criteria for wastewater reuse [7]

	Irrigation			Industrial reuse
	Crops not for direct human consumption	Crops eaten cooked, fish culture	Crops eaten raw	
Health Treatment criteria[1]	A + F	B + F or D + F	D + F	C or D
Primary treatment	+++[2]	+++	+++	+++
Secondary treatment		+++	+++	+++
Sand filtration or equivalent polishing methods		+[3]	+	+
Nitrification				+
Chemical clarification				+
Ion exchange or other means of removing ions				+
Disinfection		+	+++	+

[1] For explanation, see text.
[2] Essential.
[3] May sometimes be required.

D - Not more than 100 coliform organisms per 100 ml in 80% of samples; and

F - No chemicals that lead to undesirable residues in crops or fish.

To meet the given health criteria, processes marked "+++" will be essential and those marked "+" may sometimes be required.

Recycling techniques

Industrial wastewater which is to be re-used has to be treated. Generally speaking, there are no special treatment processes for wastewater meant to be re-used. All those processes which are used in the treatment of wastewater before discharge into fresh water, as well as those by which natural fresh water is treated before use, are applied in the treatment of wastewater to be re-used.

The usual primary and secondary treatment methods often may not be sufficient for wastewater to be re-used. Primary treatment is usually understood to mean the removal of coarse solids (screening) as well as sedimentation of suspended solids in 2-4 hour periods. At the same time, part of the floating materials is removed (flotation) and BOD is decreased. Secondary treatment is the term used for biological processes by which biodegradable waste is removed from water. Activated sludge, trickling filters and lagoons are the processes most frequently adopted in conventional secondary treatment. The effect of primary and secondary treatment of municipal wastewater may be sufficient in some cases of direct and indirect re-use. The quality of water treated in this way is shown in Table 10 [26].

However, industrial wastewater contains higher waste concentrations, apart from some compounds which inhibit biological processes and/or nonbiodegradable matter. Also, conventional secondary treatment processes cannot be applied to some kinds of wastewater.

Advanced wastewater treatment is often necessary when water is to be re-used directly or indirectly, i.e. it is discharged into fresh water. There are several advanced wastewater treatment processes which remove material which remains in wastewater after primary and secondary treatment [26, 27]. Colloids are removed to decrease turbidity, colour and BOD in industrial wastewater. They are removed from wastewater by coagulation, flocculation, sedimentation, filtration and adsorption.

Nitrogen conversion and removal represent a special problem in wastewater treatment. Ammonia in wastewater reduces the effect of chlorination and may lead to corrosion. The conversion of ammonia to nitrates lowers the oxygen content in water. An increase of nitrates and phosphates stimulates the growth of algae. In the re-

Table 10. Water quality at various stages of treatment [26]

Quality parameter	Raw wastewater	Effluent	
		Primary	Secondary
BOD (mg/l)	300	100	30
Chemical oxygen demand	480	220	40
S.S. (mg/l)[1]	230	100	26
JTU[2]	250	150	50
MBAS (mg/l)[3]	7	6	2
Phosphorus (mg/l)	12	9	6
Coliform (MPN/100 ml)	5×10^{7}	1.5×10^{7}	2.5×10^{6}

[1] Suspended solids.
[2] Jackson turbidity unit.
[3] Methylene blue active substances.

use of wastewater for agricultural purposes, an increased quantity of nitrates may add to the quantity of nitrates in drinking water and may cause methaemoglobinaemia in children. The biological processes of nitrification-denitrification, stripping, breakpoint chlorination and ion exchange are used to remove nitrogen from wastewater.

Phosphorus removal from wastewater is necessary to prevent the stimulation of aquatic plants (if wastewater is used for recreational lakes), and the interference in the process of water softening (re-use in industry). The removal of phosphorus is achieved by chemical precipitation.

Refractory organic compounds cannot be removed by conventional processes. Compounds such as biocides, phenols and surfactants may be toxic or harmful to organisms in water and may change water taste and odour and produce foam. They may be removed from wastewater by means of activated carbon adsorption and chemical oxidation.

Industrial wastewater contains specially dissolved inorganic substances which have to be removed before re-use. Some inorganic substances such as heavy metals, cyanides and fluorides, are toxic; others, such as calcium and magnesium, increase water hardness and chlorides increase salinity and decrease the possibility of the re-use of water in agriculture and industry. Dissolved inorganic matter is removed by chemical precipitation,

ion exchange, reverse osmosis, electrodialysis, evaporation, and chemical oxidation-reduction.

Disinfection is the last treatment process of waste to be discharged into fresh water. Disinfection is also applied to wastewater before re-use. Advanced treatment processes may help decrease microbiological pollution and enhance the effect of disinfectants. Reports suggest that with removal of turbidity of 0.1-1 JTU, the effect of disinfection is significantly increased, and it is sufficient to keep 1 mg/l of free chlorine residual after 30 minutes of contact time [26]. The removal of viruses from wastewater may be achieved by coagulation, sedimentation, filtration and adsorption.

Direct re-use of industrial wastewater is most frequently applied by in-plant recycling followed by the re-use of municipal wastewater in which industrial wastewater is already discharged. In the steel and iron industry, the once-through use of water is being abandoned. Facilities for water recycling have been built in modern plants, primarily for cooling and then for processes not requiring high-quality water. About 70% or more of water is used for cooling, and recycling is possible without higher degrees of additional treatment. The recycling of water from blast furnaces and gas washers reaches 90% or more. Special attention is paid to the recycling of dust and sludge containing tramp metals such as lead and zinc.

In France, such methods of recycling waste matter (dust, sludge and slag) are applied in such a way that the quantity of waste matter disposed of from steel plants does not exceed 100 kg per ton of steel [28]. In Algeria, water recycling has reduced the use of water in the El-Hadjar steel plant from 20-25 m^3 to 10-15 m^3 per ton of steel [10].

In the petroleum industry, the major part of the water is used for cooling. Modern refineries recycle cooling water which need not be of high quality. In the United States of America, 90% of in-plant recycled water in refineries and the petrochemical industry is used for cooling water [18]. Older plants without recycling facilities use a significantly higher quantity of water (up to 70% more per ton of steel) and also show a higher waste matter load - 5 to 30 times higher after treatment - in comparison with wastewater before treatment in modern refineries [29].

In the refinery in Rijeka, Yugoslavia, cooling was carried out with sea water. Owing to the fact that all waste water was discharged into a single canal system, it was impossible to achieve the demanded quality of treated water. The improvement in the conservation of the coastal marine environment was achieved only when a closed cooling cycle was introduced (with fresh water) and a separate sewer system built [30].

The chemical industry (organic and inorganic) is another major waste consumer. In part of the chemical industry, water is not used in the technological process, but in some processes technological wastewater represents a difficult treatment problem.

Recycling of water and matter in the treatment processes both controls pollution and helps economize with water. Mercury recycling in an Italian chloralkali plant made it possible to obtain treated water with 0.005 mg Hg/l, which significantly diminished the introduction of mercury into fresh water [31].

Characteristically, the food industry uses large quantities of water and its wastewaters contain a high organic load. Some processes are carried out only in the course of a single season as, for example, sugar production from sugar beet which poses special problems for wastewater control. For water used in processing operations, the prescribed quality is that of potable water, which slows down the efforts to re-use wastewater. However, large quantities of water are used for cooling and washing and as flume water, and a large part of these waters can be re-used. Some sugar beet plants use a closed cycle for water recycling [32]. To lessen the high organic load, besides conventional treatment plants and advanced technological treatment, anaerobic digestion process is applied in wastewater degrading [33], as well as the aerobic deep-shaft process, especially in cases of space shortage [34]. The recovery of protein and fat from the food industry is useful both from the point of view of recycling organic matter and improving wastewater for re-use [20]. Wastewater from food-processing plants located in agricultural areas is often re-used for irrigation [32]. In Egypt, an efficient system of waste matter recycling is applied so that waste from the food industry is used in the preparation of animal feeds [35].

Wastewater from leather tanning and finishing causes environmental pollution and complications in municipal treatment plants. Recycling of dehairing liquor, chrome tan waste and fat liquor results in useful re-use of materials and wastewater [36]. The textile industry, a large water consumer, uses 90% of its water for technological processes, making in-plant recycling a possibility [37,38]. The pulp-and-paper industry uses large quantities of water as a transport medium, for cooling, and as boiler feed. Raw water quality requirements vary with the type of mill, but in principle water quality need not be too high, which makes in-plant recycling possible.

Since this wastewater carries a heavy organic load, the possibility of anaerobic treatment of waste using biogas has been investigated. Results have indicated technological possibilities and economically viable processes of anaerobic wastewater treatment [39]. Wastewater from the pulp-and-paper industry can be re-used for irrigation after treatment and recycling of useful waste matter.

Technical and Practical Problems

When the Kaiser Steel Company built its steel mill in Fontana, California, in 1942, there was clearly not enough fresh water available. Maximal in-plant recycling of wastewater was applied, as a result of which the demand for fresh water use decreased to one tenth of the average United States of America consumption per ton of produced steel [40]. Since then, many countries faced with a fresh-water shortage have accepted the principles of wastewater re-use as a part of the general policy of interdependence of (water) supply - (water) discharge - (water) conservation and (water) re-use.

In the Mediterranean zone, increased consumption of fresh water causes additional problems as, for example, in Malta, where increased pumping has raised the danger of saltwater intrusion into the underground aquifer. In Venice, increased pumping led to the sinking of the soil [41]. The problem of water re-use cannot be considered a technological problem without considering its legal, social and political aspects.

General considerations

The following considerations are of special interest when coming to a decision on water re-use:

- quantity of fresh water available for use;
- costs for preparing fresh water for use;
- costs of treatment and disposal of wastewater;
- possibility of modifying plant processes for reducing waste;
- costs for preparing wastewater for in-plant recycling or re-use;
- costs for preparing and disposing of treatment concentrates and possibility for their recovery.

The re-use of industrial wastewater requires the construction of separate sewerage systems according to waste matter origin or composition. Wastewater with low concentration of waste matter can then be re-used without major treatment. Separate sewerage systems open the possibility of a cascading system for in-plant re-use of wastewater. Purer water is used first for processes requiring higher quality water and subsequently for processes which require progressively lower quality. With separate sewerage systems, the recovery of materials may be economically viable from relatively smaller quantities of water or from sewers where waste matter is found in higher concentration.

Renovated water for in-plant or out-of-plant re-use requires a special water system. This increases the cost of re-using water and may be dangerous for health (because of the possible exchange). The use of different materials and colours for the pipes is necessary but not fully safe.

The use of water and the quantity of discharged water are not always equal. There are industrial processes with batch operations. For a short time, large quantities of water are necessary which are then kept in reservoirs and subsequently gradually discharged. The position is similar with surface runoff which may be re-used after treatment. In both cases, water must be kept in surge basins. The surge basin for the flow balancing is necessary in connection with the dimensions of treatment plants which for economic reasons are not designed for the maximum flow. In the case of direct re-use of wastewater for agricultural purposes, a surge basin must be planned not only for daily or weekly discharge but for many months.

Surge basins sometimes require a large space, a requirement that local circumstances may make it difficult to meet. Storing water underground has several advantages. Among others, evaporation occurs in surface basins and there is a possibility of further pollution. In underground storage, the soil acts as a filter through which wastewater becomes further treated. Storing water underground is cheaper than in surface basins, and the re-use of water from underground sources has a psychological impact. In some cases, groundwater recharge may serve as a fresh-water barrier in coastal aquifers against the intrusion of salt water.

From the point of view of health, industrial wastewater must be treated before discharge in order to prevent clogging of the soil and pollution of ground water.

Specific problems of direct re-use of wastewater

Specific problems arise with the direct re-use of wastewater for agricultural purposes. Wastewater may be re-used on condition that the protection of surface water and groundwater has been provided for. Surface water and the surrounding soil are protected by means of ditches and berms which prevent washing of the agricultural land. Certain countries require a minimal distance of 3.0 m to the level of underground water [42]. To protect the neighbouring soil, especially in housing areas, a buffer zone must be planned. In the United States of America, the width of buffer zones to houses is about 60 m and to water-supply wells between 150-300 m [42]. The planting of suitable trees in the buffer zone prevents the spread of aerosol.

Health protection of agricultural workers is achieved by personal hygiene. This term is understood to mean avoiding exposure to recycled water where possible, the use of protective garments and changing of clothes at the end of the work period, care in hand washing, and bathing after exposure and prior to eating food or smoking [10].

RECYCLING AND RE-USE OF INDUSTRIAL WASTEWATER

The re-use of industrial wastewater presumes prior treatment and simultaneous use of solid and treatment concentrates. For the rest which cannot be re-used, a safe disposal method must be found. With some waste, (e.g. metal-working sludge, used oils and grease, paint sludge, high organic sludge, paper, plastic and wood) the energy level must be used before final disposal [43].

In conclusion, re-used water should be considered a new water resource and handled adequately. In countries with dry climate, each new water resource is very useful. As long ago as 1958, the United Nations Economic and Social Council suggested: "No higher quality water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade".

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DISPOSAL OF SOLID WASTE AND SLURRY IN THE MEDITERRANEAN AREA

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Introduction

Population expansion and the ever-increasing pace of industrial activities constantly challenge the concept of a clean environment. A polluting environment, on the other hand, resulting from improper and sometimes illegal waste discharges, greatly stimulates public concern for environmental protection. This in turn, results in more stringent laws and regulations controlling waste disposal practices.

Among the many types of waste generated by industrial activities, solid waste and sludge have a particularly important place. The amount of solid waste increases tremendously as industrial production expands and diversifies: more than one billion tons of solid waste are produced annually by mineral industries alone [1]. More importantly, there has been enough evidence to show that some of the industrial waste is hazardous in the sense that exposure may lead to death, injury or serious impairment of human health, as in the case of Minimata Bay in Japan. Finally, legislation providing directives for a cleaner environment by more stringent effluent limitations, has made treatment and disposal of solid waste more important, difficult and costly. Indirectly, higher levels of liquid waste treatment produce an increased mass and volume of sludge to be managed, so that treatment systems of solid waste not only must handle more material but must be operated much more effectively.

Since pollution control and economics are inseparable, there is a constant urge to balance the need for better treatment and disposal performance and the need for desirable development. In view of this delicate balance, it becomes imperative to get a better insight of all factors related to handling problems of solid waste and to review and update existing treatment and disposal technologies constantly. Within this framework, this paper attempts to present a broad overview of requirements and problems associated with the disposal of industrial solid waste and slurry.

DISPOSAL OF SOLID WASTE AND SLURRY

Nature and Classification

Of the different types of waste actually generated by industrial activities, solid waste and sludge are the most difficult to classify rationally. The difficulty arises from the fact that a great number of factors may be considered while attempting such an inventory. Specific properties of the waste involved, sources, treatment and disposal options, and hazard factors can all be given priority for the assessment of waste characterization. In a general sense, only a global classification may be offered (Table 1).

Within this framework, waste defined in the third group are mainly sludge, whereas auxiliary services generate mostly solid waste of the same type as municipal waste. Production-related waste may revert almost all possible characteristics, depending on the specific industry or a given operation within an industrial activity. Table 2 illustrates the variety of production-related wastes associated with the chemical process industries.

The conventional approach to characterize sludge from wastewater treatment facilities of industrial installations is to group them as biological and physical/chemical sludge. Biological sludge produced by the biological stage of the treatment system is somehow similar in character to its counterpart generated by domestic plants. This similarity may be related to the fact that the satisfactory performance of a biological treatment unit depends on a number of factors that need to be equally sustained both for industrial and domestic wastewaters. In other words, biological units must be protected by necessary physical/chemical pretreatment units from industrial wastewater that contains elements that would adversely effect biological degradation. This aspect, however, makes the quantity and quality of physical/chemical sludge from industries differ considerably, as compared with primary sludge, from those of domestic plants. Typical examples of industry-specific sludge are:

- sludge consisting mainly of very fine inorganic particles, for example from cement works or the ceramics industry;
- metal hydroxide sludge produced, for example, by the neutralization of metalliferous wastewater;
- oily sludge from gravity separators or emulsion-breaking plants; and
- sludge containing coal dust, for example, from power stations or briquetting factories [3].

Table 1. Global classification of industrial solid waste and sludge

1. Production-related waste: Byproducts, side products, process residues, spent reaction media, contaminated plant of equipment from manufacturing operations, discarded manufactured products
2. Waste from auxiliary services Municipal-type solid waste (canteens, cafeterias) power plant waste, packaging/shipping waste
3. Waste arising from pollution control systems: Wastewater treatment system sludges, incinerator residues

Table 2. Solid waste and sludge generated in the chemical process industries [2]

Origin	Physical and chemical characteristics
Coke manufacture	Coke and coal fines
Dyes and pigment	Reaction or raw-material sludge, highly variable
Fine chemical and pharmaceutical	Raw-material solids, biological waste
Inorganic chemicals	Insoluble salts, tailings, slimes
Metal processing (secondary)	Ash, scrubber waste, metal hydroxide sludge
Petrochemical	Oily, greasy, asphaltic
Plastic and rubber	latex or plastic crumbs, often alum-coagulated
Pulp and paper	Fibrous, some fine filter, often with lime or alum

DISPOSAL OF SOLID WASTE AND SLURRY

Many solid wastes and sludges generated by a variety of industrial sources are considered to be hazardous because they may present:

- short-term acute hazards, such as acute toxicity, corrosivity or risk of fire or explosion; or
- long-term environmental hazards, including chronic toxicity, carcinogenicity, resistance to biodegradation, and potential to pollute the environment by irreversible and cumulative processes.

WHO [4] associates the potential hazard of a waste with the following characteristics and factors:

- substances present in the waste;
- concentration or chemical reactivity of such substances;
- physical form in which the substances are present;
- quantity and rate of generation of potentially hazardous material;
- mobility and persistence of the potentially hazardous materials in the environment in which they are placed;
- targets available in that environment and their vulnerability to the potentially hazardous materials; and
- possibility of remedial measures and their cost.

The presence of such waste makes it imperative to consider a possible inventory from a different angle and to reclassify industrial solid waste and sludge as either hazardous waste or non-hazardous waste. It is evident that the above differentiation coincides with the previous classification so that each waste in Table 1 may be termed hazardous or non-hazardous depending on the quantitative information related to its composition, physical form and quantity.

There are different efforts to identify hazardous waste. One approach is to list wastes that present no short-term handling and long-term environmental hazards and to define hazardous waste by exclusion. The more widely adopted approach is to use inclusive lists indicating hazardous waste from specific industries, containing specific compounds or specific waste streams (Table 3).

Table 3. List of toxic or dangerous substances and materials selected as requiring priority consideration [4]

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1. Arsenic and compounds
2. Mercury and compounds
3. Cadmium and compounds
4. Thallium and compounds
5. Beryllium and compounds
6. Chromium (VI) compounds
7. Lead and compounds
8. Antimony and compounds
9. Phenolic compounds
10. Cyanide compounds
11. Isocyanates
12. Organohalogenated compounds (excluding inert polymeric materials and other substances referred to in this list or covered by other directives concerning the disposal of toxic or dangerous waste)
13. Chlorinated solvents
14. Organic solvents
15. Biocides and phytopharmaceutical substances
16. Tarry materials from refining and tar residues from distilling
17. Pharmaceutical compounds
18. Peroxides, chlorates, perchlorates and azides
19. Ethers
20. Chemical laboratory materials, not identifiable and/or new, with unknown effects on the environment
21. Asbestos
22. Selenium and compounds
23. Tellurium and compounds
24. Polycyclic aromatic hydrocarbons (carcinogenic)
25. Metal carbonyls
26. Soluble copper compounds
27. Acids and/or basic substances used in the surface treatment and finishing of metals

Methods of Disposal

Despite their variety, there are relatively few ways available for disposing of industrial solid waste and sludge. If combustible, such wastes may be incinerated; if they can yield usable gases or liquids, pyrolysis may be employed and if biodegradable, composting may be envisaged. Disposal on land or at sea are the other options. In most cases, solid waste or sludge needs to be treated to a degree that is suitable for the particular method of disposal. Quantity, physical and chemical characteristics, noting possible hazardous effects, and possible methods of recovery and use should be identified to define properly the most suitable treatment scheme that will equally comply with the nature of the waste and the available or selected disposal system.

A brief account on methods of treatment and disposal of industrial solid waste, sludge and hazardous waste is given below.

Disposal of solid waste

The disposal options defined for municipal solid waste are also applicable to nonhazardous solid waste of industrial origin. The number of treatment methods available which conform with the type of final disposal method are normally limited. For example, compaction of the raw waste to reduce its volume is desirable if landfill is to be the final disposal method, but the same process will reduce the efficiency of incineration. Separation of materials such as glass, metals, plastics and paper is another form of pretreatment either for reclamation of these materials or because they would not react properly to the subsequent treatment or disposal method. Another consideration for treatment is to use a method of size reduction, providing not only smaller volumes but also uniformity and better suitability to the disposal option. In this connection, it should be stressed that the major incentive in solid waste handling is resource recovery; namely, recovery for re-use, recovery of heat, and recovery for other purposes where the waste material recovered has changed its character but, nevertheless, may be useful in another process.

Disposal of sludge

Disposal of nonhazardous industrial sludge is generally evaluated along the same concepts as those for solid waste. However, because of their high water content and potential environmental incompatibility, a totally different sequence of appropriate treatment methods has to be used before final disposal. Alternative treatment sequences are illustrated in Figure 1 and Table 4 [3, 5]. Generally, treatment of sludge presenting no potential hazard must fulfil the following conditions: sludge volume must be reduced, and its degradable constituents must be stabilized so that it can eventually be used or stored without damage to the environment. Within this framework, selection of the best treatment sequence involves considerations such as:

- quantity of sludge and its solids content;
- condition of the biomass or chemical solids in terms of water retentiveness and extent of stabilization;
- other slurry streams more amenable to dewatering which are available for blending with the problem material;
- local costs and availability of land, energy and labour; and
- option of proceeding stepwise, with time for interim evaluation, versus proceeding with ultimate sequence at the start [6].

Final disposal of industrial sludge can be effected by use and, where the sludge cannot be used as a resource due to a number of constraints such as high content of metals or other toxic substances, by non-utilization disposal processes. Sludge disposal options involving beneficial uses are land cultivation (soil amendment), source of heat and work, and source of other useful products. A great potential of energy recovery exists from the gas produced during anaerobic stabilization, pyrolysis or burning of suitable sludge. This energy may be converted to heat or work to be used inside or outside the plant.

A number of recovery methods are now feasible to enable usage of the recovered materials as waste treatment chemicals, landfill toppings, industrial raw materials, animal feed and construction materials.

Sludge can also be used as a fertilizer and in the reclamation of disturbed lands. Land cultivation is defined as a process whereby waste sludge is mixed or incorporated into the surface soil at a land disposal site. Industrial sludge can be considered suitable for land cultivation only if it fulfils the following conditions:

1. The organic portion biologically decomposes at a reasonable rate.
2. It does not contain material at concentrations toxic to soil microorganisms, plants or animals. In addition, there must be reasonable assurance that long-term toxic effects resulting from accumulation through absorption or ion exchange can either be prevented or mitigated.

Fig. 1 Sludge treatment: alternative paths [3]

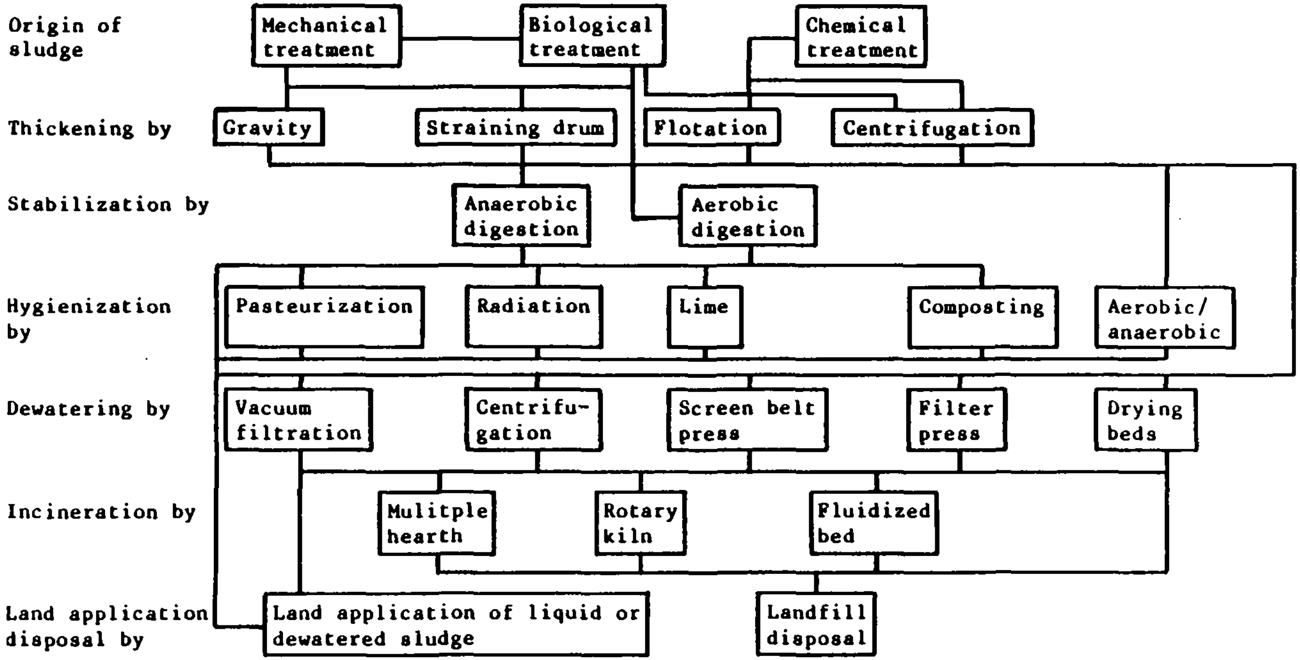

Table 4. <u>Enumerations of sludge treatment processes and their functions</u> [5]

Unit Processes	Functions
Thickening (blending)	- Water removal - Volume reduction - Post-process efficiencies - blending
Stabilization (reduction)	- Pathogen destruction - Volume and weight reduction - Odour control - Putrescibility control - Gas production
Conditioning rate (stabilization)	- Improve dewatering or thickening - Improve capture of solids - Improve compactability - Stabilization
Dewatering	- Water removal - Volume and weight reduction - Change to damp cake - Reduces fuel requirements for incineration/drying
Heat drying	- Water removal - Sterilization - Utilization
Reduction (stabilization)	Destruction of solids - Water removal - Conversion - Sterilization
Final disposal	- Utilization (cropland) - Utilization (energy) - Utilization (land reclamation) - Disposal (landfill) - Disposal (ocean)

3. It does not contain substances in sufficient concentration to affect adversely the quality of groundwater.

4. It does not contain substances in sufficient concentration to affect adversely soil structure, especially infiltration, percolation and aeration characteristics [7].

Waste-specific land cultivation considerations so far compiled are listed in Table 5.

The two disposal options not involving utilization are disposal on land and at sea. Disposal on land is generally accomplished by a landfill operation, defined as the planned burial of industrial sludge together with other compatible waste, at a designated site; the waste is put into a prepared site or an excavated trench and covered with a layer of soil. A slightly different operation called "dedicated land disposal" [8] involves surface application of sludge loadings to some finite land area which has limited public access and thus dedicated for this purpose.

In disposal of sludge at sea, two different methods are currently employed: dumping at sea from vessels, and discharge to sea by pipeline. In certain countries, disposal at sea is practiced extensively and claimed to be effectively geared to needs for protection of the environment [9]. In others, numerous laws and regulations prohibit disposal of sludge by barge to the sea while the technical grounds for such action are still debated [10].

Disposal of hazardous waste

Special care should be taken when dealing with hazardous wastes because of the potential consequences that may be associated with such an operation. WHO [4] recommends the preparation of comprehensive hazardous waste disposal plans, covering the following subject areas:

- kinds and quantities of hazardous waste expected to be treated and disposed of in the area;
- number, type and location of treatment/disposal authorities;
- number, type and location of reception centres and pretreatment facilities;
- management of the waste disposal facilities;
- proposed methods of disposal and/or recycling; and
- identification and location of special facilities suitable for individual, particularly hazardous, wastes.

An example of a comprehensive hazardous waste disposal facility designed on the basis of the above considerations is given in Figure 2. It should be noted that solid and liquid wastes are handled together in the same facility.

Regarding treatment and disposal aspects of the many technologies currently available in developed countries, any particular one is not necessarily appropriate for all kinds of hazardous waste. The best practicable way of treating a given waste is normally a function of a number of factors, including the availability and suitability of disposal or treatment facilities, safety standards and cost considerations. Most treatment systems are used to modify the physical and/or chemical properties of the waste prior to ultimate disposal. The expected modification may be reduction in volume, immobilization of toxic components or detoxification. Although similar methods of disposal, such as landfilling or incineration, are also employed for such waste, no disposal option may be said to offer absolute safety.

Legislation

There are many legal procedures adopted by different countries in accordance with their waste disposal practices. Some pieces of legislation implement international conventions: in the United Kingdom for example, the Dumping at Sea Act of 1974 implements the Oslo and London conventions on sea disposal and prohibits the dumping of waste without a licence. In countries such as the United States of America, management of solid and hazardous waste is undertaken by a sequence of federal and state laws and local regulations and ordinances. The differences in various approaches may be explained when different cultural, constitutional and economic backgrounds are envisaged. In the case of the Mediterranean Sea, the dumping of waste at sea requires prior authorization by national authorities under the terms of the 1976 Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft.

In a global sense, legislation concerning disposal of solid waste, slurry and hazardous waste need not be essentially different from a general waste disposal policy, where the objective is to dispose of these wastes, regardless of their nature, in such a manner that no unacceptable risk is inflicted upon public health or the environment. The basic components of such a policy should be prescribed by law, since a coherent and satisfactory waste management system should not be expected to develop naturally. The laws and control procedures have to be adequate to protect, to a sufficient degree, all receiving environments. Stringent rules controlling waste disposal to one environment may not produce expected results, if coupled with inappropriate protection for the other potential receivers. Some of the important components of a

Table 5. Considerations for waste-specific land cultivation disposal [7]

SIC[1]	Industry	Waste type	Specific potential hazards	Recommended precautions
20	Food and kindred products	Wastewater, sludge and screenings	High sodium and TDS[2] content resulting in detrimental effects on soil properties and plant growth	Gypsum addition; segregation of high sodium and TDS waste streams
2231	Textile finishing	Secondary wastewater treatment sludge	Heavy metal content	Plant and water monitoring; appropriate loading rate
2491	Wood preserving	Wastewater	Pentachlorophenol creosote and possible contamination of water supplies	Appropriate loading rate about 28 to 37 m^3/ha (3000 to 4000 gal/ac)
26	Paper and allied products	Primary wastewater treatment sludge	Contamination with toxic materials may occur at some plants reprocessing secondary materials	Sludge analysis and subsequent appropriate site design and operating precautions
2824	Organic fibres, noncellulosic	Secondary wastewater treatment sludge	High zinc and nitrate content	Appropriate application rate and cover crop
283	Pharmaceuticals	Waste mycelium	High zinc and TDS content	Appropriate application rate and cover crop
2841	Soap and other detergents	Wastewater	Possible water supply degradation from excess nutrients	Use cover crop with good nutrient uptake characteristics
286	Organic chemicals	Wastewater treatment sludge	Potential hazards are dependent on the specific chemicals produced	Chemical analysis of sludge to detect potentially hazardous constituents
291	Petroleum refining	Nonleaded tank bottoms vanadium and lead content	High nickel, copper,	Monitoring of soil and groundwater concentrations to determine when disposal-site life is expended

Table 5. cont'd

		Waste biosludge	High chromium and zinc content	Monitoring of soil and groundwater concentrations to determine when disposal-site life is expended
		API separator sludge	High chromium, zinc, nickel and copper content	Monitoring of soil and groundwater concentrations to determine when disposal-site life is expended
		Dissolved air flotation float	High chromium and zinc content	Monitoring of soil and groundwater concentrations to determine when disposal-site life is expended
		Slop oil emulsion solids	High chromium and zinc content	Monitoring of soil and groundwater concentrations to determine when disposal-site life is expended
		Crude tank sludge	High chromium, zinc and copper content	Monitoring of soil and groundwater concentrations to determine when disposal-site life is expended
3111	Leather tanning and finishing	Vegetable tannery wastewater	High chloride and TDS and associated detrimental effects on plant growth	Dilution, addition of gypsum

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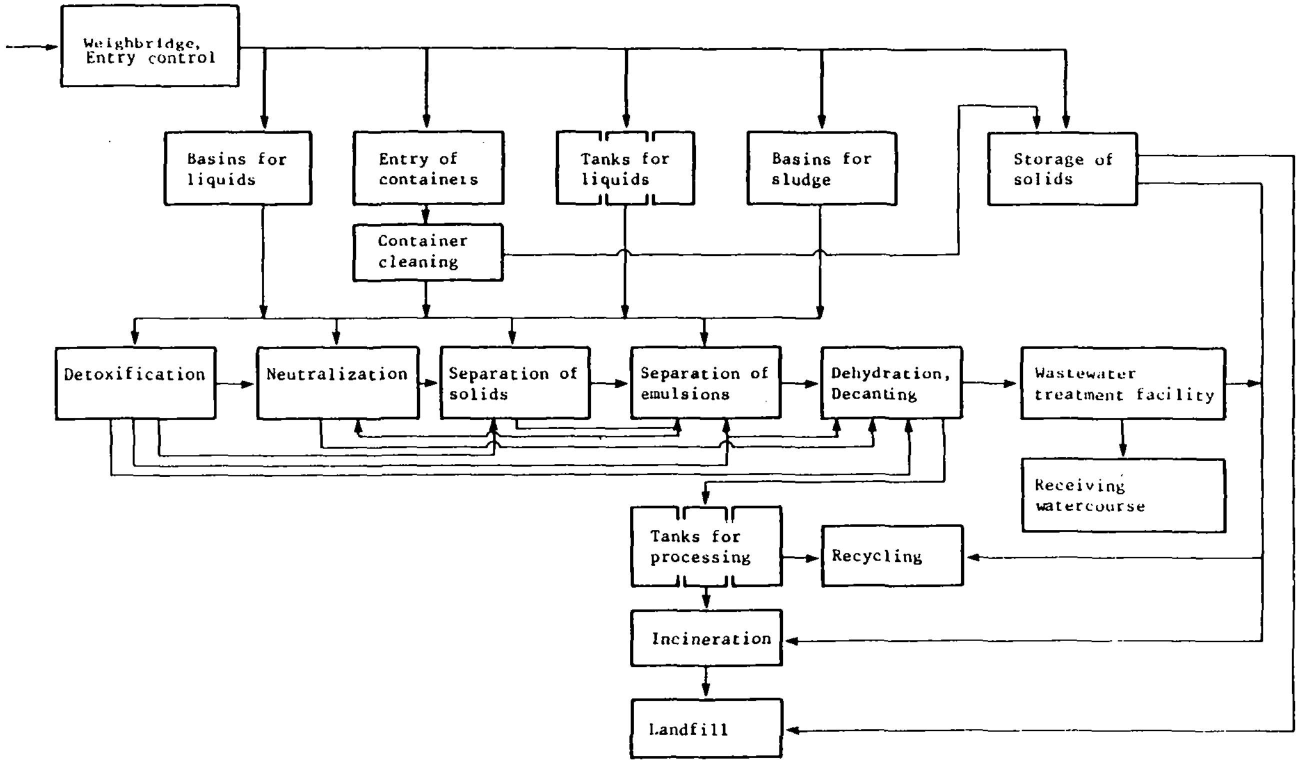
[1] SIC = Standard Industrial Classification
[2] TDS = Total dissolved solids

Fig. 2 Example of a comprehensive hazardous waste disposal facility



comprehensive waste disposal policy are:

- waste should be minimized by such approaches as low or nonwaste technologies and recycling;
- waste should be controlled from its point of production to its final disposal by licensing;
- properly sited and managed disposal facilities should be available;
- costs of using licensed disposal facilities should not be excessive;
- responsibilities and duties of those involved in all stages of the management should be well defined;
- waste producer should be responsible for the proper disposal of his waste;
- laws should be enforceable and enforced; and
- where the politicoeconomic nature of a nation permits, the principle that "the polluter pays" should be adopted [4].

Technical and Economic Problems

Despite the existence of many techniques proposed or in use, problems are always encountered in the disposal of solid waste and sludge. Problem areas include adverse environmental impact, excessively high costs and scarcity of acceptable disposal sites. Increasing volumes of waste being produced and growing public concern over environmental issues aggravate the situation. Table 6 lists disposal methods together with significant drawbacks likely to be encountered at each specific application.

The main economic issue in the disposal of solid waste and slurry is to protect and maintain the delicate balance between environmental protection and economic development. This is crucially true for hazardous waste management. On the one hand, hazardous waste, by definition, needs to be strictly controlled to prevent possible damage to public health and the environment. On the other hand, the fact that most waste is produced by those industries - such as iron and steel, nonferrous metals, basic chemicals and secondary chemicals industries - providing a major contribution to the development of a modern industrial society, has to be taken into serious consideration.

Table 6. Disposal methods for solid waste and slurry and associated drawbacks [7]

Disposal method	Significant drawbacks
Sanitary landfill	Leachate and methane gas production; local lack of acceptable sites; longterm commitment of land to disposal purposes
Incineration	Costs and air pollution
Pyrolysis	Unproven and costs
Composting	Costs and low demand
Discharge to sewers	Treatment plant operational problems and water pollution
Ocean dumping	Potential adverse effects on marine life
Deep-well injection	Highly dependent on favourable geologic conditions; water pollution
Evaporation and infiltration	Air and water pollution
Recycling	New market development
Cropland application	Limited wastes
Land cultivation or biodegradation	Water pollution; high land requirement

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