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WORLD HEALTH ORGANIZATION
TECHNICAL REPORT SERIES

No. 318

WATER POLLUTION CONTROL

Report of a WHO Expert Committee

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WORLD HEALTH ORGANIZATION

GENEVA

1966

WHO EXPERT COMMITTEE ON WATER POLLUTION CONTROL

Geneva, 6-12 April 1965

Members : *

- M. N. J. de Baenst, Chef de l'Administration du Génie sanitaire, Ministère de la Santé publique et de la Famille, Brussels, Belgium
- Dr L. Coin, Chef de Service, Laboratoire d'Hygiène de la Ville de Paris, Paris, France
- Dr F. Guimarães, Assistant Director, State of Guanabara Institute of Sanitary Engineering, Rio de Janeiro, Brazil
- Mr Harry G. Hanson, Assistant Surgeon General, US Public Health Service, Washington, D.C., USA (*Chairman*)
- Dr A. Key, Senior Chemical Inspector, Ministry of Housing and Local Government, London, England (*Rapporteur*)
- Mr R. S. Mehta, Director, Central Public Health Engineering Research Institute, Nagpur, India
- Mr J. M. Paz Maroto, Ingeniero Director de Obras Sanitarias del Ayuntamiento de Madrid, Madrid, Spain

Representative of the United Nations :

- Mr A. Pichler-Stainern, Associate Economic Affairs Officer, Commission Affairs and Trade Development Division, Economic Commission for Europe, Geneva

Representative of the Food and Agriculture Organization of the United Nations :

- Mr W. A. Dill, Chief, Inland Resources Section, Fisheries Division, Rome, Italy

Representative of the Organization for Economic Co-operation and Development :

- Mr P. Lieben, Administrator in the Scientific Affairs Directorate, Paris, France

Secretariat :

- Dr Allen V. Kneese, Head, Water Resources Programme, Resources for the Future Inc., Washington, D.C., USA (*Consultant*)
- Mr R. Pavanello, Chief, Environmental Pollution, Division of Environmental Health, WHO (*Secretary*)

* Unable to attend :

- Professor S. N. Čerkinskij, Chair of Community Hygiene, First Moscow Medical Institute, Moscow, USSR.
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PRINTED IN SWITZERLAND

WATER POLLUTION CONTROL

Report of a WHO Expert Committee

INTRODUCTION

The WHO Expert Committee on Water Pollution Control met in Geneva from 6 to 12 April 1965. Dr P. Dorolle, Deputy Director-General, opened the meeting on behalf of the Director-General. The Committee elected Mr Harry G. Hanson as Chairman and Dr A. Key as Rapporteur.

Because water pollution is caused by the activities of mankind, it is natural that it should manifest itself to the greatest extent where the density of population and degree of industrialization are greatest. The Committee was therefore appointed to review the most important problems of water-pollution control in such areas and to advise on appropriate corrective measures ; to evaluate progress and trends in measures for the control of water pollution, including new problems of pollution created in developing countries where urbanization and industrialization are rapidly increasing ; to identify broad areas where there is a need for investigation and research into the scientific, technical, economic, social and administrative aspects of such problems ; and to formulate recommendations for national and international action.

The Committee did not deal in any detail with radioactive pollution, partly because the problem is being dealt with elsewhere and partly because in most countries it is now (and perhaps will be for some time to come) due to natural radioactivity and fall-out from the atmosphere. It is not therefore associated with the major problem of what may be termed " conventional pollution " and does not influence in one way or another the urgency for the control of conventional pollution.

1. EXTENT AND PROBABLE GROWTH OF WATER POLLUTION

1.1 Water pollution in the developed countries

Almost all countries of the world have a water-pollution problem, and where it is serious it first became so as a result of urbanization and industrialization. The countries with the longest experience of it are therefore those that are now industrially well developed, and it is those, too, that have had the most experience in ways of overcoming the problem. The fact that some of these countries are spending hundreds of millions of

dollars each year on capital works to secure pollution abatement is itself evidence that they are conscious of the harm that it does.

A few of these countries consider that they now have the problem under control in two senses : first, they have the necessary laws and administrative arrangements to enable control to be effective ; secondly, they feel that after growing year by year for many decades, pollution is now being reduced in severity.

But this is not to say that any country is satisfied with the present position or looks forward to the future with any degree of confidence. Even the developed countries are still developing. The demand for water, both domestic and industrial, is continually increasing, and even if the rate of increase is as low as 4% per annum, the demand will double about every 20 years. This has several important consequences.

First, even supposing that the proportion of water requiring purification before use does not increase, it will be necessary to double water-treatment works every 20 years. Secondly, the additional water will become increasingly costly to obtain, because the nearer and cheaper sources have already been tapped. Thirdly, polluted waste water will also increase in volume, and expenditure on treatment plants will increase proportionately. Fourthly, even if the rivers that receive the resulting effluents remain the same size, the amount of dilution available to absorb the resulting pollution, expressed as a ratio of river flow to effluent flow, will progressively fall so that the degree of treatment provided must be correspondingly increased, at an additional cost. Fifthly, the natural flow in the rivers is not likely to remain as large as it is now, because increasing quantities of water will be abstracted to provide for the additional water demand. Still more efficient effluent treatment will be necessary to compensate for that.

When all these factors are taken together, it is clear that even a well developed country, with adequate authorities, good intentions and no lack of money, must view the future with a certain misgiving.

1.2 The problem in the developing countries

The problem is likely to be even more severe in the developing countries, where rates of population growth are higher, where industry must not only provide for an increasing population but also raise the standard of living, and where financial resources are slender and subject to what must seem at first sight to be more urgent demands.

A few statistics will suffice to establish the point. A recent survey¹ by WHO stated that the rate of population growth in 75 developing countries was 40% greater than the average for the world as a whole, which probably means that it is at least double that in some of the older industrial coun-

¹ *WHO Chronicle*, 1964, 18, 180.

tries. Water supply and pollution problems may therefore double, or more than double, every ten years for some decades.

Further, the world's increasing population, already greatest in the developing countries, is taking place largely in towns and cities; it is estimated that the world rate of urban growth is $2\frac{1}{2}$ times greater than the rate of rural growth. Since it is urban growth that causes the most intense pollution problems, it would appear that a doubling of the problem every ten years may well be a gross understatement of the position.

But there is another serious aggravating factor. In the developed countries most people are already satisfactorily supplied with water, and with a sewerage system to remove the water after use. This is not so in many countries. In the countries referred to in the survey mentioned above, only 30% of the population were supplied with piped water in or near their houses, and even these supplies often functioned for only a few hours each day. Even to rectify this gross deficiency is a formidable task, although much is undoubtedly being done.

The provision of a good water supply, however, must necessarily be followed by the provision of sewers, and in this matter there is a great deal of leeway to make up. In some countries there are virtually no sewers, but for the sake of good sanitation they will presumably be provided in due course. In that case much waste polluting matter, now allowed to defile the immediate environment of man, will be washed away and, unless treatment is provided, make a further great addition to the pollution of rivers.

Many of the developing countries (and, indeed some of the developed countries) are situated in arid parts of the world or where such rainfall as there is is largely seasonal. To supply the food that is urgently needed, the practice of irrigation is growing rapidly. Irrigation is needed only in the dry season, when the rivers are low, and, since much of the irrigation water is evaporated, there is a net loss of water from the area at a time when it can least be spared. On this account, the capacity of rivers to absorb pollution is likely to fall rapidly. It should also be borne in mind that irrigation can itself cause river pollution—pollution, moreover, of a kind particularly difficult to rectify (see section 3.3).

It is quite apparent, therefore, that water pollution must be expected to increase very much faster in the developing than in the already developed countries. If the cost of remedial measures increases proportionately, the problem will shortly be of overwhelming magnitude, and advice and assistance are urgently needed so that it may be tackled, effectively and economically, as soon as possible.

The evidence is not wholly statistical. Many countries have reported the occurrence for the first time, within the last decade or two, of rivers that are repulsive and stinking, of fisheries destroyed, of water supplies no longer as acceptable as they used to be, of water-treatment plants now unable to

provide a satisfactory supply and of beaches once attractive now repellent and unhygienic. Firm figures of these occurrences are hard to obtain because countries do not like to publish them, and no accurate assessment can therefore be made, but it is plain that these conditions are likely to become the rule in rapidly developing countries unless prompt action is taken.

2. CLASSES OF WATER POLLUTION

There are many types of water pollution, each with its own particular effects. It is convenient to divide them into classes, as follows :

(a) pollution by bacteria, viruses and other organisms that can cause disease ;

(b) pollution by decomposable organic matter, which, by absorbing the oxygen in the water, kills fish, produces offensive smells and gives rise to general unsightliness ; such pollution, if not excessive, is largely destroyed in due course, and the river becomes wholesome again ;

(c) pollution by inorganic salts, the characteristic of which is that they cannot be removed by any simple conventional treatment process ; they may make the water quite unsuitable for drinking, for irrigation and for many industries ;

(d) pollution by plant nutrients—potash, phosphates, nitrates, etc.—which are also largely inorganic salts but which have the added property of increasing weed growth, promoting algal “ blooms ” and producing, by photosynthesis, organic matter that may settle on the bottom of a lake (see section 3.6.1) ;

(e) pollution by oily materials, which may be inimical to fish life, cause unsightliness, screen the river surface from the air thus reducing reoxygenation, accumulate in troublesome quantities in suitable circumstances, and have a high oxygen demand ;

(f) pollution by specific toxic agents, ranging from metal salts to complex synthetic chemicals.

Also worthy of mention are : waste heat, which can be considered a pollutant in the sense that it renders the river less suitable for certain purposes ; silt, which can be washed into the river in very large quantities, causing changes in the character of the river bed ; and radioactive substances.¹

¹ For further information on radioactive-waste disposal, see Kenny, A. W. (1956) The safe disposal of radioactive wastes, *Bull. Wld Hlth Org.*, **14**, 1007-1060; Kenny, A. W. (1962) Sanitary engineering aspects of nuclear energy developments, *Bull. Wld Hlth Org.*, **26**, 475-494; and the following publications of the International Atomic Energy Agency, Vienna : *Radioactive waste disposal into the sea* (Safety Series No. 5, 1961) ; *Disposal of radioactive wastes into fresh waters* (Safety Series No. 10, 1963) ; *The management of radioactive wastes produced by radioisotope users* (Safety Series No. 12, 1965) ; and *Disposal of radioactive wastes into the ground* (Safety Series No. 15, 1965).

Human sewage contains matter of the first four classes, industrial wastes any or all of the classes, and drainage from agricultural land can cause pollution of classes (c), (d) and probably (f).

3. THE EFFECTS OF WATER POLLUTION

Water pollution can affect adversely and even catastrophically every beneficial use of water such as public supply, industrial use, the production of fish and other aquatic foods, irrigation, stock watering, transport, recreational activities, and amenity.

3.1 Effect on human health

While the story of the almost complete eradication of the classical waterborne diseases from many of the developed countries is well known, these diseases are still endemic in other parts of the world, and it will accordingly be useful to describe the part that polluted water plays in their transmission.¹

Cholera, typhoid fever, and dysentery have long been known to be associated with polluted water, in which the causative organisms are transported and survive until they enter, directly or indirectly, the human host. Mortality rates for these diseases vary from virtually nil to 50 per 100 000, and the gross inequalities are largely a reflection of the adequacy of pollution control of water used for drinking.

There are other diseases, particularly important in developing areas, in the transmission of which polluted water plays a major role. Bilharziasis, for instance, is commonly transmitted by bathing in polluted canal water. Urban filariasis is transmitted by the bite of an insect vector that breeds in polluted water. Water polluted by the virus of infective hepatitis has been shown to be responsible for a major epidemic of 29 000 cases in India.

Polluted waters may also be the cause of non-infectious diseases, because they may contain toxic material of various kinds originating largely in industrial wastes, although domestic sewage may not be entirely guiltless. The toxicology of many new pollutants is not yet well understood, but it

¹ Further information on water-borne diseases will be found in the following publications:

Emili, H. & Tomašić, P. S. (1956) *The health aspects of polluted water with special reference to the epidemiology of water-borne infections*. In: *Water pollution in Europe, Fourth European Seminar for Sanitary Engineers, Opatija, Yugoslavia, 22-28 April 1954*, Geneva, p. 94 (World Health Organization, Regional Office for Europe);

Bull. Wld Hlth Org., 1961, **25**, No. 4-5;

Bull. Wld Hlth Org., 1962, **27**, No. 1;

WHO Expert Committee on Poliomyelitis (1954) *Wld Hlth Org. techn. Rep. Ser.*, **81**;

WHO Expert Committee on Filariasis (1962) *Wld Hlth Org. techn. Rep. Ser.*, **233**; and

WHO Expert Committee on Hepatitis (1964) *Wld Hlth Org. techn. Rep. Ser.*, **285**.

is known that some of them have an adverse effect on fish and other aquatic organisms, and it is clearly wise, in the absence of proof to the contrary, to assume that waters that are toxic to fish are unsuitable for human consumption. Treatment may make the water safe to drink but can greatly increase the costs of water supply. Even then the water may have unpalatable tastes and odours that are expensive to remove and may compel consumers to rely heavily on bottled water, the cost of which is a further part of the over-all price of water pollution.

3.2 Industrial water supplies

Water pollution may reduce the utility of water for industrial processes. Many such processes utilize a quality of water not unlike that usually prepared by municipal treatment plants. However, the range of qualities required or desirable in industrial application is very wide. Cooling water can often be of comparatively low sanitary quality, but the presence of waste heat and of corrosive and scale-forming materials is undesirable. Some processes require unusually soft water; others can tolerate hard water. A large part of the water used in the paper and pulp industry can be of relatively low quality in some respects, but it should contain little iron, manganese or carbon dioxide. High-pressure-boiler feed-water, used in a variety of industries, must be of very high purity to prevent corrosion, scale formation, and the accumulation of biological slimes. Steel-rolling mills are damaged by water containing concentrations of chloride tolerable in drinking water. In short, polluted water sources can involve industry in substantial costs—the costs of purifying the water, of repairing damaged equipment or of making extensive adjustments to the industrial processes themselves.

3.3 Water pollution and agriculture

Without question, the world cannot be supplied with the food and raw materials it needs without large-scale irrigation. But irrigation can be a major cause of water pollution, and water pollution in turn can greatly affect the productivity of irrigated land.

All natural water contains inorganic salts, particularly chlorides, the concentration of which depends on the history of the water after it has fallen as rain. As the irrigation water evaporates in the field, the salts concentrate in the wet soil. If they were allowed to accumulate, fertility would diminish and eventually the land would become barren. They must therefore be washed away. If this is done by heavy subsequent rainfall, little harm may result, because the salt will be diluted again. But if the salts are removed by using excess irrigation water, the concentration of salt in the drainage, which often goes back to the river, may be far greater

than it originally was. The drainage will also carry away salts applied to the land as fertilizers, for example, sulfate from ammonium sulfate. The consequence will be an increase in the salinity of the raw river water. Irrigation may therefore itself produce a pollution problem—pollution, furthermore, of a type that cannot be removed by conventional processes. Failure to provide adequate drainage for irrigation projects may also gradually raise the salinity of underlying ground waters.

These effects (which are not merely hypothetical—they have occurred in several places) will naturally be worst in the case of long rivers, the waters of which are used repeatedly. They clearly illustrate the necessity of giving full consideration to matters of water pollution before deciding on irrigation schemes. The appropriate authorities should be so constituted as to ensure that this is done.

Whether in such cases it would be worth while to control upstream irrigation because of its polluting effect would depend on the damages associated with increased levels of salinity. A high level of salinity in water is very damaging to a number of industrial processes, and it reduces the suitability of water for municipal supplies. Yields of crops irrigated with saline water also tend to be reduced. Also the amount of water applied for irrigation has to rise to flush out the salts if the fertility of the soil is not to be destroyed. In devising a management programme, all these effects should be identified and as far as possible evaluated in terms of their economic impact.

On the other hand, irrigation with water that contains organic wastes can yield benefits, since some of these wastes may be plant nutrients. Highly treated effluents may contain these nutrients in an already mineralized form. If discharged into a stream or lake, they may cause undesirable levels of algal growth in the receiving waters. In assessing the economics of transporting such wastes to irrigated areas, their beneficial effects to agriculture should be borne in mind. In many arid areas irrigation will turn out to be the preferred means of disposing of effluents, but the possible contamination of water supplies resulting from this practice needs careful consideration.

There is another way in which irrigation can seriously increase pollution problems. Water used for irrigation does not return to the river in its entirety; frequently only a small proportion returns. Moreover, it is taken from the river principally at those times when the flow in the river is near its minimum, so that the natural flow is seriously diminished, frequently to only a small fraction of what it would normally be. The amount of dilution available to domestic and industrial effluents is reduced in like proportion, and the intensity of pollution is correspondingly increased. Water that is polluted to a small degree but that is still safe as a source of public supply can become completely unsuitable for this purpose if irrigation water is drawn from the river above the point of entry of the pollution.

The question would naturally arise of who was in fact responsible for the water being unsuitable for public supply. The pollution-control authority clearly could not discharge its duty of maintaining suitability unless it also had some control over the abstraction of water for irrigation. There is obviously a strong case for creating authorities that are responsible for quantity as well as quality, i.e., making them the custodians of the water resources of their area.

Drainage from the land (irrespective of irrigation) may introduce plant nutrients (nitrates, ammonia, phosphates) into a river, and these substances can also act as nutrients for aquatic plants, especially algae. It is not practicable to do much about this, but it is a matter to be borne in mind. Traces of pesticides may also enter the river in this way. Again it is difficult to institute any form of control, but the question of the fate of pesticide residues is one of current world-wide concern, and nothing more need be said about it here.

Finally, it should be pointed out that the health of animals can be affected by certain pollutants in the water they drink, and occasionally the effect could be passed on to human beings through milk and meat.

3.4 Aquatic food resources

The effects of water pollution on fisheries have long been recognized ; in fact it has often been the killing of fish that has drawn man's attention to the presence of polluting substances.

Harm to a fishery through pollution may arise in several ways. Fish may be destroyed directly by specific toxins or through oxygen depletion ; their spawning grounds may be damaged by the sedimentation of suspended matter ; their behaviour and abundance may be affected by changes in temperature ; and their fitness as food may be spoiled or their market value lowered through changes in flavour or through contamination by pathogenic organisms. Commonly used pesticides may also kill fish, and this danger to fisheries may increase rapidly.

It is important to realize that, although in developed countries fresh-water fish comprise only a small—though not insignificant—proportion of the food consumed, in some developing countries they comprise a most important source of food supply, particularly of protein. It would be a tragedy if this source were destroyed, and the greatest risk may be that the destruction may occur so slowly as not to be proven until the damage has been done.

Shellfish, which live and are often cultivated in shallow coastal or estuarine waters, present a special risk because micro-organisms concentrate within them, and, if they are eaten raw and without special cleansing, they can easily transmit water-borne diseases. Cleansing processes have been developed, but they increase the price of the shellfish. In the absence

of these processes, the bacterial quality of the water they inhabit should approach that of drinking water.

3.5 Aesthetic and recreational considerations

While the quality of water for municipal and industrial uses and for food production is a basic consideration, there can be no doubt that some of the earliest efforts to control pollution in the developed countries had their origin in man's aesthetic sensibilities. The repulsive suffocating reek resulting from discharge of untreated sewage by the large cities of early modern times is made plain in many accounts. The smells so graphically described were largely the results of anaerobic processes. Problems of this kind still exist in the neighbourhoods of cities in developing countries, and, in the absence of effective sewage treatment, they will undoubtedly become worse. This is one important reason for trying to find inexpensive treatment methods as sewerage systems are provided for cities in developing countries.

Aesthetically repulsive conditions are not limited to those offending the sense of smell. Floating materials of any kind are likely to be offensive, and floating sewage solids especially so. Suspended sediment and industrial wastes, including dyes, also reduce the visual appeal of water. Dense algal growth resulting from residual plant nutrients can also make water both unattractive and odorous. In developed countries, the grossest aesthetic nuisances have mostly been dealt with; the provision of standard sewage treatment can usually keep them under control. However, a large demand has developed and is continuing to develop for high-quality water for recreational purposes. Political pressures for the improved water quality of streams, which have been evident in the United States, the United Kingdom, France, Belgium, the Netherlands and Germany in recent years, probably arise principally from aesthetic and recreational demands. In some developing countries, too, the demand raised by tourists may be important. Recreational uses may demand higher qualities of water, at least in some streams, than could be justified solely on the basis of meeting municipal and industrial demand.

3.6 Special cases of water pollution

3.6.1 Lakes

Polluting substances in rivers are continually travelling seaward, and in times of flood even substances that form sludges on the river beds are washed away. This is not so in lakes, even if they form part of the river. The velocity of water through them in times of flood is usually not great enough to carry away deposited matter; indeed, they are often so deep that the current never affects the bed at all. Deposited pollution therefore

accumulates and remains in the lake almost indefinitely. The character of the lake changes fundamentally ; it becomes subject to algal blooms, which may be unsightly and create embarrassing difficulties in water-treatment plants, and to periodic deoxidation, which may affect all life within its waters. To keep a lake in its most desirable condition frequently necessitates a much more stringent pollution-control policy than is required to maintain a satisfactory river, and the cost may be far higher. Lakes are a valuable resource, however, and are worth preserving, although whether they are worth preserving at all costs is a matter of policy, national or international according to the situation of the lake. The decision would depend at least partially on economic analyses and on the wealth of the country.

3.6.2 Beaches

Much has been written about the pollution of bathing beaches by sewage in various parts of the world. Present evidence is that in temperate countries the risk of bathers contracting water-borne diseases is far less than might have been thought. How far this applies to tropical areas, where such diseases are already endemic and the proportion of carriers high, is not known, and more research is needed. A better understanding is also required of the death-rate in the sea of disease-causing organisms of all kinds.

Apart from health, however, beaches fouled by sewage are offensive and unhygienic. In many parts of the world the public rightly believes that it is entitled to something better than this. The offensiveness can be removed from the beaches either by the retention of sewage on land (i.e., by sewage treatment) or by discharging the sewage to the sea at a point and in a manner that will ensure its not being carried back to the beaches. Sewage undoubtedly purifies itself in the sea, and, provided the discharge point is well chosen, satisfactory conditions should be maintained. Whether the removal of offensiveness will reduce the health risk to negligible proportions is still a matter for argument. It is likely to do so in temperate climes, but it is doubtful if it would do so in tropical ones. More research is needed to provide the answer.

Tourism has become a major source of income and foreign exchange in many countries. A number of these are low-income countries in which tourism can play a substantial part in plans for raising *per capita* income. In, for example, the Mediterranean and Latin American countries, the recreational value of fine sunny beaches and clear water is a major factor in attracting tourists. Unfortunately many of these beaches have become fouled by untreated sewage, which, while not perhaps creating a great risk to health, does present a major aesthetic problem. Research has demonstrated that the demand for outdoor recreations tends to rise much faster than *per capita* income, and the recreational industry promises to be one

of the most rapidly growing of all. Many countries would do well to take account of this and of the important role which a safe and attractive environment will play in it.

3.6.3 *Underground water*

Underground sources provide a high proportion of people with their drinking water, although the proportion is falling as the population increases and becomes urbanized. It is an undoubted fact that ground water without treatment is much safer to drink than any river water. It is evident that the ground itself provides an effective purifying medium, although it has so far proved impossible to define quantitatively its capacity in this respect. If ground water does become polluted, however (and many cases, usually of shallow wells, are certainly known), the effect is serious, because provision may not have been made to treat it after abstraction. It is therefore important to protect ground water as far as possible. In particular it is important to protect it from the effects of effluents that are discharged onto or into the ground—a measure sometimes resorted to when effluents would cause too much pollution if discharged into rivers. The subject is a complex one and by no means fully understood, but it may be justly held that ground-water no less than surface water constitutes part of the water resources of an area and should therefore come under the purview of the river authority. This would allow some over-all policy embracing ground-water protection and utilization to be worked out and followed.

Because far less is known about the quality management of groundwaters than that of surface waters, it presents an especially important area for research. In particular, means should be developed for forecasting the effects of recharging ground water with contaminant-bearing surface water. This is particularly important in view of the increasing recharge of ground water with sewage water that is occurring in such diverse locations as Israel and the USA. The practice of ground-water recharge with effluents is carried on as a means of tertiary treatment, to utilize the aquifer as a storage basin and distribution facility, and to repel saline water intrusion along sea-coasts and deltaic areas. A related matter involves forecasting the effects of surface-water irrigation projects on ground-water resources. In view of the experience in the Indus basin, this is a factor that cannot be neglected in the planning of irrigation projects.

4. METHODS OF TREATING POLLUTING LIQUIDS BEFORE DISCHARGE INTO RIVERS

Methods of reducing pollution to almost any desired degree, up to certain limits, are available and in widespread use in the developed countries.

4.1 Domestic sewage

The simplest way of treating domestic sewage is by sedimentation, which largely removes the suspended solids and reduces the general polluting effect by up to 50%. The grosser signs of sewage contamination are removed, and in a few instances no more treatment may be needed. But the resulting effluent still has a high demand for oxygen, is highly charged with potentially harmful bacteria, can cause trouble from offensive smells and can destroy the character and desirable properties of a river.

Further treatment usually takes the form of biological oxidation, which causes natural purification to take place at a greatly increased rate, followed by further sedimentation. The total effect of the treatment is to reduce the solid pollutants by 90-95%, the oxygen demand by a similar proportion, and the bacterial content to an extent which may vary widely from 80 to 99%. The effluent is usually clear and relatively stable, in the sense that only in extreme circumstances will it deoxygenate a river and create smells. Usually the river can be relied on to remove almost the whole of the remaining organic impurity within a few kilometers, although in some cases residual plant nutrients and associated algal growths are a menace, particularly in lakes and estuaries.

Domestic sewage inevitably adds to a river a quota of inorganic pollution and also a certain amount of persistent organic pollution. Both these types of pollutant are unaffected by sedimentation or biological treatment. Their effect, however, is only a minor one, unless the water is reused several times.

One of the greatest problems associated with sewage treatment is the treatment and disposal of the resulting sludges. In one sense they are not directly connected with water pollution unless they are allowed (by design or accident) to enter a stream, but the cost of dealing with them is so great a proportion of the total cost of sewage purification that a substantial reduction would materially cheapen pollution control. In many cases they can be applied to land as a low-grade manure, but sometimes public health considerations prevent this, and the presence of toxic substances, particularly metal oxides from industry, may do harm. Another method that has been advocated is the composting of sludge with garbage. The advantages of this have been widely publicized, but there are some disadvantages, and the costs may be considerable. A dispassionate economic appraisal based on large-scale experience would be valuable.

More important, perhaps, is the possible use of composting in the disposal of night-soil. This contains more plant-nutrient matter and less water than sewage sludge and can be a much greater danger to health, besides being offensive. Composting is therefore a more attractive proposition, and it is suggested that it be considered for those towns and cities, of which there are many, where sewerage is not likely to be provided for some years.

4.2 Industrial effluent

Many industrial effluents are also amenable to biological treatment, particularly if sewage is present. There is a marked tendency in the developed countries for industrial effluents to be discharged to the sewers for treatment in admixture with sewage. In suitable cases and under proper control, this makes for economy and efficiency and, within limits, is to be encouraged. Sometimes, however, the industrial effluent may not only fail to respond to treatment but may inhibit the purification of sewage or even affect the structural materials of the sewers and plant. Such effluents may need to be excluded from the sewers or to be admitted only after effective prior treatment at the factory. The whole problem is one of considerable complexity and requires specialized knowledge of the various factors involved.

Some industrial effluents contain considerable quantities of inorganic salts not removed by treatment. There is no practical way of dealing with these, and, if they are likely to have too much effect on a river, the effluent should be diverted elsewhere or, in an extreme case, the factory sited in some more suitable location.

Specifically toxic materials are not, so far as is known, present in harmful concentrations in purified domestic sewage, but this is a matter that would merit medical investigation. Of much greater importance are industrial effluents, which may contain substances toxic to man, or substances that can kill fish, damage agriculture, or interfere with the normal functions of a stream. Some of them are destroyed during sewage treatment, so that the discharge of industrial effluents to sewers is a considerable safeguard. No complete list of these substances can be prepared since new ones are continually being produced, but for many of them sufficient information is available to allow tolerable concentrations in rivers and water supplies to be worked out. Their possible presence in water supplies obtained from rivers receiving industrial effluents is a matter of continual concern.

Some industrial effluents are unsuitable for immediate discharge into sewers and must first be treated. This treatment is often chemical and sometimes biochemical. The process depends on the nature of the effluent, and, if adequate incentives are offered, suitable processes can usually be developed, so that it is possible to preserve in reasonably good condition a river that passes through an industrial area. But to do so needs continual vigilance, a strong and technically competent river authority, and sufficient financial resources.

In some developed countries, industry accounts for a far larger share of the total waste load discharged to receiving waters than does the sewage flow of municipalities. In developing countries, industrial sources of water pollution are rapidly increasing. While the treatment of effluent is a very important means of reducing industrial pollution, the design and management of industrial processes, including waste recovery, can be at least

equally significant. Studies have shown that the waste load per unit of product varies by a large multiple from plant to plant in the same industry, depending on the processes used and the way they are managed. This is especially true in industries producing organic oxygen-demanding wastes. Sometimes waste-reduction procedures will turn out to be profitable. More often they will be the least expensive way to reduce waste discharge, at least over a certain range.

It is particularly important that developing countries should be informed about, and should take account of, these possibilities. The most economical way to reduce waste discharges through process design is to incorporate the waste-reducing processes when the plant is constructed. They are often very expensive to introduce once the plant is in existence.

4.3 Developing countries

Lack of financial resources is one of the formidable difficulties of developing countries, and there is a great need for cheaper methods of purification, both of sewage and of water, than are generally available at present. The developed countries, too, would welcome cheaper methods, and there is scope for more research towards this end. The developing countries often have advantages that might well be exploited. One is a greater amount of sunshine accompanied by high air temperatures, and another is (for the time being) a greater availability of land. There is wide scope for developing methods of sewage treatment that utilize these advantages, and such methods could well be much cheaper than conventional ones. Research could profitably be carried out in this direction.

It is becoming increasingly evident that purification processes will be needed that are far more effective than those at present being used. This is particularly true where development is so concentrated that the same water is used repeatedly for various purposes. Such processes may also be needed shortly in some developing countries, particularly those where water is scarce. Some research into more efficient processes is being carried out in the more developed countries, and this work is to be strongly encouraged.

4.4 Other methods of controlling water quality

Although the treatment of effluents is the major means of improving the quality of water, there are other possibilities that deserve mention.

It is sometimes feasible to store effluent during times of low river flow and to release it when high flow gives a large dilution. This method is particularly applicable to concentrated wastes of small volume. It is already practised in some countries and might find considerable further application in those parts of the world where annual floods alternate with periods of

drought, or in schemes in which deliberate action is taken to augment stream flow for other purposes, when the ability to accommodate a greater pollution load without diminution in quality would be an added economic advantage.

In dry periods, when stream flows are low, it may be advantageous to use domestic sewage, partially or completely purified, directly for irrigation purposes, provided public health considerations do not militate against such a practice. The use of domestic sewage for this purpose would prevent pollution reaching the river, would preserve for the river the flow that would otherwise be used for irrigation, and would supply plant nutrients to the wanted crop and deny them to the unwanted algae and other stream vegetation. This practice could also be applied to certain industrial effluents, particularly those of the food and drink industries and others whose effluents do not contain synthetic organic compounds or excessive mineral matter.

Other possible methods of improving stream quality include the introduction of artificial aeration at critical points and the construction of lagoons, oxidation ponds or sedimentation basins within the river itself.

The applicability of these courses of action would depend on the local topographical, geological and hydrological conditions, and each would need detailed economic appraisal and comparison with other means of achieving the same end. A competent and effective river-management body is needed if such opportunities are to be most effectively exploited.

5. ASSESSMENT OF QUALITY OF RIVERS AND EFFLUENTS

The adoption of a policy of water-pollution control in any country or river basin is ultimately a matter for the government or governments of the area concerned. There are, however, certain preliminary matters on which such a policy, if it is to be a sound one, should be based.

5.1 Measurement of quality

The first requisite for quality control is to establish a basis for the measurement of quality. No single measurement is sufficient, because quality can be impaired in many different ways, and each way needs to be assessed separately. There are, however, a few fundamental measurements that apply to most kinds of water.

5.1.1 Dissolved oxygen

Probably the best single indicator of the general condition of a river is the amount of dissolved oxygen that it contains. The figure more than any other determines whether the river is wholesome, whether fish can live in it, and whether natural purification is likely to proceed satisfactorily. Naturally, these properties are also influenced by other factors, but a major

step will have been taken in policy-making if it is agreed that the dissolved-oxygen content shall not be allowed to fall below a certain figure, expressed either in milligrams per litre or, perhaps not quite so satisfactorily, as a percentage of saturation. The Expert Committee therefore recommends this test as a primary one by means of which the condition of a river shall be both judged and controlled.

5.1.2 *Biologically oxidizable matter*

It is generally important to know how much biologically oxidizable matter is present. This indicates how much oxygen is required for the river to purify itself. A test that has found wide acceptance for this purpose is the so-called biochemical-oxygen-demand (BOD) test, which gives a laboratory measurement of the oxygen utilized under standard conditions. It can be applied both to river-water and to effluents and has particular merit in the quality control of the latter. It is possible, though it may not always be necessary, to arrive at a policy that aims at limiting the BOD of a river to a stipulated maximum. However, it is more practicable to control added pollution by limiting the BOD of effluents to a certain figure. The Committee recommends the use of the test for this purpose.

5.1.3 *Ammonia*

The content of ammoniacal nitrogen also gives a useful general index of the quality of river water. Ammonia may, in sufficient concentration, be toxic to fish, and it seriously affects the chlorination process if the water is to be abstracted for public supply. Moreover, it represents an ultimate demand for oxygen that is not revealed by the usual BOD test. A test for ammoniacal nitrogen can be used both for assessing river quality and for controlling effluents.

5.1.4 *Organic matter*

It is useful to know the total amount of organic matter present, because that which is not oxidizable biologically may in certain circumstances be as important as that which is. For this purpose, a chemical oxidizing agent is used. There is no universally agreed technique, but in principle it would be wise to use the reagent and technique that give the most nearly complete oxidation of all organic matter without giving misleading results in any other way. Several methods may be used, and there is scope for research to determine the best.

5.1.5 *pH*

It is necessary to secure that the pH value (indicating the intensity of active acidity or alkalinity) of the river lies between certain limits, in order to ensure that the biological reactions that occur in it are beneficial and

sufficiently active. The test for pH is a well recognized one that may be used both for river-water and for effluents.

5.1.6 *Salinity*

For most rivers the question of excessive salinity due to the presence of sodium chloride does not arise. But where there is much reuse of water and particularly where irrigation is carried out on a large scale, the threat of excessive salinity, which makes the water unsuitable for public supply or for further irrigation, is very real. Accordingly the Committee included the determination of chloride among the basic tests for water quality.

5.1.7 *Temperature*

It is now commonly agreed that temperature variations from the normal, particularly higher temperatures, constitute pollution in the sense that they make water less suitable for certain purposes. Temperature, of course, can be readily determined, but it must be remembered that heated discharges are likely to set up a temperature gradient with depth, which may persist for a surprisingly long time before complete mixing occurs.

5.1.8 *Harmful bacteria*

One of the main purposes of water-pollution control (and historically the first reason for it) is the prevention of water-borne disease, and to this end it would seem to be a prerequisite to detect the presence in water of harmful bacteria and other forms of life. The fact is, however, that in many developed countries the bacterial content of river water is not determined nearly so frequently as some of the properties already discussed, the reason being that, because of the almost 100% provision of piped water supplies, people no longer take water for drinking direct from rivers and have in fact learned that they should not do so. It is believed that it is quite impracticable to maintain any river water flowing through an inhabited area in such condition that it will, without treatment, satisfy the bacteriological requirements of drinking water. Although there is some benefit in, and even necessity for, keeping the bacterial quality of rivers as high as reasonably possible (particularly if they are used for bathing or shellfish culture, when scientifically derived standards should obviously be maintained), it may be more practical, and perhaps preferable, to keep the water in a condition where harmful bacteria can easily be killed by treatment than to maintain low bacterial counts in water that is less easily treated.

The situation may be different in some developing countries, where piped water supplies are less common and where water for drinking may be taken direct from rivers. In these countries, the bacterial condition assumes greater importance, and greater efforts are justified to keep it as good as possible. This poses a difficult, and perhaps insoluble,

problem, because it will never be possible to achieve perfection, and it is precisely the developing countries that are economically less able to achieve standards that might be possible elsewhere. Also it is in such countries that the risk of water-borne diseases is usually greatest.

Where it is necessary to determine and control the bacterial content, the best general group of indicator organisms are the coliforms, and the tests described on pages 65-73 of the WHO publication on drinking-water standards¹ should be used.

5.1.9 Other tests

The foregoing tests may be loosely described as general tests for quality, and most of them will need to be taken into account when devising and implementing any pollution-control policy. There are, however, many other tests that will need to be made in certain circumstances. These include tests for hardness, for the content of metal salts, nitrate and phosphate, and for the content of toxic materials that are, or may be, discharged into a river. It is not possible in this report, however, to describe all the circumstances in which all the tests become important.

5.2 Purity required for various purposes

It is necessary to know what degree of pollution begins to affect, or seriously affects, or completely prevents, certain uses of river-water, including water supply, fisheries, irrigation, recreation and various industrial uses. In the case of public water supply, the requirements for the protection of health are paramount, and the public health authority should be responsible for specifying them. WHO has already published International¹ and European² standards for drinking-water. The latter book includes figures for raw water from which the drinking-water is produced by treatment, but it must be realized that treatment processes differ in efficiency and are continually being improved. The fundamental requirements are for the water after treatment; the raw-water quality is less important so long as the treatment will reliably raise it to drinking-water quality. Further information is available about other uses, but in each case, except fisheries (which occur in the river itself) and irrigation (where treatment may be impracticable), allowance must be made for the possibilities of treatment after abstraction.

Many attempts have been made to relate the quality and the use of rivers, so that it is possible to say either that a river, being of a certain quality, may be used for certain purposes, or that the river, being required for

¹ World Health Organization (1963) *International standards for drinking-water*, 2nd ed., Geneva.

² World Health Organization (1961) *European standards for drinking-water*, Geneva.

certain purposes, must be maintained at a certain quality. Such classifications can never be absolute because of the complexity of pollutants and their interrelationship, but even approximate classifications can be valuable and can assist in determining the action necessary to achieve desired objectives. Some countries have used such classifications and have found them to be valuable tools. But the Expert Committee is not able to recommend any one system of classification in preference to any other.

5.3 Level of quality

The final stage of policy-making is to decide the level of quality at which a river should be maintained. This requires the criteria and guidance given in 5.1 and 5.2 above, but superimposed on them must be an assessment of the costs involved and the benefits obtained, as outlined in section 7.4.

Having decided on the quality of river-water desired, the river-control authority must determine the restrictions to be imposed on the effluents discharged, or likely to be discharged, into the river. To do this requires a knowledge of the nature, concentration and volume of the effluents and a knowledge of the flows in the river, which quantities determine the final dilution.

6. LAWS RELATING TO POLLUTION CONTROL

The Expert Committee considered the pollution laws of several countries and found them to be extremely varied.

The laws may be divided into two groups according to their age. Those that were established many years ago and whose efficiency can be soundly judged on the basis of experience were not designed to cope with the situation as it now is. They are therefore generally quite inadequate. On the other hand, the laws laid down recently, while relevant to the present situation, are not supported by a sufficient body of experience to allow their effectiveness to be judged. It is therefore possible only to offer an opinion on how effective the laws are likely to prove in practice. For some of them, the prospects appear to be good.

6.1 Practicability of laws

Countries with severe laws against pollution have not in fact avoided the occurrence of widespread pollution. One reason for this may be that laws calling for no pollution at all do not represent a practical policy and therefore fall into disrepute. In a world becoming rapidly urbanized and industrialized, it is not possible to preserve rivers in their natural condition. The law should aim at *controlling* pollution.

In many cases, the penalties for breaking the law appear to be too small to act as a deterrent. The penalties, whatever form they take, should be such as to secure that the law is obeyed. The aim is to control pollution and not to collect fines.

6.2 Administration of the law

The law, however, is not primarily concerned with penalties ; it deals also with organization and administration and should be based on an agreed general policy. It should set up appropriate control bodies with specified duties and endow them with adequate powers.

The old laws were generally based on the assumption that water pollution was a local problem—in other words, that each case would affect only a small area and could be dealt with by a local organization, often the municipality. The history of pollution laws in the developed countries shows a gradual appreciation of the fact that these assumptions no longer apply in an industrialized community. Water pollution is no longer a local problem ; a single case may affect the whole of a large river system, and any scientific control may have to take into account the total situation in the whole of a river basin. Furthermore, no small local authority has either the technical reserves or the expertise to control pollution in the most efficient way. The general trend, therefore, is towards the creation of special authorities whose area of action covers a whole river system. The Expert Committee considers that this is the correct approach and recommends all countries, developed or developing, that have an actual or potential water-pollution problem to follow this trend and to frame their laws accordingly.

7. A RATIONAL APPROACH TO WATER-POLLUTION CONTROL

7.1 The need for a single authority for each river basin

In the more-developed countries during the past few years there has been a marked trend towards the creation of a single authority for each whole river system, or for more than one river system. The Expert Committee considers that this is a rational policy, because the pollution of water can affect, and be affected by, events in the drainage area far distant from the places at which polluting discharges occur, and it is clearly necessary that the body dealing with it should have a sufficiently wide outlook to consider the area as a whole.

It is true that when the river system is very large, pollution control in specific regions of it may best be administered by smaller regional bodies, but the work of these smaller bodies should conform to a general policy for the

whole basin evolved at the highest level. It is also true that, in some developing countries, action in a single locality may be so obvious and urgent that it ought not to wait for the setting up of a river-basin authority, in which case a more localized body would temporarily suffice. If this is the quicker and more practical way of proceeding, then clearly it must be commended, but it should be planned in such a way that the local body can eventually take its place within the larger body smoothly and without difficulty. The experience of the developed countries indicates the importance to the whole community of establishing the comprehensive authority as soon as possible, and the independent existence of any necessary smaller body should be regarded as purely temporary.

However, in some developing countries, staff with the ability to plan and operate on a comprehensive basis may be limited, and it may then be better to retain them in a centralized position so that they can readily turn their attention to important problems occurring in any part of the country.

7.2 Structure and responsibilities of a river authority

It has been explained how efforts at water-pollution control can be nullified by the abstraction of water not under the control of the pollution authority. It is also clear that pollution control adds to the water resources of an area as effectively as the actual provision of more water. This leads to the conclusion that pollution control and the quantitative management of water resources in a river basin are part of the same problem and should be functions of the same authority.

The water-control authority should be created by the central government, and should be given sufficient powers to administer the kind of broad national policy that has been decided on. It should be able to compel conformity with the decisions it makes and be able to exact penalties where necessary. In other words, the enforcement law should match the organization adopted. The authority should be answerable to the government, which should satisfy itself that the task of the authority is being carried out efficiently and to the advantage of the nation as a whole.

The authority should be manifestly representative of all the interests involved—public health, water supply, industry, agriculture, fisheries, transport, recreation and waste-disposal (the last being, if properly controlled, one of the uses of rivers). The claims of some of these interests are often presented very strongly, and it is felt that this could result in too little attention being paid to the health aspects. The Committee wishes to emphasize, therefore, that the claims of public health should always be regarded as of prime importance. The precise method by which all these interests are represented in the controlling authority is, of course, a matter for individual countries.

It should be noted that in this report emphasis has been placed on the planning and implementation functions to be performed by the river-basin authority and not on its exact legal or constitutional form, which will differ from place to place and should properly do so. In some countries, regional agencies of the central government may be the preferred means of performing these functions. In others, agreements between the various parties in the river basin, with greater or lesser participation by the central government, may be better. In each case, however, the major point is that the agency selected should be suitably empowered and financed to pursue an effective programme.

7.3 Staffing of a river authority

It is essential that the river-basin authority should be served by a highly competent, highly technical and independent staff, whose duties are to advise and assist in working out general policy, to examine and report on ways in which it can be implemented technically, to discuss on equal terms with experts representing various interests on matters affecting those interests, to report on (and possibly to design, execute and even operate) purification schemes and schemes for conservation and development, and to establish that their work is producing the desired results. The question of staffing is so important as to justify elaboration.

The importance in water-pollution control of sanitary engineers, chemists, biologists and medically qualified men is generally accepted. The complexity of the technical matters discussed above shows that highly competent people are necessary. But there are reports from several countries that, in competition with industry, water-pollution control and its allied fields are no longer attracting men of the necessary calibre. If means are not found of securing the services of highly competent technical people for water-pollution control and water-resource development there is a likelihood that a great deal of money will be expended wastefully and the task still not accomplished.

In many of the developing countries the situation is worse, owing to the general scarcity of competent personnel. These countries require assistance in meeting this urgent need. Without adequate staff, river-basin authorities may never come into existence, or if they do, they will remain empty shells.

7.4 Economics

Only rarely and in recent years have economists played any major systematic part in the activities of water-pollution control authorities. Of course, costing procedures have always been carried out, and indeed, all too often water-pollution control has not been initiated for allegedly

economic reasons, but economics in the true sense has a much more positive and constructive part to play. For example, once a management aim has been provisionally agreed (so much water of one quality here and so much of another quality there), there may be several ways in which it can be achieved. While there may be reasons of policy why one way is preferable to another, the decision will be largely a matter of economics, and a comprehensive analysis of all possibilities can reveal the optimum.

Further, the process could be repeated on the basis of another provisionally agreed aim, which would reveal how the cost of the project depends upon the aim to be realized. The task would be difficult and complex, and the calculation would doubtless involve computer techniques, but the answers would be valuable and, within limits, precise and quantitative.

Of course, the harm done by pollution and the benefits conferred by its proper control cannot be assessed completely on the economic level. But economic analyses can be used to compute the benefits of pollution control to industry and to water-treatment processing and even to some extent the benefits realized in the form of health, recreation and amenity. Insofar as this is possible it should be done, and the river-basin authorities should avail themselves of economic-assessment techniques performed by appropriate staff at as early a stage as possible. The Expert Committee was in no doubt that economics is part of the rational approach to the water-pollution problem, although it is by no means the total approach.

7.5 The financing of a river authority

The river authorities must be adequately financed and their income sufficiently assured to allow them to plan ahead for a number of years. This is necessary because most of them will require laboratory facilities, some of them research facilities, and all will need staff whose value will increase with length of service because of their accumulation of knowledge of local conditions.

The financing of water-pollution control may be effected in several ways, the method chosen being a matter for national decision. One obvious arrangement is that the treatment of effluent should be carried out and paid for by those who are discharging the effluents—municipalities, individual industrial firms, and so on. In this case, the river authority's task would be to ensure that the treated effluents were satisfactory. An alternative is for the producer of a discharge to pay for the treatment according to the volume and strength of the discharge and the complexity of the treatment required, but for the treatment itself to be carried out by the river authority. The authority would decide which effluents needed treatment and would design and operate the appropriate plants. Again, it might be decided that since pollution control benefits the community generally it should be financed out of general taxation—that is, by grants from the national

revenue to the river authority. Or there could be a combination of the above; for instance, an arrangement that those who pollute would be responsible for purification but that some government subsidy would be available to help them.

These are matters of national policy, and the Expert Committee cannot say with certainty that any one method is either the best or even the most appropriate in any particular case.

7.6 Public relations

The river-basin authority should, as deliberate policy, seek to establish good public relations. It is there to serve the community and each section of the community and should take pains to show that this is what it is doing.

Much will be gained in goodwill if the community is educated in the value of pollution control and is continuously informed of the activities of the authority. Certainly the various sections of the community directly affected by control measures will be more willing to co-operate if the authority explains fully the reasons for its decisions and directives and what it expects to gain by them. Even though a single authority may be in charge, the willing co-operation of all concerned makes good results far more likely.

7.7 National standards

It has been assumed that the river-basin authority will work out its own requirements for quality and composition of permitted effluents, having regard solely to the requirements of its own area. However, it is possible that the operation of all authorities within a country may be aided by minimum national standards, which would be laid down centrally. Such standards could provide a base from which the separate authorities could work towards improvement in their own individual manner. In addition, nation-wide standards might counter the argument that effective pollution control in one area will drive industry into another, where control may be less rigorous. In addition, if a need was felt to classify rivers in any way the classification could be ratified by the central government.

Cases occur, and will be more frequent in the future, where the proper development of water resources involves the transfer of water from one river basin to another. Such water would be the concern of at least two river-basin authorities, which would have to work together, probably within the limits of policy laid down by the central government. It is important that the effect of any proposed scheme on the water-pollution situation should be taken into account.

7.8 River flowing through two or more countries

A special case is where the river basin extends into two or more countries. The essential difficulty here is that there is no single river-valley authority and no central body with the power to create one. The situation calls for co-operation and agreed action by two or more separate governments. A somewhat similar situation arises in a federation or in a nation composed of states each of which has a considerable degree of autonomy. The problems so created are largely political and beyond the purview of the Expert Committee. It may, however, be emphasized that the technical problems are not altered by the fact that national boundaries run through river basins. A single administrative body for a whole river basin remains the rational way of controlling pollution, even though it may be more difficult to put into practice.

8. RESEARCH AND DISSEMINATION OF INFORMATION

A list of research needs is given in the Annex. Although these are very important, the need for action is often even more urgent, especially in the developing countries, and techniques already exist for dealing with the majority of problems. The need for improving scientific understanding should never (as has happened) be used as an excuse for permitting an obvious menace to health or a gross aesthetic nuisance to persist. The Expert Committee fully appreciates the need for, and the value of, research. Indeed, for some problems, further constructive action may be dependent on the results of research. But there are countries where the need for action is so great and the availability of trained personnel so limited that it would be difficult to justify devoting any significant number of those personnel to research.

WHO can play a unique and important role by transmitting technical information to areas of need and communicating the results of current research as efficiently as possible to practitioners who can use them.

Between the developed countries there is much in common in the methods used in, for example, the analysis of river-water, sewage and industrial effluent. But there are also important differences (often in details), which can greatly affect the final result, especially when the tests are general and empirical. It is desirable that there should be more uniformity, but this is very difficult to achieve. Research will undoubtedly help, but in the meantime many developing countries need to decide on methods that would be most suitable for their particular circumstances. It would be a great help to them if methods in general use could be collected together and critically reviewed in such a way that their task, which might otherwise be very time-consuming, would be simplified.

Even more important is the fact that such countries do not readily have access to all the information that is at present available on water-quality management, water treatment, sewage treatment, and industrial-effluent treatment. Even developed countries feel this a problem, too. The information is scattered in technical journals in many countries dealing with public health, water supply, effluent treatment and various industrial activities. It would be most useful if this information could be collected so as to be available on request and if summaries on selected subjects could be published periodically as guides on the kind of information available. Such a service, which seems particularly suitable for an international agency such as WHO to undertake, might avoid a great deal of duplication of experimental work which the developing countries can ill afford to undertake. It might also avoid expensive mistakes being made in projects for water-pollution control.

9. CONCLUSIONS

The following is a summary of the major conclusions of the Expert Committee.

Widespread and serious water pollution has occurred in the developed countries over the period of their industrialization and has more recently occurred in many of the developing countries. Unless urgent measures are taken, water pollution in the latter is likely to increase with very great rapidity.

Severe water pollution is largely associated with urbanization and industrialization, which necessitate increasing demands for water and increasing amounts and increasing complexity of waste in liquid form.

Water pollution takes many forms. Each has its own characteristic properties and each can, in its own way, make water less suitable or even unfit for many purposes.

Polluted water can greatly affect human health by giving rise to outbreaks of infectious disease, some of which have been calamitous. It can also affect health in other ways, direct and indirect, and may have insidious long-term effects that are not yet fully understood.

Polluted water may be unsuitable for industry or more expensive to use. The requirements of different industrial processes, however, are so diverse that no useful generalization can be made.

Polluted water may be unsuitable for irrigation or may reduce crop yields. On the other hand, drainage of irrigation water from land may give rise to serious pollution of rivers.

Polluted water may destroy or damage fisheries, which in many areas are an important source of protein for human food.

Polluted water adversely affects the aesthetic and recreational values of water and may spoil areas such as coastal resorts and lakes that depend on water for their attraction.

Pollution has special cumulative and almost irreversible effects on lakes, and measures for the protection of lakes therefore need to be taken well in advance of the manifestation of these effects.

The pollution of ground water can be more serious than the pollution of surface water.

Although more research is needed on methods of dealing with water pollution, lack of full knowledge should not be allowed to hold up progress.

Methods of treatment of sewage and most industrial effluents are known and well established; there is, however, a very great need to develop less costly methods for use in developing countries whose financial resources are meagre.

It is usually good practice to discharge industrial effluents to sewers and to treat them with domestic sewage. But there are important exceptions, to discern and deal with which requires knowledge and skill (see section 4.2).

Some types of pollution, such as salinity, cannot be dealt with by conventional treatment processes.

In future, as sources of pollution multiply, the efficiency of treatment processes will need to be progressively increased, and research must be directed to this end.

Methods of controlling pollution in addition to effluent treatment and industrial waste control are sometimes available (see section 4.4).

The assessment of the degree of pollution is often complicated, but there are general tests covering most cases, from which it is possible to derive permissible limits (see section 5). It may be useful to attempt some classification of rivers.

Pollution control and water conservation react upon one another to such an extent that they should be managed by a single authority.

A river-basin authority empowered by law is necessary to carry out effective control of water pollution.

Special authorities representative of all water interests should be established with appropriate powers to work out and execute a total water-management policy of which pollution control would be a major part.

It is necessary for these authorities to be staffed by experts of high quality in both the technical and the economic fields. In particular, emphasis is placed on the value of economic analyses of the situation and of the possible remedial courses of action, within the constraints of health requirements and other policy decisions.

Developing countries need much assistance in all matters relating to pollution control.

For international rivers the technical problems remain the same, and the creation of an appropriate river authority by international agreement should be aimed at.

Developing countries would be greatly assisted by the preparation of a critical review of analytical methods. The formation of a technical information centre (and the issuing of publications showing what is available there) would be most helpful and should save much duplication of effort.

Annex

RECOMMENDED RESEARCH

The Expert Committee consider that further research on the following topics is desirable for the improvement of water-pollution control. The topics are not placed in any particular order of priority.

Health effects of certain substances contained in surface waters

(a) Methods of assessing the adverse effects of waste discharge. Refinement of methods of determining the minimal active concentrations of toxins in the receiving water through the use of bio-assays.

(b) The long-range toxic effects of certain metals and of new synthetic organic substances that persist in the receiving water even after conventional treatment and are stable to biological attack.

(c) The possible correlation between bathing in polluted water and incidence of disease.

Water quality

(a) The possibility of prescribing scientifically based standards for the permissible number of coliforms in water used for the following purposes: (i) processing for the public supply; (ii) unsupervised public bathing; and (iii) stock watering.

(b) Survival rates of pathogenic micro-organisms in sea-water. Assessment of the validity of coliform and streptococci tests for determining sea-water quality.

(c) Determination of appropriate dilution ratios for toxic or other undesirable substances in raw water intended for processing for public drinking-water supply.

(d) Determination of specific biochemical oxygen demand (BOD) for organic substances of known structure and in current use.

Ground water

(a) The purification effect of ground-water recharge on effluents of various types and under various geological conditions.

(b) The accumulation of chlorides and other dissolved solids in ground waters receiving recharge from irrigation projects.

Treatment processes for drinking-water

(a) The development of an economic and rapid filter plant with minimum mechanical parts and easy back-washing facilities.

(b) Methods of destroying water-borne viruses and nematodes in water supplies.

(c) The possible value of indicator organisms such as coliforms and streptococci in the assessment of water quality in relation to enterovirus contamination.

Treatment techniques for waste waters

(a) The removal and inactivation of viruses by sewage treatment processes.

(b) The action, under various conditions, of oxidation ponds. Treatment methods for domestic sewage ; the efficiency of removal of pathogens, macro- and micro-parasites, and viruses.

(c) The use of oxidation ponds and oxidation ditches for the treatment of industrial wastes.

(d) The development of practical methods of tertiary treatment of waste water with a view to its reuse.

(e) Sewage farming and the use of effluents from oxidation ponds for irrigation ; the effects of these practices on crops, ground water, and the health of farm-workers.

Management and administration

(a) Methods of establishing the economic value of improved public health, better municipal and industrial water supplies and improved recreational opportunities resulting from pollution-control programmes.

(b) The rationalization of population-equivalence criteria applied to municipal and industrial pollution in various parts of the world.

(c) The determination of public attitudes to pollution control. The assessment of the value that people place on water for recreational and aesthetic reasons.

(d) Comparative international studies on the effectiveness of institutions and administrative techniques for pollution control.

(e) The establishment of minimum water requirements to satisfy individual needs (consumption, waste disposal, personal hygiene) and community needs (cleaning and sanitation).

(f) Determination of the cost and effectiveness of measures other than waste-water treatment for controlling water pollution.

(g) Application of system analysis and computer techniques to the river basins in developing countries.
