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SOLID WASTES DISPOSAL AND CONTROL

Report of a WHO Expert Committee

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WHO EXPERT COMMITTEE ON SOLID WASTES DISPOSAL AND CONTROL

Dübendorf, 15–21 June 1971

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SOLID WASTES DISPOSAL AND CONTROL

Report of a WHO Expert Committee

A WHO Expert Committee on Solid Wastes Disposal and Control met at Dübendorf from 15 to 21 June 1971, at the Swiss Federal Institute for Water Resources and Water Pollution Control, which is associated with the Swiss Federal Institute of Technology, Zürich, and is also the host institute of the WHO International Reference Centre for Wastes Disposal.

Dr B. H. Dieterich, Director, Division of Environmental Health, opened the meeting and welcomed the participants on behalf of the Director-General. He also thanked Professor W. Stumm, Director of the host institute, for the facilities made available for the meeting.

INTRODUCTION

The objectives of the Committee were:

(*a*) to review existing knowledge of the impact on health and on socio-economic factors of improper handling of solid wastes;

(*b*) to make an appraisal of current practices in solid wastes management; and

(*c*) to identify areas for future action.

A good description of the background to the Committee's deliberations is contained in the report of the WHO Scientific Group on the Treatment and Disposal of Wastes convened in 1966 to advise WHO on the planning of a wastes disposal programme:[1]

> The disposal of wastes must take place within a closed environment comprising only earth, air, and water. When the liquid, solid, or gaseous residues from waste treatment are disposed of, they must be discharged into one or more of these phases of the environment. Any or all of the phases may be polluted, and any solution to the general problem of the disposal of wastes therefore involves a decision as to which part of the environment can accept residues with least damage to the whole. In other words, in deciding on a site for the disposal of residues, their total effect on the environment must be studied. Wastes must no longer be transferred from one environmental phase to another without adequate study. This is particularly important in view of the fact that some residues persist permanently.

[1] *Wld Hlth Org. techn. Rep. Ser.*, 1967, No. 367, p. 6.

Thus while the main concern of this Committee was to produce an action-oriented report, it has been necessary to recognize at every stage in the handling and disposal of solid wastes the possibility of interaction with the total environment. For example, health was considered not merely as a matter of direct or indirect day-to-day risks, but also in the context of man's dependence for food on a complex chain of energy conversion.

In reviewing present technical processes for the disposal of solid wastes, the Committee sought to emphasize where gaps exist and where the requirements of developed and developing countries may differ.

Just as health issues are linked with our total environment, so is the solution of organizational problems connected with solid wastes disposal constrained by aspects of social organization, economic structure, and the division of powers between the different levels of government: national, regional, and local.

Some of the recommendations made by the Committee may seem of a radical and far-reaching nature, involving such matters as legislation, reorganization, new kinds of training, and the possible imposition of new kinds of control. The Committee is convinced, however, that such measures are necessary to safeguard the present health of the people, the welfare of the generations to come, and possibly even the future productive capacity of our society in terms of food and other goods.

1. THE EFFECT OF SOLID WASTES ON HEALTH AND WELFARE

1.1 Health aspects

Solid wastes vary throughout the world because both the quantity and the constituents are determined by social customs and living standards. As a society becomes industrialized the traditional domestic solid wastes are augmented by industrial, commercial, and agricultural wastes, each of which adds a new potential for nuisance and sometimes a new threat to the health and welfare of human beings.

Most wastes are heterogeneous and may vary seasonally; thus there can be no uniform approach to the problem they present. However, two main categories exist universally: fermentable organic wastes, which will decompose rapidly, and non-fermentable wastes, which resist decomposition or decompose very slowly. Wastes in the first of these two groups arise primarily from the preparation of food for human consumption. They are closely linked with the pattern of food consumption, and vary with the way of life and with living standards. In summer the volume of these wastes increases because of the abundant supply of fruits and vegetables and in winter it may decline if some of the wastes are burned on

fires. However, the importation of fresh foodstuffs out of season tends to modify the traditional composition of household wastes.

Ideally, solid wastes should not contain any faecal matter or urine, and the mixture of the latter wastes with household wastes should, as is the case in some developed countries, be prohibited by law. Difficulties of enforcement, however, and variations in way of life mean that some tolerance has to be accepted in this matter. Where it occurs, such mixing makes it more difficult to undertake the collection of solid wastes in a manner satisfactory from the point of view of environmental health. The handling of pathological wastes, slaughterhouse wastes, and similar materials in association with household wastes should also be prohibited. But pathogenic organisms will continue to be present in wastes in spite of all possible precautions.

Harm from waste products can arise from other causes : inflammability because of paper content or by spontaneous combustion when in heaps ; production of smoke ; disgusting or nauseating smells and liquids during exposed fermentation in the open ; the scattering of paper, plastic, and dust by the wind ; and the breeding of flies and rodents, the role of which is still of great importance in the spread of disease.

It is necessary to concentrate attention on certain of these immediate problems : insects, rodents, polluted water and air, contact contamination, and accidents. There are also some long-term problems of man's food chain that have to be examined.

Insects

Various flies, particularly the housefly and the blowfly, breed near houses when there are waste products in the vicinity. They are also to be found at solid wastes disposal sites at which good standards of operation are not observed. Of course, it is relatively easy in temperate zones to avoid fly proliferation near human dwellings, but control is much more difficult in countries with high temperatures and high humidity and where the rate of decomposition of wastes is faster. Flies have a very great power of dispersion, with a flight range over land of about 10 km in radius.

Improper discharge of solid wastes in open drains or rivers may result in the creation of breeding places, as may the improper disposal of tin cans and automobile tires that hold water.

Rodents

Rodents proliferate very rapidly in uncontrolled deposits of refuse, which provide their main sources of food. Throughout the world there are periodic campaigns to exterminate rats and mice, but the presence of food wastes permits rats to persist and to migrate from dumps to human dwellings in the vicinity. This creates a serious health problem because

the rat may be a reservoir of plague, murine typhus, leptospirosis, histoplasmosis, rat-bite fever, salmonellosis, tularaemia, trichinosis, and many other diseases.

Solid wastes and air pollution

Uncontrolled and incomplete combustion of solid waste materials can result in the release into the atmosphere of a number of undesirable pollutants, including particulate matter, sulfur dioxide, nitrogen oxide, various hydrocarbons, and other noxious gases that may have deleterious effects on the health of those who inhale them.

The main source of air pollution from this cause is the deliberate, accidental, or spontaneous combustion of waste deposits in the open, which gives rise to large volumes of smoke and offensive odours. When rubber is present in the burning material the problem becomes especially serious.

Another source of pollution is the old or inefficient incinerator plant. Combustion causes a large amount of dust to be suspended in flue gases, and if dust eliminators are not installed it may be very unpleasant to live in the immediate environment of the plant. Some incineration plants have installed equipment to limit the generation or emission of dust, but only the newer plants are equipped with electrostatic precipitators.

The burning of plastics, particularly polyvinyl chloride, gives rise to hydrochloric acid, which not only causes corrosion in the plant but may also produce unacceptable aerial pollution in the vicinity. For this reason consideration is being given to the possibility of replacing polyvinyl chloride by other synthetic products that do not have the same disadvantages. A warning is necessary with regard to the possible future marketing of even more dangerous plastics, for example, those based on fluorine.

Small (household or institutional) incinerators, which usually lack dust extraction equipment, should be subjected to stringent controls, especially in urban communities. Well-designed incinerators are, however, a preferred method of destruction of pathological refuse for hospitals.

Solid wastes and water pollution

Rainwater that passes through a deposit of fermenting solid wastes emerges as a leachate, which contains a very high proportion of fermenting organic matter. While the possibility exists that pathogenic organisms may be carried some distance, studies have shown that in normal permeable soils the bacterial penetration does not exceed a dozen metres. But where the deposit is sited on fissured rock distant water sources may be contaminated. Hence, a geological and hydrological investigation by specialists is a necessary prerequisite to the use of a site for the deposit of solid wastes. When fermentable solid wastes are deposited in water-filled sites in impervious ground the damage is of a different nature and is due rather to the

sulfite-reducing organisms, which may produce obnoxious odours over a considerable area.

Large quantities of industrial solid wastes are deposited in landfills and some of these are toxic. Certain highly toxic wastes are dumped at sea. Leachate from industrial solid wastes may contain dissolved chemicals, particularly heavy metals, which are poisonous. It has been demonstrated that such materials may be concentrated in nature by some organisms in man's food chain.

Epidemiological studies

A study in India of stool specimens from refuse workers indicated that 94 % of this group were infected with selected parasites as against slightly more than 4 % in the control group.[1] The same study indicated that the infection rate with worms and related organisms was 3 times that in the control group. Contamination of this kind is liable to occur at all points where waste is handled. However, although it is certain that vector insects and rodents can transmit various pathogenic agents of diseases (amoebic and bacillary dysenteries, typhoid fever and salmonellosis, various parasitoses, cholera, yellow fever, plague, leptospirosis, etc.), it is often difficult to demonstrate the precise relationship between the sources of infection and the health of the population affected.

Another danger to refuse workers is the high accident rate attributable to heavy lifting and mechanized equipment. Although no study has been completed specifically identifying the types of accident and permitting an accurate comparison of this rate with that in other occupations, it is believed that—at least in some countries—the rate is much higher among this group than among any other comparable working group.

Some evidence suggests that certain population groups may also be particularly influenced by improper solid wastes handling or disposal practices. In this connexion, it would be desirable to investigate the influence on the mental and physical health of the aged, the infirm and the very young as well as on that of people living in the vicinity of treatment or disposal sites.

The importance of such studies cannot be overestimated because all the evidence suggests that a thorough clean-up of the environment is followed by a significant reduction in disease and a fall in the death rate.

1.2 Socioeconomic aspects

What some people consider wastes may, for social or economic reasons, be of value to others. The socioeconomic aspects of solid wastes manage-

[1] Arceivala, S. J. (1971) *Solid wastes disposal in India*, Nagpur, Central Public Health Engineering Research Institute, p. 14.

ment or mismanagement are bound to differ between the developing countries and the industrialized ones. But in both cases there are tangible socio-economic effects, some of which are dealt with below.

Site selection and property devaluation

Land is usually necessary for the final deposit of solid wastes and if these materials are dumped without prior treatment or planned operation the land is spoiled for further use and the surrounding area is subjected to nuisance from insects, rodents, dust, and smoke. Unfortunately this is the way in which most of the world's solid wastes are disposed of. To keep transport cost to a minimum these sites are often very close to the urban areas that produce the wastes and they therefore cause economic blight: devaluation of land and property in the vicinity. Devaluation can also spread along the truck routes leading to the site, as a consequence of the steady stream of collection vehicles, sometimes with their contents exposed.

Bad practices of the past have often created a climate of public opinion that leads property owners to oppose the location of any kind of treatment or disposal site in their vicinity, and renders the acquisition of sites extremely difficult, even when high standards of operation are promised. Even professional urban planners are often reluctant to allocate land for solid wastes disposal. Far from being detrimental, however, a well-planned and well-operated solid wastes disposal site may offer vast possibilities for land improvement, e.g., the reclamation of abandoned surface mineral workings, and the improvement of marsh or other unproductive land. Even when sites of this kind are not conveniently situated in relation to the source of the solid wastes, they may be chosen for final deposition, if this is likely to result in social and economic benefit in the form of public recreation land or industrial estates on reclaimed land.

Waste of material resources

There are other ways in which solid wastes are not being made full use of as potential resource materials. In the developing countries fermentable organic matter forms a high proportion of domestic wastes and can readily be transformed into a compost, which in many countries would be a valuable soil conditioner and a minor source of plant nutrients. In the industrialized countries the improper management of solid wastes can lead to loss of valuable mineral resources such as copper, lead, tin, zinc, aluminium, iron, and crude oil. When a nation's reserve of one or more of these mineral resources has declined to the extent that practically all of its needs are imported from other parts of the world, it does not make economic sense for that nation to use these materials to produce items that are used

briefly and then discarded and lost in a mass of heterogeneous materials buried under the surface of the ground.

Industrialization

The intense desire for industrialization often works to the detriment of environmental protection. The enforcement of good environmental practices, should it in any way endanger a promising industrial development, is likely to be made subservient to the more apparent economic gains to be derived from the industry. Plentiful evidence of this, and of the disastrous effects that can result, exists in the world's more industrialized nations. Since the costs of correcting the damage done may far exceed the economic benefits gained through the original decisions, good solid wastes management practice should be established at the beginnings of industrialization.

Aesthetic standards

The mental and social well-being of man cannot be achieved merely by attainment of material wealth. It requires also a physical environment in which he can lead a comfortable and stress-free life.

One of the more obvious ways in which aesthetic standards are abused is the dropping of litter in towns and the countryside. Improper management of solid wastes—in collection, transport, treatment, and disposal —could well be a major factor contributing to the litter problem, which may be regarded as a measure of a citizen's pride in his surroundings. Where lack of national pride and community pride are visibly demonstrated in disgraceful solid wastes management practices, it is not surprising that attitudes concerning litter will reflect this. In addition to the aesthetic problem of litter, there is a serious economic aspect. It is much more costly to retrieve items of litter from streets and parks than through well-organized storage and collection. Another economic aspect that has been demonstrated in the USA is that, for many items found in litter, the cost of their recovery from the landscape greatly exceeds the original cost of production.

Tourism

For some countries, tourism is a major source of foreign exchange and of vital importance to their economy. Tourists are sensitive to health and aesthetic standards and are quickly discouraged by deficiencies such as uncollected refuse stacked along the streets, odours and smoke from burning dump sites, litter in the countryside, floating debris, and scum on scenic water.

1.3 Special problems of the developing countries

The Committee noted that in tropical and subtropical countries, where temperature and humidity favour proliferation of insects and rapid decomposition of organic matter, frequent collection or exceptionally careful storage is required. Densely populated areas in which direct vehicular access is difficult or impossible necessitate the use of hand collection methods.

In some countries nightsoil has to be collected from house to house. Since the faecal matter is not completely digested and methods of collection and transport are not satisfactory, there are serious health hazards in handling such waste. Nightsoil is sometimes brought to a compost heap, where it is mixed with domestic refuse to add to the fertilizing value of the product. Close control is necessary to minimize health risks. If composting of refuse is not practised, nightsoil should be digested separately before being used on land.

1.4 Special problems of the industrialized countries

Although the following problems are more obvious at present in the industrialized countries, they are latent in the developing countries, which should seek to avoid some of the mistakes made by the industrialized countries by planning for solid wastes disposal at an early stage of industrialization.

The greatest growth in the volume of domestic wastes is caused by the increasing prepackaging of food and other goods. Although there can be no objection to the resulting improvement in hygiene, the necessity for some forms of packaging is questioned.

A difficult economic problem surrounds the recovery of raw materials, such as metals, from solid wastes in areas where labour costs make this unprofitable. Should such activity be subsidized?

Many improvements in waste-water treatment increase sludges, which add to the solid waste problem. Digested sludge from a sewage treatment plant must be disposed of either separately or mixed with refuse. Disposal of raw sludge should not be allowed because of the health hazards involved in such a practice. However, if both sewage and solid waste treatment facilities are located on one site and the solid waste treatment facility can handle raw sludge safely, the sludge may be added to refuse provided that it is mechanically transported to the refuse treatment unit. In some areas it may be economical to dry digested sludge and sell it for use in agriculture, but such markets are rare. In disposing of sludge, due attention should be paid to the possibility of its containing toxic substances—such as mercury—with a view to preventing their entering the water system or the food chain. Dredging of watercourses or estuaries often results in

considerable amounts of contaminated material, which must be disposed of on land in well-defined and contained locations.

Solid wastes from hospitals include pathological wastes; they should be collected separately from domestic wastes and burned in a well-designed incinerator.

Agricultural wastes may have special health implications and therefore need careful disposal. The most difficult agricultural wastes arise from intensive rearing of poultry and other animals, packaging and canning of foodstuffs, and slaughtering of livestock. The changing pattern of agriculture is resulting in a steady growth in the volume of agricultural wastes, particularly when burning of crop residues is prohibited to prevent air pollution. The obvious and satisfying solution is to return them to the land by working them into the soil, by efficient composting or in association with sanitary landfill.

The disposal of much industrial solid waste can be integrated with the disposal of domestic and commercial wastes. Most mining wastes are harmless, but the leachate from certain industrial and mining disposal sites does contain toxic matter, which may have serious health implications. Such wastes should be strictly controlled because conventional water treatment methods do not normally remove dissolved toxic chemicals. Where industries are restrained from disposing of their wastes into streams, lakes, and public sewers, it is possible that sludges, slurries, and sometimes liquid wastes may be put in landfills. When this occurs additional care should be taken to prevent toxic chemicals from entering the water system.

During the past few years large holiday camps have become popular in many countries. The amount of solid wastes produced at these sites has risen to such levels as to require their inclusion in the refuse collection and disposal organization.

2. PRESENT KNOWLEDGE AND TECHNOLOGY

Unfortunately there is no internationally accepted terminology for solid waste handling and disposal. This makes it difficult to establish precise definitions of what is here being considered: sources, quantities, and characteristics of solid wastes and the associated technical procedures. For this reason the Committee did not seek to produce its own definitions, but rather to offer descriptions that, while not universally valid, are widely applicable. For its own purposes, the Committee regarded solid wastes as being those useless, unwanted, or discarded materials that arise from man's activities and are not free-flowing.

2.1 Main sources of solid wastes

Domestic wastes

These wastes are a consequence of housekeeping activities, such as food preparation, sweeping, and vacuum cleaning; they also comprise fuel residues; empty containers and packaging; wastes from repair and redecorating, gardening, and hobbies; old clothing; reading matter; old floor coverings; and old furnishings. In the last decade increasing quantities of bulky wastes have been discarded, such as furniture, refrigerators, washing machines and hot-water tanks, which cannot be accommodated by many storage and collection systems.

Commercial wastes

These are mainly the wastes produced by shops and offices and consist largely of fibreboard containers, wooden crates, paper packaging, paper, carbon paper, typewriter ribbons, punch-cards, tape, etc., but may include food waste from cafeterias. Wastes from hotels, restaurants, hospitals, and barracks are also included in this category. Most of these wastes are collected with domestic wastes, but hospital wastes must be treated separately, as described earlier.

Street-cleaning wastes

These wastes are composed mainly of paper and small containers, often mixed with stones, dust, and debris fallen from passing trucks.

Industrial wastes

These include construction wastes (excavated material from building sites and other building wastes) and all unsaleable factory wastes. The latter will comprise packaging materials, food wastes, offcuts and spoiled material of metal, plastic, wood or cardboard, textiles or other materials. Factory refuse will also include fuel residues resulting from the incineration of chemical wastes which require treatment within the factory before being released for disposal. Refineries also produce solid waste, much of it bituminous. Some industrial wastes are highly toxic.

Agricultural and animal wastes

These are made up of crop residues, poultry and other animal manures (particularly from intensive breeding and fattening), certain wastes arising from slaughter and from the preparation of carcasses, and the waste products from processing and canning plants. Another important waste arises from the intensive threshing of grain in central areas where great volumes of straw are produced and cannot be burned owing to pollution regulations.

Mining wastes

The mining industry produces such a large amount of waste that special emphasis should be given to this material. Large accumulations of processed or unprocessed minerals containing contaminants may be exposed to rain, which percolates through the mass and carries toxic or deleterious materials to bodies of water and thus contaminates them.

2.2 Composition and quantity

Because solid wastes are generated from many different sources they naturally comprise an almost infinite variety of materials; these range in size from a speck of dust to a discarded automobile, and in density from foam plastics to lead. The major constituents of domestic and commercial wastes are paper and fermentable organic matter. Dust, cinder, textiles, glass, crockery, wood, metals, and plastics are often present, the relative proportions depending upon many local factors.

The proportions of the constituents of domestic wastes collected at a disposal site are virtually constant for a particular town and subject only to seasonal and long-term changes, although this could be upset by industrial deliveries. But differences in the characteristics of solid wastes as between towns, and especially as between countries, can be enormous, and the collection of local data is therefore essential for good design of collection and disposal systems. The wide variation in values for domestic solid wastes between different countries is demonstrated in the following table:

	Range of extreme values (excluding industrial wastes)
Per capita weight (kg/day)	0.2 – 3.0
Density (kg/m³)	100 – 500
Putrescible matter (%)	5 – 90
Paper (%)	0.25 – 55
Plastics (%)	0.1 – 7

Where refuse production is low the density tends to be high (and *vice versa*) with the result that the daily *per capita* volume may have a range of as much as 1–80, thus significantly affecting the costs and techniques of collection and disposal.

It is emphasized that the above ranges relate only to domestic wastes. If industrial and agricultural wastes were to be taken into account, the variations might be several times greater.

2.3 Handling

The collection and transportation of solid wastes is the most costly phase and may account for up to 80% of total costs. Some cities have been able to achieve good standards at reasonable cost by means of efficient

and highly mechanized systems of collecting, compacting, containerizing, and unloading of the wastes ; some have also benefited from systems analysis techniques and from incentive bonus schemes to increase output per man-hour. There still exists great scope for application of these methods to other cities, subject always to the limitations imposed by special local conditions. For example, the existence of very narrow streets in some towns may necessitate the use of hand-barrows, cycles or motor-scooters instead of trucks. The nature of the wastes may also be such as to limit the usefulness of compaction equipment.

Many countries have developed standards that define satisfactory methods of home storage and frequency of collection. The quality of the service may range from the emptying of communal containers in streets to a complete house-to-house collection. Each country would do well to develop its own guidelines, related to hygienic, technical and financial considerations. Efficient management, based on sound public health objectives, is vital, because in any event this is a costly service.

Unconventional systems such as hydraulic or pneumatic transport in pipes are being developed, especially for use in new towns, in order to reduce the labour element of collection and to minimize human contact with wastes. At present, however, such systems do not seem likely to be applicable to existing urban areas because of the very high installation cost.

2.4 Treatment

While considering the adoption of suitable treatment facilities, particularly in the developing countries, due regard must be given to the characteristics of the waste, the climate, and the desirability of introducing minimal mechanization in the initial phases. The health of the public in general and of refuse workers in particular also needs consideration. Long-term changes in the character of the wastes and the development of new packaging and other materials will also, in due course, inevitably require modifications in existing treatment methods.

The processing of solid waste prior to disposal on land should be in part determined by the planned future use of the land once deposit is complete. It may also be necessary to extend the landfill life of the site, in which case a treatment offering maximum volume reduction would be required.

Incineration

Direct incineration in a plant with mechanical grates and internal ash quenching is a well-established method for wastes of suitable calorific value when shortage of space or a need for ash makes it desirable. Recovery of energy in the form of steam is sometimes practicable and can partly offset operating costs. If the ash has to be disposed of in sanitary landfills,

only about one-third of the space will be necessary compared with the deposit of untreated refuse.

Incinerators can cause air pollution problems unless they are designed, equipped, and operated to meet air pollution control requirements.

Pulverization

Pulverization (usually by hammer-mill) is a quick and relatively simple treatment that produces a dense, homogeneous, and relatively inoffensive material capable of reducing subsequent transport costs and land requirements for sanitary landfill. Land reclaimed with pulverized refuse has a much more predictable soil structure than land on which crude refuse is used.

Composting

Composting could be regarded more as a recycling than a treatment method because its purpose is to convert the fermentable organic content of wastes into a soil conditioner and no specific land allocation is required for final disposal of this product but only for the rejected materials, usually a minor proportion of the total. Composting methods range from manually operated pits to highly mechanized plants that also include separation of useful materials so as to recycle as much of the waste material as possible. Problems of marketing compost restrict the use of this method, particularly in Europe and in the USA, although it is practised on a wide scale in some of the developing countries.

High-pressure compaction

The desire for volume reduction, to reduce the land space required for disposal of solid wastes, has led to intensive development work to bale household and commercial wastes into blocks of high density. This offers the prospect of subsequent low-cost transport over distances exceeding 100 km and may make possible the increased use of solid wastes from cities for the reclamation of mineral excavation sites.

2.5 Recycling

The perfect solution to the problem of finding land for the deposit of solid wastes would be to sort the wastes into their separate constituents—paper, rags, glass, steel, copper, etc.—and to return each to industry for re-use. If waste food could be kept separate at the point of origin and collected separately it could be converted to animal feed. All these things are possible; they have been done at times in many countries, but the advantages of salvage are limited by the relationship between the labour cost of extracting these materials and their market value. In future two

forms of pressure are expected to create a situation in which this economic difficulty will have to be overcome; they are the shortage in some areas of sites for disposal and the need to conserve the world supply of certain raw materials.

The situation is fraught with problems. First it is necessary to devise methods of extraction that do not depend upon hand-picking, which is costly and unpleasant and which some may think a degrading occupation. However, at least one pilot plant for separation by density, after pulverization, has been built. Then, markets must be created for some of these materials, and economic imbalances may have to be corrected. Finally, it must be recognized that recycling could have a profound influence on the basic raw material industries, such as forestry for paper production.

In the case of paper there is no technical problem in its re-use; the problem is one of matching the price offered by the mills against the cost of extraction, sorting, grading, baling, and transportation.

Textile salvage has been hampered by the introduction of man-made fibres and consumer demand for "virgin" materials.

Steel is readily extracted by electro-magnet and the tin from cans can be recovered electrolytically.

Non-ferrous metals in household wastes require meticulous sorting because a simple household object may contain several different metals together with plastic or other materials.

Recycling requires the application of technical research in extraction and also in the re-use of the materials extracted. It may require legislation to bring about preseparation, to create new markets for the recovered materials, and to compensate producers of basic raw materials.

2.6 Final disposal

The most usual practice is to dispose of solid wastes on land, with or without prior processing. Disposal in the sea, particularly of toxic wastes, is questionable.

Reference has already been made to the need to subject all sites for final deposit of solid wastes to hydrogeological survey and to take appropriate steps to ensure that ground water and surface water will not be put at risk from leachate or run-off.

Throughout the world, at present, most refuse is delivered to the site of final disposal untreated and there is a well-proven practice known as sanitary landfill or controlled tipping that, if carefully followed, avoids health risks, reduces nuisances to the minimum, and can be valuable in land reclamation. Enormous tracts of land have been rendered useless by unplanned strip-mining; other areas are desert by nature or have been rendered so by man's abuse of his environment. To restore the environment

is a fine way to use wastes but it is essential to encourage proper sanitary land-filling practices adequately related to climatic and other constraints.

The essence of sanitary land-filling is that the solid wastes are deposited in layers not exceeding 2 m in depth which are compacted and the exposed surfaces of which are covered daily with earth. Good operation also requires detailed attention to site preparation, access roads, fencing, supplies of covering material, and screens to catch wind-borne litter.

2.7 Research and development needs

The Committee formed the opinion that research and development should be undertaken in order to find solutions to a number of problems. It emphasized the fact that techniques developed to match the needs of the industrialized countries cannot necessarily be exported to the developing countries without adaptation. However, a gradual transition from the manual and relatively primitive methods of wastes disposal to more mechanized systems would be desirable in the course of time and should become one of the important aims of research.

The following specific needs may be listed:

Data collection and analytical techniques

A vastly increased effort to collect adequate data, particularly from developing countries.

Standard procedures for the collection of samples and their preparation for analysis, in particular physical analysis of house and commercial wastes.

Development of standard methods of analysis, including physical analysis.

Adaptations of chemical analysis methods commonly used for pure substances to the needs of analysis of solid wastes, which are heterogeneous in character and may contain interfering substances.

Improved methods of estimation of carbon and nitrogen and of biodegradability.

Standardization of costing methods to permit comparative studies of cities or countries.

Storage

Home storage containers that are hygienic, economical, and suited to the accepted mode of collection.

Large (200- to 300-litre) plastic units on wheels so that they can be easily rolled to the curb.

Collection and transportation

Development of small unit-train systems to make house-to-house collections and unload into a " mother " vehicle at a rendezvous point, so that large vehicles can be kept out of residential areas and the number of stops reduced.

Hydraulic transport of solid wastes through an underground pipe system (as for sewage) by use of slurries.

Development of low-cost vacuum transport in underground pipes.

Improved methods for the collection of refuse in very narrow lanes, often unpaved and at times steep, where use of conventional vehicles is impossible.

Salvage and re-use

Identification of areas where land can be conserved, and costs reduced by salvage and re-use of the constituents or by their conversion to saleable products, including briquettes, oils, proteins, etc.

Alternative materials for those that commonly pose problems in treatment and disposal, such as plastic packaging materials, which, in addition to causing problems in incineration, cannot be properly compacted and thus reduce the ultimate bearing capacity of landfills.

Processing

Continuing development of pulverization and high-pressure baling equipment.

Mechanical separation systems that facilitate salvage and recycling.

Development of pyrolysis techniques.

Improved incineration techniques (fluidized bed incinerators, high-temperature slagging incinerators, vortex incinerators).

Study of the effect of climatic conditions on the concentration of undesirable substances such as hydrogen chloride in the ambient air.

Development of flue gas removal devices for hydrogen chloride and sulfur dioxide (for example, by injecting calcium hydroxide into the flue and combining dust removal and wet scrubbing).

Encouraging the plastics and other chemical industries to co-operate in research on waste-processing techniques.

Improvement of manual methods of composting widely used in the developing countries by introducing minimal mechanization; this would help to reduce the land requirement and improve the quality of the product.

Fine grinding of the solid waste, if necessary twice, by using suitable hammer-mills, etc., followed by direct application to the soil where it can undergo further stabilization until the sowing of the next crop, in the same manner as green manuring (this method would be applicable in areas where the waste contains a very small amount of metals, glass, etc.).

Incinerator designs based on refuse data from developing countries where the calorific value of the refuse is low.

Treatments for animal manure from intensive breeding centres.

Disposal

Improved methods for handling gas production and leachates from landfills.

Investigation of how sanitary landfills could be put to use much earlier and have improved bearing capacities.

Disposal of fly-ash from the steel industry and thermal power plants.

Investigation of traditional rural methods of disposing of agricultural and human wastes by land-filling and crude composting methods that aim at recycling the wastes, to make them more hygienic and more efficient.

The use of extension services to ensure the adoption of better methods in the rural areas.

Socioeconomic problems

Market development, for better utilization of materials produced by recycling (e.g., compost).

Development of incentives and/or disincentives to reduce sources of waste, encourage recycling, and conserve resources.

Research on container standardization, package redesign, etc., to facilitate recycling.

Research on social attitudes to find better ways of motivating people to correct their habits, e.g., not to leave litter, to use recyclable materials, and not to use excess packaging.

Research into social attitudes affecting acceptance of disposal sites, employment in solid wastes management organizations, etc.

Study of costing methods to make it possible to compare collection and disposal practices at different places or different disposal methods at the same place.

3. PLANNING AND OPERATION OF SOLID WASTES SYSTEMS

3.1 Introduction

Solid wastes management has always been a function of local government (or a problem of an industry), until recent years rarely assisted or co-ordinated by higher levels of government. This fragmentation of management has often resulted in unplanned and inefficient operation, unnecessary risks to health, and damage to the environment.

Planning, in the sense of systematic collection and analysis of all relevant data covering a sufficiently large area, has only recently been applied to solid wastes but is now recognized as a vital procedure for the introduction of hygienic, efficient, and economic methods of operation. Solid wastes management is an important facet of environmental hygiene and needs to be integrated with total environmental planning. Its purpose is to provide a hygienic, efficient, and economic service organization to collect and transport solid wastes rapidly to treatment or disposal points, and to render the solid wastes innocuous without transferring pollution loads to the water system or the atmosphere.

If these criteria are to be met, planning is necessary at four levels.

International planning

This aspect of planning should include the collection of data and dissemination of technical knowledge, and provide for bilateral or multilateral aid in the training of personnel, and the exchange of experts, viewpoints, and equipment. It may extend to co-operation and co-ordination regarding the location, design and installation of disposal plants, so as not to pollute the water resources of, or the air over, neighbouring countries.

National planning

Every country should have at ministry level a body of experts in solid wastes systems to collect and collate data on solid wastes management practice, to draw up standards and codes of practice for the guidance and training of personnel at state and local level, to assist in feasibility studies of solid wastes projects, and to enforce compliance with legislative provisions. The national government should enact legislation to create regional authorities or provide for local authorities to unite voluntarily to form regional solid wastes management bodies in order to optimize the use of available land and to minimize haulage costs.

Regional planning

At this level systematic collection and analysis of data, definition of problems and of objectives, and careful evaluation of objectives should be applied for the purpose of producing a master plan. This becomes the basis of future operation.

Local planning

Planning at local level should include comprehensive provision for present needs and future requirements. It should be closely integrated with regional planning.

At all levels of planning it is essential for representatives of the health authorities to be continuously represented during the planning process in order to examine all proposals for their health implications. It may be advisable to make statutory provision for the compulsory reference of all solid wastes projects to the ministry of health.

3.2 Defining objectives

Careful identification of both present and future problems provides the basis for establishing the objectives of a comprehensive plan, be it at national or local level. In some countries where waste generation is low the main objective may be to achieve adequate disposal of all wastes. The objectives become more extensive in countries where waste generation rates are high, where many communities each maintain separate collection and disposal systems, or where there are competing demands for the use of land.

But all these objectives, whether considered separately or in combination, aim essentially at the protection of health and the prevention of degradation of the environment.

The following objectives may be applicable to most countries :

Protection of health

This will have two aspects : protection against the short-term direct and indirect health risks due to improper collection and disposal services, as well as protection from the long-term effects on public health of possible ecological changes resulting directly from degradation of the environment by unsafe disposal methods.

Recycling of materials

There is need to recycle and conserve certain raw materials in some countries. But in all countries there exist opportunities to re-use solid wastes as land-filling material, as a source of compost, or as a low-grade fuel.

Aesthetic standards

Next in importance to a healthy environment is a beautiful one. Disposal methods must not mar beauty. On the contrary, every opportunity must be sought to use solid wastes as materials for the correction of former mistakes, e.g., for restoring the landscape where there are disused open mines.

Restriction of production of solid wastes

It may be necessary to create conditions for the reduction of refuse production at source by incentives or legislative restrictions.

Efficiency

Because solid wastes services may absorb 0.5% of the gross national product it is important to provide an efficient collection and disposal service at minimum cost.

3.3 Data required for planning

Planning is only as good as the data on which it is based. It is important, therefore, that information should be complete, accurate, and in accordance with international standards. What follows relates primarily to regional planning, although parts may be applicable to national or local planning.

General data

Demography, climate, and the economic and industrial background of the review area are basic factors. The *per capita* production of solid wastes from all defined sources and the physical analysis and density must be known, and projections must be made in the light of background factors.

Storage and collection

In considering the storage and collection of refuse it is necessary to know the size of the average family unit and to take into account social and religious influences. There are contractors' interests that should be allowed for, such as private enterprise salvage of kitchen waste or other materials. The character of town planning and building construction affect storage methods and vehicular access. There are alternative forms of transport: human, animal, and mechanical, each of which may play its part. Even the physical stature of the local workers is important, since it affects lifting capacity and loading height.

Street cleansing

Street clansing requires knowledge of road areas, quality of surfaces, density of pedestrian traffic, and potential sites of street cleansing depots.

Disposal

The data necessary for planning refuse disposal may be very complex. They should begin with a land use survey, from 15 km to 75 km in radius, which should record areas of man-made dereliction (such as worked-out sites of surface mineral extraction) and natural dereliction (such as swamps or marshes) as potential sites for reclamation by landfilling. Knowledge of the present and future road and rail patterns is necessary in considering transport. Constraints on the nature of filling material at such sites must also be ascertained. These may range from water pollution risks to bird-strike risks near airports, when aircraft are at risk from birds in the vicinity attracted by the presence of organic wastes.

The soil structure and agriculture pattern of the review area should be known, as an indicator of the need to produce compost. Power and heat requirements of the area should be ascertained if the solid wastes are of high calorific value, and in this context the potential demand for ash for industrial purposes may be an important factor.

Planning for disposal should aim at a total and integrated solution for wastes from all sources, including toxic materials, and therefore the data collected should embrace industry and agriculture as well as municipal sources.

3.4 Evaluation of alternatives

The prime factors for the evaluation stage are:

(1) the quantity and character of refuse;

(2) the location or the site or sites of final deposit; and

(3) constraints imposed by the ultimate use of the site after the solid wastes have been deposited, e.g., the need to satisfy other environmental standards, particularly for water and air; available techniques; and cost. These are the constraints that determine what kind of treatment is necessary, if any.

It is common for a number of alternative strategies to emerge, all of which may satisfy to some extent the main objectives. It is then necessary to develop outline programmes based on these alternatives in terms of cost and other requirements and to establish criteria for choosing between them. Some of these criteria may be unrelated to solid wastes management as such, for example, capital-intensive or labour-intensive solutions may

each be desirable in different economic circumstances. Systems analysis techniques are useful at this stage.

3.5 The master plan

Planning is a continuing process because it concerns a continuously evolving situation. Thus a master plan should be regarded not as the blueprint of a fixed structure, but rather as a flexible framework for future operation. The master plan will have many elements and these will differ between countries and between plans at different levels within a country. Most of the following will, however, be covered:

Legislation

This is the framework: it defines the powers and duties of central, regional, and local government, and the duties of citizens.

Finance

Finance has two aspects: capital and revenue. Capital may be raised in many ways; by loans or grants from the central government to the solid wastes authority, or by loans from the general public or from commercial institutions. Revenue is most commonly raised as part of a general property tax, but in some cases a specific service charge may be levied or, more rarely, the central government may provide funds from general taxation. Revenue, whether from taxation or service charges, must be adequate in amount to service capital and to pay operating costs and its source must be entirely reliable to ensure stability of the services.

Political direction

The elected body that formulates and directs policy for solid wastes management would normally be a regional, a local, or a single-purpose body. For the regulation of solid wastes storage and the organization of refuse collection small population units can be quite successful; but disposal requires land, and for the best exploitation of land resources for this purpose large areas, perhaps 40 km or more in radius, are desirable, although the requirements will vary from one country to another. In large urban areas with multiple local authorities it may sometimes be found advantageous to establish a single-purpose solid wastes authority similar to those administering public utilities such as gas, electricity, and water, and with power to raise its own revenues.

Executive direction

The administrative, managerial, professional, and technical structure should be closely defined, together with suitable methods of recruitment

and training of personnel. (Some aspects of training are considered in detail in section 3.6.)

The welfare of operators in terms of health, safety, and social conditions should be well defined.

The form of records and statistics for management, methods of feedback of information, and regular monitoring of the plan and revision of projections should be described.

Storage methods

Standard methods of storage should be defined for domestic buildings and commercial and industrial premises. Sometimes the amendment of building regulations will be necessary in order to achieve satisfactory standards of design and cleanliness—for example, in refuse chutes.

Collection methods

The plan will include frequency of collection, hours of work, and details of collection vehicles—the number required, the type, and the capacity (which will be optimized in relation to team size and length of haul). The method of vehicle organization for each collection district, whether single or relay, will be indicated.

Street cleansing

Sites for depots, the extent of equipment required for mechanical sweeping, the lengths of beats in relation to pedestrian density, and the type and frequency of litter bins will be decided.

Treatment and disposal

Treatment and disposal processes and equipment will be described and specified. Sites for treatment plants and for final disposal will be shown and their estimated lives indicated. Codes of practice will be laid down for the operation of treatment plants and for the preparation, operation, and finishing of final disposal sites. Where appropriate there will be a construction programme for treatment plants or transfer stations.

Central workshops

A site or sites will be allocated and a construction programme prepared for maintenance of vehicles and plant.

Projected costs

In the light of all the detailed programmes, the estimated capital and operating (including amortization) costs will be established, and revenue sources defined.

3.6 Professional and technical training

Solid wastes management embraces operations and skills that vary in complexity. It involves simple, manual operations, such as household refuse collection, and the various operations of treatment and disposal. Professional engineers with good managerial skills are required for overseeing large municipal or regional operations. For the planning of solid wastes handling systems high competence is required in economic analysis, in operations research, as well as in engineering ; thus a multidisciplinary team is necessary. Three kinds of education and training in solid wastes are therefore needed : for manual workers, for technical personnel, and for planners.

Manual workers

Training of manual workers will be of short duration and should aim at instructing men in the techniques of their tasks ; it should provide them with an overview of the entire solid wastes handling systems so that they can understand where their functions fit into the overall programme. The solid wastes management industry appears to have one of the highest accident rates of any industry. The probable reason for this is inadequate training. The training programme should therefore include personal hygiene as well as safety techniques. Such training may reduce the incidence of the usual complaints, which include diseases of the joints, muscles and tendons, dermatitis, hernia, worm infections, etc. The same basic training would be required in both the developed and the developing countries.

Technical personnel

The function of the technician is the day-to-day supervision of refuse collection and disposal, which requires thorough training in applied technology and administration. Very few courses of this kind exist. Part of the reason for this is the general assumption that operation of solid wastes collection and disposal requires no special skills or training. Another possible difficulty is that in many countries the number of technicians required would be insufficient to sustain a regular course.

Thus it is necessary to establish sufficient of these courses to satisfy world needs, and to devise appropriate curricula. It is suggested that one solution would be to group countries on the basis of language and climate, since the latter is one of the factors that affect the technologies required.

The sort of course envisaged would embrace technology in the field of solid wastes storage, collection and disposal, and vehicle maintenance, together with some training in administration and staff management. Those admitted could be of secondary school level academically, with some

background in mathematics, physics, and chemistry, but before proceeding to the course they should have had three or more years of service with a local authority. The first courses should be of one year's duration leading to a certificate or diploma in solid waste practice. After the shortest possible time, courses should be extended to two years. When the courses have been established, manuals covering the curriculum should be produced in all languages appropriate to the region.

Managers and supervisors of large-scale solid wastes facilities may be drawn from the engineering professions, which provide a good basis for specializing in solid wastes operation. Short courses reviewing the principles and practice of solid wastes management technology have been successfully used for such staff.

Planners

For the planning function, a multidisciplinary approach is necessary, as noted above. Civil or mechanical engineers, economists, systems analysts, and urban planners may take part. A number of universities in the USA are already offering postgraduate courses in solid wastes management that are attended by students of various disciplines. Such men must have competence not only in their own disciplines but also in the social sciences, so that the human factors can be duly considered in the planning stages.

3.7 Public relations

Keeping an environment clean requires not only efficient solid wastes services, but public acceptance, co-operation, and participation. The plan must include a programme aimed at improving the behaviour and practices of the people in this respect where necessary. It is necessary to arouse the individual's concern for personal health and well-being and for social and economic security, which are consequences of a clean environment. Many educational techniques and media are available for this purpose.

Posters, publicity leaflets, films, and cinema slides should be prepared, emphasizing various aspects of keeping the environment clean. Educational leaflets should be distributed to householders, to teachers and children in schools, and to those at their places of work. Talks, lectures and film shows may be given in clubs, youth organizations, schools, and community centres by both experts and well-informed laymen, and articles in the press and radio and television programmes may also be used to impart information and stimulate thinking and discussion.

The detailed operation of the solid wastes education programme should be handled by the professional and technical staff of the environmental health department, and in particular by the solid wastes management section.

The assistance of people of influence, such as religious leaders, physicians, elected representatives, trade union leaders, and active officials of chambers of commerce, community centres, clubs, etc., should be enlisted.

The value of an informed public is particularly great when proposals are being considered for new refuse treatment or disposal sites, particularly sanitary landfills. Often the people living in the vicinity of proposed sites are violently opposed to the projects because they are unaware of the high operating standards that would be used and the ultimate benefit that would accrue to the area.

The timing of public education programmes is important. To help secure acceptance of a new site public education must begin some time before a decision is necessary. In the case of anti-litter campaigns, however, installation of litter bins should precede the publicity.

Unfortunately, education alone is not likely to be sufficient; enforcement should also be envisaged. If existing laws are inadequate then new laws and regulations must be enacted for more effective control over persons who create nuisances. The environmental health department, and, in particular, the solid wastes management section, should have adequate enforcement personnel in order to apprehend and prosecute offenders.

3.8 Sequence of programme implementation

(1) The first stage of implementation of the master plan is enactment of all necessary legislation, e.g., for the establishment of a regional authority or on such detailed matters as the duties of householders in assisting the collection of their wastes.

(2) Organization of the service, including the recruitment of staff, should follow, phased in accordance with the period over which the plan will be implemented. As mentioned above (section 3.6), provision should be made for advanced training and for this purpose some specialist staff may need to be appointed a year or more before their full duties commence. All newly recruited staff should be allowed time to familiarize themselves with their jobs. Salaries and wages should be established at such a level as to offer a sufficient inducement to attract personnel of high calibre. The most modern management techniques should be employed to guide the operations.

(3) It is necessary to commence land acquisition and planning for site development at an early stage, including consultation with other public bodies (ministries, water authorities, etc.) to ensure availability of land for future plants and disposal sites.

(4) The preparation of designs, specifications, and contract documents will follow, and these should incorporate satisfactory guarantees of construction and performance.

(5) Commissioning of treatment plants, and the organization of collection rounds is the final stage.

(6) There will be a continuing feedback of information and review of the master plan to allow for necessary revision from time to time.

4. GUIDELINES FOR POLICY AND ACTION

On the basis of the considerations in the foregoing chapters, the Committee endeavoured to set down guidelines for policy and action at different levels.

4.1 Policy and action at international level

Epidemiological methods authoritatively established at an international level are needed for studying the direct and indirect relationships between solid wastes and health, including occupational hazards to workers, as well as the health effects of home storage and of collection and disposal, especially on high-risk groups such as children, the aged, and the poor. Special attention should be devoted to the handling and disposal of toxic materials, as well as to the importance of their physical and biological concentration in the food chain. International action is also desirable to ensure that adequate weight is given to public health considerations in all environmental policy making of broad scope and significance. International co-operation to prevent pollution by solid wastes of extraterritorial regions, especially the seas, would fall in this category. International agencies should identify specific wastes and disposal practices that are potentially deleterious to health and should be subjected to international control, develop monitoring systems, collect data and publish information on significant trends, and establish a framework for international action. Investigations of a similar nature might in future be undertaken concerning the disposal of wastes in outer space.

Stimulation and co-ordination of research and development activities in the field of solid wastes, especially in developing countries, are important responsibilities of the international agencies. The establishment of the WHO International Reference Centre for Wastes Disposal was an important first step in this direction. The development of uniform terminology and standard methods for reference and correlation (including surveying, sampling, analysis, costing, evaluation and reporting) are recognized as important functions of the International Reference Centre. Existing bilateral and non-governmental international arrangements for research on solid wastes management, such as the establishment of the International Solid Wastes and Public Cleansing Association, should also be encouraged and extended.

International action is needed to conserve resources, taking into account the health and economic needs of individual countries. International agencies should also assist in identifying materials that are suitable for re-use and in the development of the technology for recovering and recycling such materials.

With the growing realization that the problem of solid wastes must be tackled at source, attempts are being made through legislation and incentives to restrict the quantity and diversity of wastes produced and to facilitate their disposal. In collaboration with other agencies WHO could usefully assist countries in identifying types of solid waste suitable for control by legislation or incentives, and could study possible legislative and incentive measures applicable to solid wastes.

Multilateral and bilateral assistance should be made available especially to developing countries for the planning, construction, and operation of wastes disposal systems. Such assistance should encourage a comprehensive approach, and should, as appropriate, include project identification and formulation, feasibility studies, management, legal and financial studies, design, choice of equipment, staff training, and technical advisory services to assure optimum utilization of constructed facilities. International agencies could provide assistance in the drafting of solid wastes legislation and codes of practice by formulating model legal frameworks and model codes of practice, as well as by establishing a reference service on existing legislation.

Attention should be given to the possibility of developing new methods to encourage international private investment in wastes disposal systems, for example, co-operative financing of projects underwritten by the International Bank for Reconstruction and Development.

The Committee particularly emphasized WHO's role in training personnel for responsibilities at various levels in solid wastes management organizations. Short courses for senior officials need to be continued, regional technical training courses of one or two years' duration would be valuable, and assistance is needed in the preparation of training manuals in local languages. The training value of pilot plant installations and demonstration projects was emphasized.

4.2 Policy and action at government level

An expert technical body should be established at national level in each country to carry out or sponsor solid wastes research and development in collaboration with the International Reference Centre, to promulgate codes of practice for the operation of solid wastes systems and to monitor the effectiveness of operating systems. This body should work closely with, and be guided by, the national public health authority.

The present advantages of, and ultimate necessity for, regional management of solid wastes should be recognized, and suitable regional authorities should be set up where necessary. Such authorities should have legally defined powers and duties, including adequate control over individual citizens and industries, and should be staffed with both professional and technical personnel who have been specially trained in wastes disposal technology.

Solid wastes planning activities, utilizing appropriate management techniques, should be carried out by all levels of government in order to establish priorities, make feasibility studies, develop construction projects, revise operational programmes, and justify the allocation of financial, material, and manpower resources for the programme. Central government grants for local construction may be appropriate in some cases. A resource allocation system relating financial burden to the source, quantity, and character of wastes generated should be a national policy objective.

An effective public information and education programme is essential to the success of every solid wastes scheme. The education of both officials and the public should begin when the scheme is initiated and should reach a climax when the scheme is implemented.

4.3 Policy and action at institutional level

The scientific resources of universities and other institutions, including certain elements of the private sector, should be enlisted in solid wastes research and development through the auspices of the International Reference Centre and national reference centres. Particular attention should be paid not only to studies of the health hazards to workers and to the general population attributed to the improper handling and disposal of wastes, but also to the development of safer and simpler methods for home handling of wastes.

5. MAIN CONCLUSIONS AND RECOMMENDATIONS

5.1 Health and welfare

Although only limited study has been made of the direct effects of solid wastes handling, available evidence shows that improper handling adversely affects health and property values and hampers the recycling of natural resources, besides being aesthetically undesirable. It may also lead to dangerous concentrations of toxic substances in food chain organisms through physical and biological processes.

It is recommended that international agencies and research institutions should investigate these phenomena, seeking in particular to develop

appropriate means for epidemiological studies and for monitoring the hazards of toxic industrial solid wastes. It is further recomended that national health agencies should be closely involved in policy making with respect to solid wastes disposal and should promulgate codes of practice for sanitary disposal, emphasizing the control of insects and rodents, faecal matter, and pathological wastes, and the pollution of natural waters.

5.2 Research and development

Because of differences in climatic conditions, living standards, affluence, technological advancement, and degree of industrialization, the characteristics of solid wastes, the amounts generated *per capita*, and the methods used for handling and disposing of them differ markedly between developing and developed countries. There is a lack of uniformity in the terminology and analytical methods used for solid wastes and there are gaps in knowledge and technology on all aspects of solid wastes management in both developing and developed countries.

It is recommended that research and field trials be undertaken by international agencies, specialized non-governmental organizations, and research institutions to bridge the gaps in knowledge and technology and to develop methods and equipment suited to local needs in developing countries. It is further recommended that every effort should be made to utilize industrial research expertise in solving wastes disposal problems, particularly those related to packaging and to the increasingly prevalent toxic solid wastes. The work of the WHO International Reference Centre for Wastes Disposal and collaborating institutions should be continued and strengthened.

5.3 Planning and operation

Satisfactory management of solid wastes is very largely dependent on good planning and efficient operation. These in turn must be supported by adequate legislation and financing. A well-trained staff and a high degree of informed citizen participation are the ultimate keys to a successful solid wastes programme.

The Committee recommends that international, bilateral, and private agencies should assist governments in planning and implementing solid wastes programmes through the provision of professional expertise in engineering, management, health education, and legal and financial questions, as well as by organizing training activities and providing direct financial assistance.