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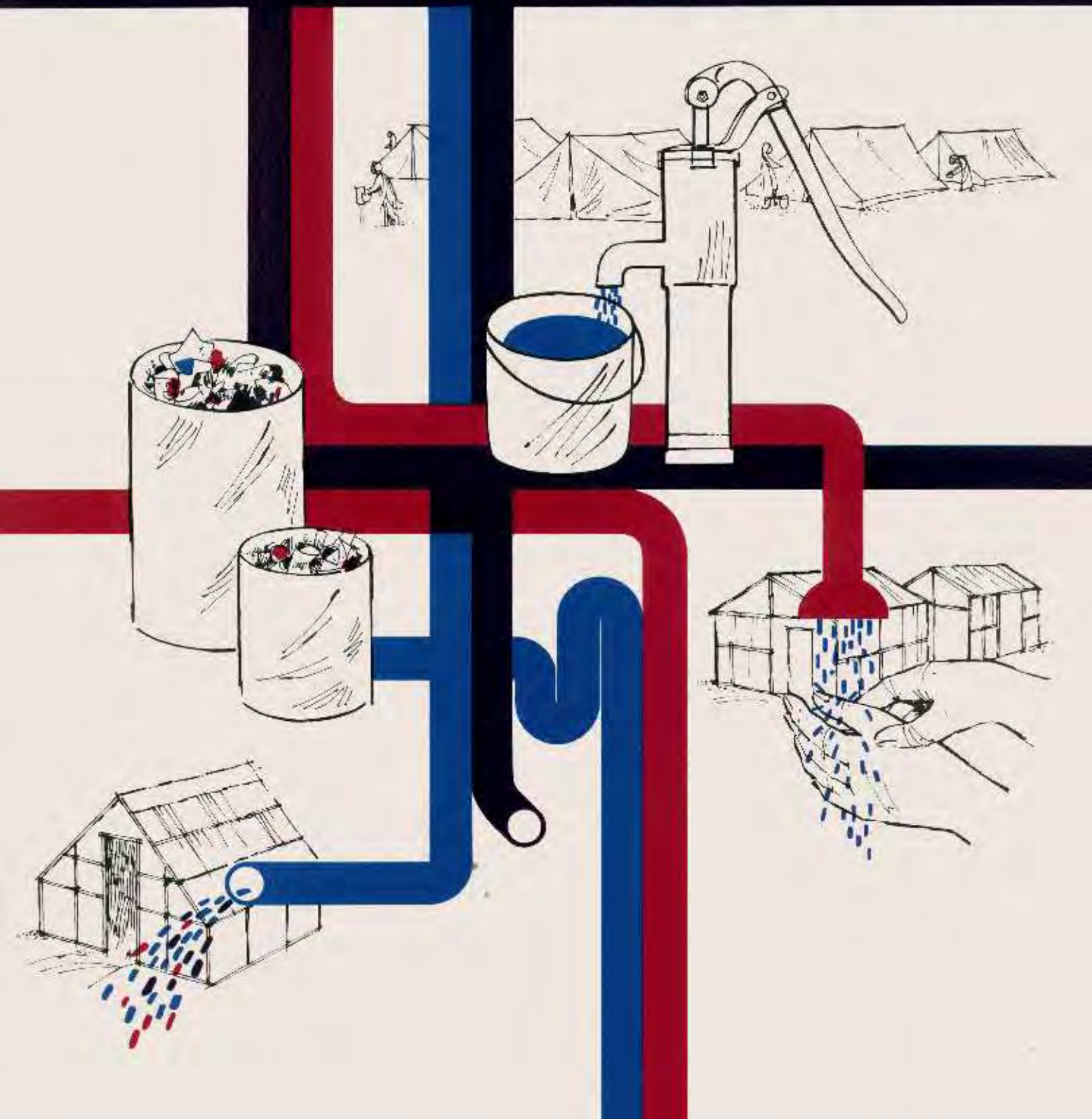
Disaster Prevention and Mitigation

A Compendium of Current Knowledge

VOL. 8. SANITATION ASPECTS



OFFICE OF THE UNITED NATIONS
DISASTER RELIEF CO-ORDINATOR
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Disaster Prevention and Mitigation

A Compendium of Current Knowledge

Volume 8

SANITATION ASPECTS

UNITED NATIONS
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FOREWORD

The Office of the United Nations Disaster Relief Co-ordinator (UNDRO) presents volume 8 in the series entitled Disaster Prevention and Mitigation. *The purpose of these publications is to provide the international community with a general review of existing knowledge of the causes and characteristics of natural phenomena and the preventive measures which may be taken to reduce or eliminate their impact on disaster-prone developing countries.*

These volumes are prepared in accordance with General Assembly resolution 2816 (XXVI), which calls upon the Office of the United Nations Disaster Relief Co-ordinator to promote the study, prevention, control and prediction of natural disasters, including the collection and dissemination of information on technological developments.

During the last two decades the international community has become increasingly alarmed by disasters, which have tended to be more destructive as they affect ever larger concentrations of population. While the response of the international community has been focussed primarily on relief action, it is now realized that the actual and potential consequences of disasters are becoming so serious and increasingly global in scale, that much greater emphasis will henceforth have to be given to planning and prevention. The effects of natural phenomena must be viewed not only in humanitarian and broad social terms, but also, and primarily, in economic terms. Natural disasters are a formidable obstacle to economic and social development. In terms of percentage of gross national product, the losses caused by disasters in some disaster-prone developing countries more than cancel out any real economic growth. There has thus been a growing awareness by Governments of the need to focus more attention on disaster preparedness and prevention, and a recognition of the fact that disaster prevention and pre-disaster planning should be an integral part of national development policy.

The aims of these studies are, first, to identify the existing knowledge and expertise which may be applied directly toward the prevention and mitigation of natural disasters, particularly in developing countries, and, secondly, to identify the gaps in current knowledge which require concerted action by the international community. They are addressed not merely to sanitary engineers or medical personnel but to a broad range of generalists with responsibilities in disaster preparedness, prevention and mitigation: policy makers in government, administrators at the national, regional and local levels, field experts and technicians in different disciplines.

The terms of reference and scope of this monograph were prepared in close consultation with the World Health Organization (WHO). It was agreed that UNDRO would focus essentially on the physical aspects of natural disasters most likely to jeopardize public health, that is to say, the disruption and breakdown of the sanitary infrastructure of human settlements, and associated problems of vector control. The present volume, Sanitation Aspects, *describes the effects of different natural hazards on the sanitary infrastructure. This provides a review of current practices and measures to minimize or contain damage and identifies essential emergency measures in the aftermath of disaster, both within the stricken zone and in relief camps.*

The Office of the United Nations Disaster Relief Co-ordinator is indebted to Dr. H. Gratz, Director of the Division of Vector Biology and Control, WHO; to Dr. W. Cockburn, formerly Director of the Division of Communicable Diseases, WHO; to Dr. R. Ballance, Division of Environmental Health and Technical Support, WHO; and to Dr. S.W.A. Gunn, Head of Emergency Relief Operations, WHO, for their invaluable guidance, advice and encouragement. On the recommendation of WHO the monograph was prepared for UNDRO by Dr. J. McDonald and Prof. D. Bradley, both of the School of Hygiene and Tropical Medicine, London.

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INTRODUCTION

Natural disasters profoundly affect human health in many ways. It is often the health aspects —the dead and injured— which loom largest in the public eye. Yet this very central position of health among the problems of natural disasters makes it an untidy area to review. To the extent that health is concerned with the absence of sickness, misery, disability and death, clearly all measures taken ahead of time to reduce the impact of natural disasters have health connotations. The main opportunity in the health field is preventing or reducing the risk of damage to the sanitary infrastructure of communities exposed to extreme natural hazards. The greater part of this monograph therefore addresses the problems of water supply and waste disposal; the main emphasis is on the conditions and needs of developing countries. The simple water supplies to which some resort in emergency are the norm for other less affluent communities. Indeed the acute problems of repair and maintenance of water supplies in natural disasters are a dramatic concentration of the issues that confront most water supplies of developing countries. The types of solutions in disasters depend heavily on the previous pattern of water supplies. Similarly as regards sanitation, the form of latrine proposed in some places for disaster situations is in other places the standard everyday sanitation facility. Conversely, many of the methods which fall short of full water-borne sewerage systems are much less liable to be damaged by earthquakes.

A first response to any disaster requires an evaluation of the health problems. Its value was clearly demonstrated in the Bangladesh floods when a rapid survey demonstrated that serious injury was not the major problem; the catastrophic events had either killed people or left them with massive trauma. Thus the intended response of other countries in proposing to send surgical teams and field hospitals was inappropriate and effort could be diverted to problems of nutrition that were pressing. The Bangladesh survey resulted from imaginative perception of the problem by research workers there. But in general it is necessary to allocate such responsibility in advance so that there is a team ready to take such action. If its survey and conclusions can be ready before international aid is mobilized the health responses to disaster can be greatly improved. The same, or a related organization is also needed to co-ordinate the subsequent medical activities.

Much of the preceding is obvious, yet problem evaluation is done too rarely. It is included in the areas of preparedness and disaster relief, while the main objective of this series of papers is prevention and mitigation. The main opportunity for this in the health field is preventing damage to the sanitary infrastructure of the community as a result of natural disaster. The measures here are mainly of an engineering type and are part of the disaster-proofing of the community and need to be implemented at the time of construction of houses and other community facilities. The greater part of this monograph therefore addresses the problems of water supply and waste disposal (Part A).

A further aspect of environmental health, besides water and excreta disposal, is the breeding of insect vectors of disease. Drainage lines may be disrupted, heaps of rubble may create depressions in which water can collect, failure of piped water supplies may result in assorted storage containers being

brought into use, and the disaster itself may be a flood or storm. All these happenings may create new breeding sites for mosquito vectors of disease. The damaged water supplies may prevent adequate personal hygiene with a consequent increase in ectoparasitic insects such as fleas and lice. The latter have been in the past responsible for terrifying epidemics of typhus in the wake of natural and man-made disasters. Vector control is considered in detail in Part B. Prevention and preparedness merge into each other here, as with water supply issues, and particular emphasis has to be placed on the stocks of equipment and insecticides which may be needed. In addition to the need for an organization capable of assessing the need for and co-ordinating health activities, and a resilient sanitary infrastructure, it is necessary to have reserves of materials for killing vectors, disinfecting emergency water supplies and handling excreta, together with appropriate transport for items such as water and water treatment facilities.

In the more general context of health problems, temporarily leaving aside the distinctions between prevention and preparedness, other categories are the clinical medical problem i.e. care of the injured, and medical preventive action comprising chiefly immunization against epidemic diseases, which is important though sometimes over-rated, and sometimes the distribution of prophylactic drugs in the face of known infectious outbreaks. The other category is nutrition which is a vast field in its own right. Provision of adequate food supplies is an immense topic involving decisions on agricultural policy. Which crops are to be grown? Second comes decisions on food storage. How large should stockpiles of grain and other foods be, and how far should they be central and how far located at district or household level? The more peripheral the stocks, the greater the problems of protection of stored products from depredations of rodents and pests. In the aftermath of disasters there are acute problems of deterioration of less durable foods and the hygiene of what the inhabitants have been able to salvage from their larders. If the disaster is large and its consequences prolonged, maintenance of minimal standards of nutrition may become difficult and lead to situations in which nutritional issues become the dominant problem.

These and other issues require an integrated approach involving agriculturalists, nutritionists, administrators, medical people, etc. and would require extended study, well beyond the scope and means of this series of publications. Thus, sanitation is but one part of the health aspects of disasters; it and other health topics overlap with each other and with many other problems of natural disasters. The selection of topics has therefore inevitably to be arbitrary to some degree, and much has had to be excluded to deal adequately with two topics. It is the hope of UNDRO that those concerned with disaster prevention will bear in mind the need to relate the different topics touched on briefly in this introduction.

Lastly, as the terms *"HAZARD"*, *"VULNERABILITY"* and *"RISK"* are used throughout this volume, it is as well to provide a brief definition of these terms[1]:

- *NATURAL HAZARD* meaning the probability of occurrence, within a specific period of time in a given area, of a potentially damaging natural phenomenon.
- *VULNERABILITY* meaning the degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss).

[1] Report of Expert Group Meeting on "Natural Disasters and Vulnerability Analysis", UNDRO 1979.

- *ELEMENTS AT RISK* meaning the population, buildings and civil engineering works, economic activities, public services, utilities and infrastructure, etc... at risk in a given area.
- *SPECIFIC RISK* meaning the expected degree of loss due to a particular natural phenomenon and as a function of both natural hazard and vulnerability.
- *RISK* meaning the expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently the product of specific risk and elements at risk.

PART A — WATER SUPPLY AND WASTE DISPOSAL

Chapter I

HAZARDS AND HEALTH

1. *NATURAL HAZARDS*

The types of hazards of relevance to this study are earthquakes, and other earth movements, and floods. The forecasting and prediction of these hazards are discussed in other volumes in the same series.

1.2 *Earthquakes and related hazards*

Apart from the ground shaking, large earthquakes can also open up new faults in rock and subsoil. This causes subsidence of the ground surface, triggers landslides and mud-flows, and causes soil liquefaction. (Landslides and mud flows are also caused by heavy rain.) These phenomena destroy *inter alia*, waste disposal and water supply systems, e.g. pipelines, sewers, water storage areas, dams and their related equipment and infrastructure. Water supplies are interrupted as pipelines are broken, stored water can also be lost through damaged pipes and dams, drainage systems become blocked, septic tanks fractured and pumping stations and treatment plants are either damaged or destroyed. A particular problem which occurs in areas where the water supply is drawn from wells is that an earthquake can cause unexpected flows of groundwater, which causes water tables to fall as water finds its way into newly-opened faults. As a result wells dry out. However, and more important, contamination of groundwater is likely to occur in unpredictable and haphazard ways due to increased percolation of surface water, or waste water from pit latrines and damaged septic tanks.

1.3 *Floods and related hazards*

1.3.1 *Acceptable risk*

Flooding is often a normal and beneficial phenomenon. Damage occurs only when flood levels are abnormally high, i.e. exceeding the "design flood" level. Damage is all the more likely to occur when settlements, agricultural developments, engineering works, etc. have not been designed and built to a specified "design flood" level; the lower the acceptable risk, the greater the return period, the higher the design flood level.

1.3.2 *The effects of floods*

Flooding can be caused by rain, snow melt, storm surge and tsunamis, all of which may result in damage to waterworks structures and treatment plants. The wind force of tropical cyclones is

sufficient to cause the collapse of structures such as water towers and other buildings, damaging water supply and sanitation facilities. Erosion by violent floods can expose and displace buried pipelines. But the main effect of flooding on water supply and excreta disposal systems is the contamination it causes by dispersing refuse and waste and picking up excreta particularly in areas which lack adequate sanitation. This back flow in sewers and drains allows sewage to flow into streets or buildings through man-holes and other access points. This flows into wells, broken pipelines and the water supply system. Prevention measures include sensible design and good land-use policies.

1.3.3 *Hygiene*

Floods may also make normal hygiene precautions impossible. If all fuel is wet, water cannot be boiled to sterilise it, nor food cooked, and if the ground surface is under water, wastes cannot be buried. Floods may also present the most widespread and serious health hazards in terms of sanitary conditions.

1.4 *Populations at risk*

1.4.1 *Where people are located*

Where people remain within a disaster zone, the repair of existing water and excreta disposal systems becomes a priority. Provisions should be made for temporary and alternative facilities until the main system is repaired. When people move into temporary accommodation or encampments, the need will be for the rapid improvisation of water supplies and waste disposal facilities. Very often in these places, no previous sanitation system existed. This requirement for improvised sanitation facilities is common in all types of disasters.

1.4.2 *Sociological considerations*

In all disasters in which water supplies are interrupted, or improvised sanitation is introduced, there will be educational and social problems as people are asked to take unfamiliar hygiene precautions or change life-long habits. Local cultural preferences will need to be taken into account in the design of emergency systems. Hence there will be a further need for instructing disaster victims on the use and care of water supply and sanitation facilities. This can be done by way of broadcasts, posters, and leaflets prepared in advance.

1.5 *Sanitary risks*

1.5.1 *Types of risks*

a) Contamination of water supplies.

b) Contamination of the ground (leading to a risk of diseases such as hookworm and to contamination being carried into people's homes on dirty feet).

c) Breeding of disease vector* (on decaying rubbish, excreta, and bodies of animals —and humans— killed in the disaster).

*See Part B on Vector Control.

1.5.2 *Contamination of drinking water*

The most serious disease hazard encountered in the types of disaster considered in this study arises where there is gross contamination of drinking water. After an incident of this kind, many diseases which are normally associated with bad hygiene may behave as classical water-borne diseases and affect large sections of the population, including those whose hygiene habits are normally sufficient to prevent disease. Thus in conditions of gross contamination of water supplies, diseases which may be water-borne not only include typhoid and cholera, where they are endemic, but also bacillary and amoebic dysentery, infective hepatitis, and gastroenteritis. With high risk of outbreaks of these diseases, methods for emergency treatment of water with sterilizing chemicals play an important part and in areas where typhoid and cholera are endemic, immunization may also be desirable as a secondary precaution.

1.5.3 *Diseases and epidemics*

The other major environmental health hazard during disasters occurs when people are crowded together in emergency camps. Under these conditions, lapses in sanitation or food hygiene, or any pollution of the water supply can have widespread effects. Infectious diseases, notably measles, may spread rapidly. Diarrhoea and dysentery are common, particularly where facilities for excreta disposal have been neglected. Measles epidemics and respiratory infections are sometimes associated with crowded living condition in relief camps, but others (e.g. tuberculosis) are evidently of long standing, and indicative of the poor health of the population prior to the disaster. There are also diseases symptomatic of insufficient water for washing (e.g. dermatitis, conjunctivitis and trachoma), but these probably also reflect the pre-disaster conditions of the local people. Medical provision for relief or refugee camps may therefore not only tackle immediate health risks, but also some of the long-term health problems of the people concerned.

1.5.4 *Pre-disaster context*

Apart from the special problems associated with emergency camps the risk of a serious outbreak of disease following a disaster should be seen in its pre-disaster context. It is worth recalling that even in "normal" circumstances, many people are currently dependent on inadequate water supplies which are contaminated to some extent. The World Health Organization estimates that two-thirds of the population of the developing countries do not have access to "safe" water. So the question to ask is: what *new* outbreaks of disease will a disaster create under these conditions?

1.5.5 *Disruption, speed of action*

One final consideration is that if the disruption of normal conditions lasts for any length of time, the incidence of certain diseases may steadily built up, e.g. malaria, typhus, increased skin or eye complaints. If there is no provision for excreta disposal or for disposing of organic rubbish and animal carcases, again the risks to health will steadily increase. Few serious health risks need develop if proper planning for water disposal is carried out quickly.

Chapter II

RESISTING AND CONTAINING DAMAGE TO WATER SUPPLY AND WASTE DISPOSAL SYSTEMS

2.1 *Choice of systems*

Much can be done to guard against damage from earthquakes and floods in disaster-prone areas when designing entirely new facilities for water supply or excreta disposal. Where existing systems are not designed to cope with disaster conditions, small improvements can still be made, through equipment renovation or extension of the existing system. In discussing advance precautions of this kind in disaster-prone areas, this chapter concentrates on the measures which must be taken in planning, constructing, and modifying the systems in order to reduce the risk of damage.

2.1.1 *Types of damage and response*

There are two kinds of damage to consider. First, structural damage to pipelines and installations, and second, pollution of water supplies and overflows of sewage. A modern water supply and sanitation system usually covers wide areas with a complex network, and tends to function as a single unit. As parts of it are likely to sustain damage during earthquakes or floods methods of localising damage and facilitating repairs should be devised. A series of small self contained systems may be better able to offer partial service after damage than one single, integrated system. Simple intermediate technologies may prevent massive breakdown by localising damage and easing repair and maintenance.

2.1.2 *Relevance of systems to socio-economic conditions*

In many countries, water-borne excreta disposal is not an optimum solution for a whole range of social and economic reasons. Modernized cartage equipment for emptying household vaults or bucket latrines appears to offer a promising alternative in many instances. The technology of some vault systems, in particular, may be quite sophisticated, but since there is no city-wide network of specialized infrastructure, any disruption after a disaster is likely to be highly localised. The most advanced systems of this kind are to be seen in Japan; excreta and some waste water from latrines inside each individual house are collected in an underground tank or vault built into, or near the foundations of the house. The vault and equipment used, are carefully designed so that odours and gases are carried away by a vent pipe. The vaults are emptied at regular intervals by a tank-carrying truck equipped with a vacuum or suction pump and a pipe which can be lowered into the vaults to empty their contents. In Japan, the system is managed to the highest standards of hygiene, with smartly painted and spotlessly clean vacuum trucks operated by the municipality, who also operate

the sewage disposal and treatment facility, where the trucks are emptied. With increased waste water disposal problems, it is evident that the demand for indoor plumbing is encouraging the gradual replacement of this system by piped, water-borne sewage systems, even though these often have a high exposure to risk.

2.1.3 *Design and construction*

Where extensive networks of pipes and complex systems are necessary, there are still many precautions which may be taken to ensure that damage can be contained or localized. For example, if a large water supply system draws water from several different sources in different locations, it will be easier to maintain supplies when only part of the system is damaged than if it is dependent upon a single source. The question of disaster resistant construction arises when one turns away from systems to consider structures. Here it is important to distinguish between preventing, resisting and containing damage due to earthquake or floods. Containment or localization of damage is achieved mainly by careful design of the system as a whole, in the manner described. The design of structures, however, is concerned with resisting and, if possible, preventing damage.

Damage-resistance is often inherent in systems based on simple technology which are also basically low-cost systems, as for example, when a flexible pipe is used in an earthquake zone instead of a rigid one. Attention should also be directed to features in the design and construction of installations which will enable them to *resist* damage at no extra cost. A modest level of resistance should be combined with design features already mentioned which make it simpler to contain the damage which does occur. Precautions aimed at preventing damage demand extra safety factors in civil engineering structures which are often cost-intensive and only reduce the extent of damage.

2.2 *The siting of installations*

2.2.1 *General considerations*

Treatment plants and related installations should be sited on relatively high ground where site vulnerability to flooding is low. In instances where this is impossible to achieve, because of existing settlements and activities, or because it would involve excessive costs for pumps and pipelines, the only option is to reduce the vulnerability of the treatment plant as a whole. This is done by establishing the "design flood" for a return period that is sufficiently long to cover the expected economic life of the installation.

Although key installations in a water supply system can often be located in relatively hazard-free locations, water and sewage pipes service extensive areas. It follows that the entire network cannot systematically be raised above flood levels. A clear knowledge of site hazards is therefore important. In flood-prone areas, sewer pipes should be buried more deeply than usual, and the trenches filled in with heavy, well compacted material. This reduces risk of flotation and displacement due to flooding. In the same way, when pipes enter an earthquake prone area, the incorporation of extra flexible joints may reduce their structural vulnerability.

2.2.2 *Cross-over points*

Similar considerations affect the construction of aqueducts or bridges which carry pipes over rivers. Not only do earthquake vibrations tend to have a larger amplitude near rivers, but there is a

risk that the bridge abutments will move relative to the surrounding ground during an earthquake. If these structures are based on soft subsoils, the use of expansion joints at the abutments and at the junction of separate spans of the bridge is recommended.

2.2.3 *Proximity to buildings*

Another danger point in water or sewage pipelines is where they pass near buildings likely to be damaged during an earthquake, and where the collapse of the building or the rupturing of its service connections is likely to damage the pipe. Whenever danger spots of this kind are noted, or danger spots associated with geological conditions, it is a good idea to install cut-off valves in the main pipe on either side of the hazard, with hydrants nearby to which an emergency pipeline could be connected. In the event of damage, not only can the damaged pipe then be isolated, but a temporary pipeline laid from one hydrant to the next which by-passes the damaged section.

2.2.4 *Floods and excreta disposal*

Where river flooding is a hazard, it is perhaps obvious that installations for excreta disposal and treatment should be downstream from any nearby settlement to avoid the risk of flood waters carrying sewage directly into that settlement. As an added precaution, ponds for the containment of sewage may be protected by embankments or concrete flood-walls extending above the regulatory flood level. This prevents sewage being picked up by floods. Similarly, reservoirs and tanks for water supply should be above regulatory flood level, or protected by embankments, so that contaminated flood water cannot enter the water supply system.

2.2.5 *Water towers*

There is also a special risk with structures such as water towers which may resonate with the earthquake vibrations. This tendency of tall structures to vibrate in sympathy with the natural ground frequency is greatest when the structure is located on thick layers of unconsolidated deposits. It is therefore necessary to establish the appropriate hazard maps, and from these establish the vulnerability of structures and the corresponding land-use restrictions.

2.2.6 *Landslide areas*

Particular care should be taken to assess risks associated with steep slopes where landslides may be triggered off either by heavy rain or earthquakes. Owing to the danger of violent overflows of reservoirs, the rupture of pipes, etc., vulnerable plants should not be built on or near such slopes.

2.2.7 *Liquefaction*

Soil liquefaction is one of the most predictable, and at the same time, one of the most damaging of earthquake hazards, reducing the bearing capacity of soils at foundation level. Much of the damage sustained by pipes laid in silts and sands saturated with water is due to soil liquefaction, which occurs during earthquake vibrations when pore pressures within the soil build up leaving insufficient friction between particles to resist shear stresses.

2.2.8 *Flood frequency and levels*

The frequency and level of flooding due to heavy rainfall and river-bank overflow can be

estimated, given the wide availability of modern hydrological methods and techniques. Moreover, the relative simplicity of the flooding process, compared to the complex chain of events triggered by seismic shaking, allows one to estimate with a fair degree of accuracy the vulnerability of a given location. It is usual to estimate the flood levels for 10, 25 and 100 year periods and to map them. Water supply systems, treatment works and reservoirs should be sited in accordance with the return period equivalent to their economic life.

2.2.9 *Dynamic effects of water*

The flow of floods also has a dynamic effect on structures and causes erosion. Where flooding due to tsunamis or storm surge is a possibility, dynamic forces accompanying the flood are a particularly significant factor. Where these aspects of flooding are likely to exist, a classification system analogous to that above for earthquakes could be devised.

2.2.10 *Hazard mapping*

Hazard maps should be produced for areas affected by floods and earthquakes, demarcating all the areas where it is inadvisable to build treatment plants or similar services. More generally useful in an area covered by a network of pipes, might be a map indicating the precautions to be taken in laying pipes in each zone. This includes depth (which affects vulnerability to earthquakes and floods), and the need for extra flexible joints and extra shut-off valves.

When mapping earthquake hazards on a local scale, e.g. within the confines of a city boundary, the points to consider are those where earthquake damage is likely to be greatest, i.e.:

a) Where there are deep layers of "soft" soils, sedimentary sands and gravels, marshes and filled ground; subsoils of this type do not damp earthquake vibration in the way hard rocks do,

b) Where there are layers of loose water-saturated sand and coarse silt (i.e. layers of wet, cohesionless soil), in which soil liquefaction occurs,

c) Where there are faults in the rock strata, pipelines crossing faults, or when structures straddling them are obviously at risk during an earthquake.

By combining data relevant to these factors, it is possible to determine the expected level of risk.

2.3 *Earthquake resistance*

2.3.1 *Water supply and sewer lines*

The normal functioning of water supplies after an earthquake is important not only for drinking water and personal hygiene but also for extinguishing fires. After the 1972 earthquake in Nicaragua, for example, water supplies in the capital city were completely disrupted, and thus fires burned unchecked for several days. In view of experiences of this kind, emphasis should be placed on planning water supplies so that they draw from more than one source which can be quickly tapped. In such cases if source-works were damaged by the earthquake, as happened in Nicaragua when landslides blocked water intakes, there would still be a possibility of providing some water from a subsidiary source.

Modern water supply practice is to lay main pipelines in a closed circuit, rather than having a single dead-end pipe supplying a particular neighbourhood. Ring-mains of this type are particularly valuable in earthquake-prone areas, because if one of the pipelines is damaged, there is still the possibility of maintaining supplies from another direction. Obviously, sewers and pipelines should cross geological faults *as infrequently* as possible within the constraints of the urban layouts. Better still, plans for new urban areas should take hazardous sub-soils into account.

In general, sewers and water mains should be laid on opposite sides of the street so that if both are broken by an earthquake, the risk of cross flow will be reduced. Household connections to the sewer will still have to cross the line of the water pipe, but these are easier to deal with than the large flows of sewage which may issue from a fractured main. When pipes are laid, their location should be marked on large scale street-plans.

2.3.2 *Structural design*

With regard to detailed structural design in seismic zones, a number of specific points about pipelines, water tanks, dams and wells are worth mentioning.

2.3.2.1 *Pipelines* have traditionally been made of rigid material in industrialized countries, with rigid jointing and rigid bedding. Pipe materials have often been selected according to the chemical content of the earth and water, and their ability to resist corrosion. However, flexible pipes can perform satisfactorily in corrosive conditions, and offer distinct advantages when used in earthquake-prone regions.

Some types of flexible pipes are outlined below:

(a) Steel pipelines with welded joints have a very good combination of strength and flexibility, provided that the welding is done carefully. This is difficult to achieve, since welding is done on site. Such pipelines have survived earthquakes in Japan very successfully. However, they need protection against corrosion by zinc, bitumen or plastic coating etc. and by the use of inert backfill, or by a magnesium cathode.

(b) Polythene water pipes can be laid underground using mole ploughs which pull the pipe through the ground straight off the coil at great speed. Joints are made in short trenches dug for that purpose at the end of each run. Since many failures during earthquakes occur at the connections between pipes, the use of these very long lengths with a corresponding reduction in the number of joints is a distinct advantage. When polythene pipes are used inside buildings, resistance to earthquake movement is improved if greater than normal tolerance is allowed where pipes pass through, or adjacent to, structural members.

(c) Pitch-fibre pipes are available for non-presssure sewer systems below ground, and come in a variety of sizes from 50 mm to 220 mm diameter and usually in 3 metre lengths. Lip-ring joints and fittings are in pitch-fibre and are telescopic, designed to allow for thermal expansion, but with inherent properties of some additional flexibility useful in seismic areas. Usually there are four main types of pipe failures during earthquakes: failure due to transverse shearing stress; due to axial forces of both compression and tension due to longitudinal bending; and also very frequently, failure of joints between pipes. Pitch-fibre pipes resist fractures of all these types to a very significant degree.

The use of shorter lengths with an increased number of connections actually increases the flexibility of the pipelines, and contrary to experience with most other materials, improves the ability of the pipelines to withstand earthquake shocks. Pitch-fibre pipes contain approximately 30 per cent cellulose fibre, and since pitch is technically a liquid at all normal temperatures, plasticity is permanent, and there is no risk of fatigue in the material due to continuous or reversing pressures. The report of a survey team which inspected damage in Tristan da Cunha following the volcanic eruption and tremors of 1961 commented that the only pipelines still functioning were made from polythene or butyl rubber. They are now sufficiently durable to be considered for permanent as well as temporary use.

2.3.2.2 *Small corrugated iron storage tanks* of the kind often used for domestic purposes in some countries, have been described as a bad risk due to their rate of collapse in earthquake shock, however, experience shows that this is due more to poor maintenance than to instability. In addition to the direct effects of earthquake shock on structural components, water in open tanks may assume dangerous wave motions which can be countered by inserting baffle plates inside the tank. In closed systems, surges of fluid may occur resulting in pipe damage.

2.3.2.3 *Water towers and elevated water tanks.* These are almost the only water supply components to be mentioned in most building codes for earthquake-prone areas. Supporting structures must be designed for stability when the tank is empty as well as full, particularly for resistance against high wind. Tanks supported by steel frames, if provided with ample diagonal bracing, have frequently survived earthquakes very well. The most vulnerable point being where pipes enter the ground. There is usually minor damage to braces which should be promptly repaired so that the tank can withstand another shock if necessary. The survival rate of concrete water towers is less consistent, and the precautions to be taken in construction are less clearly defined.

2.3.2.4 *Rock-fill dams* specially designed for maximum earthquake resistance, have certain advantages over both earth and concrete; they tend to be more flexible than concrete dams, not suffering from the earth slips and soil liquefaction problems which are notorious hazards with earth structures in seismic zones. However, clay or concrete is used in rock-fill dams to make them water-tight, and since both these materials are liable to develop cracks during a severe tremor, the dam may leak. The rock-fill structure, however, will withstand small leakages more successfully than an earth dam, and should survive if the leaks are promptly repaired.

2.3.2.5 *Earth dams* give way during earthquakes through failure of foundations, cracking of the cores, earth-slip on the embankment, or over-topping due to compaction or to earth-slips which lead to loss of freeboard. During the San Fernando earthquake in California in 1971, one dam whose foundations failed, moved 1.5 metres downstream, though without significant loss of water.

2.3.2.6 *Concrete dams* may crack or experience failure of the foundations, and with all dams, there is a danger of waves developing in the reservoir which will over-top the dam. This can be a very serious hazard when land-slides falling into the reservoir generate very large waves or "fresh water tsunamis".

An important point to consider when designing dams is that horizontal movements during an earthquake may create hydrostatic pressures on the dam which are 15 per cent or more greater

than normal. Seismic coefficient for the area concerned should be used to estimate more precisely what increase in pressure should be allowed in any given area. In the design of all dams, "the difficulties of analysis are so great, and the consequences of failure so serious" that the cost of refined model studies, and extra analytical checks on earthquake resistance, can reasonably be justified.

2.3.2.7 *Wells* suffer damage during an earthquake by subsidence of the surrounding ground, contamination of the water, or changes in the water table. Quite commonly, the ground will sink relative to the well lining causing the lining to collapse, or seriously damaging the whole well-head, including pump mechanisms. Little attention has been given to earthquake-resistant design.

2.4 *Flood resistance*

In considering flood resistance, it is important to stress measures to prevent contamination of drinking water and of the environment generally, as well as the resistance of structures to erosion.

2.4.1 *Surface drainage*

Surface drainage needs to be planned as part of the flood control system as well as to dispose the local run-off water and perhaps certain categories of waste water. In flood-prone areas, separate drainage systems should be provided for domestic waste water disposal and rain-water drainage; rain-water may appropriately be carried away by open ditches. In earthquake zones where heavy rains also occur, there is a definite advantage in using open ditches for rain-water drainage as they become blocked less easily.

2.4.2 *Piped sewage*

Piped sewage is an instance where the prevention of contamination is the prime issue. If flood water-levels rise higher than the level of sewer outfalls, water and wastes will back up in the sewers and discharge onto the ground. This causes contamination and may also lead to the pollution of wells, making ground water unfit for use for a long period afterwards. It is therefore important that wherever flood water-levels are likely to be high enough to have this effect, automatic or manual shut-off valves to prevent-back flow should be installed. In instances where back-flow has occurred, and ground-water has become polluted, people should be supplied with water from an alternative source, or emergency water purification should be implemented. Sewerage structures should also be resistant to erosion by flood, and should take into account water load, uplift or flotation, and the lateral forces created by flood water. Where appropriate, provisions should made for foundation drainage, with sumps and pumps. Sewer pipe laying should also take account of flood-water erosion, and where there is a particular hazard, it is advisable to lay sewers at a greater depth and in heavier material than would otherwise be necessary.

2.4.3 *Wells*

Wells have an inherent degree of flood resistance *if* properly constructed with a head wall about 1 m high around the top of the well, and a concrete apron extending about 2 m from the head wall in all directions. These precautions should be effective where shallow or short-term flooding is experienced. Where the area is inundated for long periods of time, or to greater depth, percolation of flood water into the well is very likely to reach significant levels, with a high probability of contamination. Methods are available for disinfecting contaminated well water affected by floods. (See Chapter 3).

2.4.4 *Flood-walls and embankments*

Flood-walls and embankments with a generous freeboard above expected flood levels, may be used to protect treatment works, power supplies, reservoirs and sewage ponds in low-lying areas, and need protection against erosion by floods. With concrete flood-walls, the main problem is at the foundations; protection may be provided by constructing a horizontal concrete apron alongside the wall level with or below the ground surface. Earth embankments are well protected against erosion if a good grass cover is maintained on them. Trees and bushes should not be allowed to become established as they impede the flow of water their roots can damage embankments.

2.4.5 *Dams*

Dams built for water supply purposes are vulnerable to flood conditions mainly when they are constructed with insufficient overflow capacity. Therefore, dams cannot safely accomodate the flow of water which may result from a heavy rainstorm. It is said that 23 per cent of failures of large dams are due to this. If adequate hydrological data are available when a dam is built, it should always be possible to design spillways sufficient for 100 year flood-periods. Where, as often happens, the necessary data are lacking, recourse must be made to one of several methods for estimating the peak volume of run-off water likely to be a experienced in any catchment area. These methods use a very limited range of data which can be assembled in a relatively short time. Examples are "Cook's" and the "rational" methods which have been adapted to African conditions. These by themselves are adequate for the design of spillways on small dams, provided adequate safety factors are allowed. With larger projects, rain gauges and stream gauging stations should be established in the catchment area when a dam is proposed, so that as much data as possible can be collected before the spillway design is finalized. A dam's resistance to flood water levels may also be heavily dependent on its state of maintenance, especially when there is a possibility of erosion in spillway channels, or where the settlement of an earth embankment leaves insufficient freeboard.

The failure of a dam could be itself the cause of a flood disaster of a particularly dangerous kind. Many failures are due to the rupture of foundations or insufficient bearing capacity within the structure. Therefore, these aspects of design and construction require special consideration. If a dam is likely to fail for either of these reasons, there are usually warning signs hours or even days before failure occurs. If maintenance organizations keep a regular check on conditions, disasters will be prevented by releasing water from a dam in a dangerous state. Regular maintaining should be made of a structure's settlement, creep, shrinkage, seepage water flows, etc. In small earth dams, seismic recording equipment may be installed to give a continuous record of movements in embankments as well as of tremors associated with the filling of the reservoir.

2.5 *Long-term measures*

Floods are becoming more frequent and more damaging in a number of river basins because of deforestation in the catchment area, often coupled with intensive agriculture in which water conservation is not practised. Both these developments lead to large increases in run-off storm. Over-grazing on pasture land has a similar effect.

While both timber and agricultural production provide a significant boost to the economies of some countries concerned, erosion and degradation of the soils quickly develops, which together with flood damage further downstream, is likely to wipe out the short-term economic gains very quickly. In contrast, agricultural practices which conserve soil slow down the run-off of rainwater

during storms, and therefore help to reduce flooding. Sound ecological management of forest resources is desirable. Timber and firewood create shelter belts around agricultural land and control soil erosion and floods.

When flooding is caused or greatly worsened by ecological factors of this kind, the construction of embankments and other expensive flood protection works is of little use and is expensive. Elaborate flood control measures may be partly avoided by policies such as designing flood control works in conjunction with water supply and excreta disposal works. Provision of extra capacity to hold back flood water or methods of releasing compensation water from the reservoirs may be devised to smooth out peak flows in river channels. The location of sewage outfalls in rivers can also be adjusted to reduce flows in constricted parts of the channel.

The influence of water supply systems and drainage on ground water levels in heavily populated areas may also be significant. Where flooding tends to result from a rising water table, large concentrations of aqua-privies and septic tanks discharging water into soakage pits could influence the flood hazard; alternatively, where water is mostly obtained from wells, and drainage is by pipes discharging a distance from the area, the flood hazard may be reduced.

2.6 *Maintenance to reduce vulnerability*

Damage resistance is often inherent in systems. It is essential to understand that every disaster preparedness plan should contain a maintenance programme for the satisfactory long term operation of any water supply or excreta disposal system. In many countries, poor maintenance presents a bigger threat to water supplies and excreta disposal systems than do natural disasters. In developing countries among the minority of people who have an improved water supply, many cannot be assured of its reliable and continued operation, because maintenance of the equipment is a serious and unresolved problem. It has also been rightly said that if scarce resources are to be used to their full effect, governments and aid donors must place greater priority on maintenance than on construction of water supply systems.

Most components of sanitation systems, including treatment plant, pumps, wells and pipelines have a need for regular maintenance which, if met, will increase the ability of the systems to resist damage, and will speed repairs after a natural disaster. Therefore the creation of an efficient, competent maintenance organization for sanitation systems (including water supplies) will probably contribute more to disaster prevention than capital expenditure on structures. The existence of such organization will also make disaster mitigation simpler and speedier by ensuring that spare parts, equipment and trained personnel are available wherever a sanitation system exists.

Chapter III

WATER SUPPLY AND WASTE DISPOSAL IN DISASTER-STRICKEN ZONES

3.1 *General*

This chapter is largely concerned with disaster zones containing cities, towns, and large villages. However, some of the points made, such as the disinfecting of wells, waters and the problems of supplying water by road vehicles, are relevant to the smallest rural communities.

In densely populated areas where there is a high risk to health, and where cholera and typhoid are known to be endemic, the occurrence of a natural disaster will necessitate the provision of emergency medical facilities and may call for an immunization programme. In general though effective sanitation is likely to save more lives than immunization. The early concentration on sanitary standards helps to reduce medical needs later on. Lack of adequate sanitation is often the biggest factor in the morbidity rate after a disaster. Effective hygiene and excreta disposal is far more valuable than curative treatment.

The need to give priority to sanitation may seem obvious but in the past many relief agencies, government and non-governmental organizations, have spent vastly more on medical relief than on sanitation.

When immunization against typhoid and cholera is decided on, relief workers should be the first to be treated. They may lack the natural immunity to local conditions possessed by permanent inhabitants of the area and therefore be at risk. The programme might include TAB and cholera immunization, and perhaps also immunization against poliomyelitis. Measles vaccination and B.C.G. vaccination against tuberculosis could be relevant for people crowded together in camps. It should be remembered, however, that immunization gives very limited protection against cholera, especially when it is given to people who may be immediately exposed to infection rather than as an advance precaution. The primary policy should emphasize taking precautions and only secondly immunization. Relief workers, in particular, should be furnished with water sterilizing tablets for personal use, and/or individual drinking water filters (proprietary brands include Aquapak and Filopur); they should practise the highest possible standards of personal hygiene.

3.2 *Water supply*

Restoration or provision of a safe drinking-water supply will be the first priority in many disaster situations, water being the greatest necessity for short-term survival. The quantity of water

needed to sustain life is astonishingly small: 2 litres per person per day; a minimum supply of 3 litres per person per day in temperate climates, and 6 litres per person per day in hot dry climates, respectively is recommended. A more desirable level of supply is 15 - 20 litres/person/day to allow reasonable quantities for personal hygiene. Even in the immediate aftermath of a disaster, clean water is needed for purposes other than drinking for example the preparation of food, the cleaning of wounds and some for the washing of young children.

3.2.1 *The local response*

The supply of water after a natural disaster usually depends on local resources, because supplies of spare parts, equipment and chemicals from outside the area will take time to arrive. Each community *must plan* to provide water under these circumstances, so as to limit and contain the health risks resulting from the disaster. Preparedness, based on good contingency planning, must be based on a review of the techniques which might be used to restore or maintain water supplies quickly.

3.2.2 *Rural measures*

3.2.2.1 *Disinfection of wells* is a priority measure wherever people depend on them for drinking water, and because open, hand-dug wells are very vulnerable to contamination during a natural disaster. Simply to tip chlorine solution into the well, or to sprinkle bleaching powder in it, is too haphazard, though it will certainly show some immediate improvement.

3.2.2.2 *Water filtration* however, a more satisfactory but simple method, has been developed in India. This technique makes use of a large earthenware pot of 12 to 15 litres capacity with two holes, 6 mm in diameter, drilled through the sides half-way up. A moistened mixture of 1.5 kg of bleaching powder and 3 kg of coarse sand is then placed in the pot, and should fill it to just below the level of the two holes. The mouth of the pot is covered with polythene or other foil, tied firmly round the neck, and the unit is lowered into the well to one metre below the water level. It is claimed that this can chlorinate a well of about 10,000 litres water content from which 1,000 litres are drawn daily — ideally a supply for about 50 people. In such a well, the pot chlorinator will be effective for about a week, and must be withdrawn and refilled with fresh mixture.

An alternative type of pot, effective for two weeks in a well of the same dimensions, has been tried. It is an earthenware vessel of about 10 litres capacity with a six to eight holes (6 mm diameter) drilled in the bottom. A layer of small stones covers the holes, with pea-size gravel on top. A dry mixture of 1.5 kg bleaching powder and 3 kg sand is placed over the gravel, and the remaining space in the pot is filled with more gravel, up to the neck.

With both the above types of pot, a period of one or two days is necessary after inserting the pot, before contaminated water in the well is fit to drink. A test for residual chlorine can be made to ascertain when this situation has been reached. For smaller wells, however, the pots described above will lead to over-chlorination, and an arrangement is needed which will release the chlorine from the mixture more slowly. This can be done by using two cylindrical pots, one carried inside the other. Holes are drilled in the sides of both pots; the inner one contains the mixture of sand and bleaching powder, and the outer one is sealed at the mouth with polythene foil, as before. When this is suspended in the well below water level, a chlorine solution will build up in the outer pot, which will gradually be released into the well through the hole in the side.

3.2.3 *Urban measures*

In towns and cities with piped water supply, the following precautions should be taken:

a) quick repairs to pipes using plastic patching and other modern techniques;

b) by-passing damaged pipelines by operating the relevant valves, or by installation of temporary pipelines;

c) raising water pressure to reduce the risk of polluted water entering the system, (though this will lead to increased loss from broken pipes);

d) increasing the chlorine concentration in supplies which are normally chlorinated;

e) arranging emergency chlorination of supplies not normally chlorinated;

f) use of alternative water sources, including private supplies; use of inter-connections with other supply systems;

g) use of previously untapped but accessible water sources with improvised chlorination;

h) where water treatment as in *(d)* or *(e)* is impossible instructions may be given to the local population about measures they should take at home, including the boiling and filtration of drinking water;

i) where a piped supply has been completely interrupted, or water is badly contaminated, water tankers may be used to distribute water by road to publicly announced water points;

j) water-purifying mobile tankers can cleanse and distribute water;

k) emergency storage and treatment facilities may be set up in swimming pools, milk or soft drink bottling plants or in tanks and reservoirs belonging to industrial concerns;

l) polythene or butyl rubber tanks may be usefully provide emergency storage;

m) provision of auxiliary electric power to pumps in the event of a power breakdown may be necessary;

n) where a dam or reservoir wall has been badly damaged and is in a dangerous state, the reservoir should be partly or entirely drained;

o) repairs to town water supplies, in many instances can be completed quickly provided that the waterworks authority is adequately prepared. Techniques now exist for coupling pipes, and for patching broken pipes with plastic materials, but effective use of these methods depends very much on advance preparation, including the training of technicians. Where temporary repairs depend on the use of mortar or concrete, (for example, plugging cracks in concrete channels or reservoirs), the concrete can be made to set much more quickly by adding various chemicals to the mix (calcium chloride; common salt, i.e. sodium chloride; or sodium carbonate). However, concrete made in this way is suitable for temporary repairs only, as the salt tends to cause corrosion of steel reinforcing bars;

p) where a pumping station or water treatment plant is flooded, priority will naturally be given to pumping out the flood water and then disinfecting all the equipment;

q) when water mains have been repaired, they need to be flushed clean and disinfected before being put back into use. This is done by pumping water into the pipe through a hydrant or valve, using another hydrant as an outlet. In order to flush out large pieces of dirt, it is desirable first to pump water through the repaired section as quickly as possible. Then a chlorine solution is prepared, much stronger than ordinary chlorinated water. In emergency conditions, when the pipe must go quickly back into service, the strength of this solution should be 100 mg/litre. This solution should be left standing in the pipe for at least an hour, (weaker solutions would normally be used, and left for a longer period). The solution may be pumped in at a high pressure to check whether the repair is watertight. Finally, the pipe is flushed again with potable water so that when supplies are resumed, the water is not over-chlorinated. A simpler but less satisfactory method of disinfecting pipelines after repair is to place weighed quantities of calcium hypochlorite or bleaching powder within each length of pipe as it is laid. When water is first let into the pipe it will then form the necessary strong chlorine solution which can be left to stand in the pipe as before. The difficulty is that the solution will not be of even strength, but will be relatively weak at the point where the water is admitted.

3.2.4 *Other measures*

Large water undertakings may normally use several sources of supply, and it may be possible to isolate a contaminated source or rely temporarily on others. In a disaster-prone area it will be necessary to develop a standby water source in advance of a disaster, or make arrangements with other nearby water-supply authorities to make emergency connections with their supply. In many cases, alternative sources will supply less water than the usual source, and it may be necessary to cut off supplies from non-essential users.

If it is not possible to get rid of contamination in water supplies very speedily, the most immediate desired action is to instruct the public regarding precautions to be taken in their homes. These are the following:

a) *Boiling water* for sterilization is only possible if sufficient fuel is available and this often proves to be a problem. It is important to note that a vigorous boil is required, and not just a simmering. In lowland areas, within 1,000 metres of sea level, five minutes boiling is needed. On higher ground, an extra minutes boiling for every 1,000 metres of altitude is required.

b) *Tablets.* The use of water sterilizing tablets will usually depend on contingency plans having been made to distribute them rapidly in the event of a disaster. One of the disadvantages of tablets is that packages which are exposed to air lose their effectiveness and they can be quite easily mistaken for household medicine.

c) *Storage of water* in a closed container for several days can be an effective method of treatment, as most pathogens in the water will die in these conditions. If water supplies are likely to be interrupted for more than two or three days, this method may be useful. However, containers should be thoroughly cleaned, and securely covered to prevent dirt or insects gaining access —otherwise they may become breeding sites for disease vectors.

3.2.5 *Alternative water sources*

Alternative water sources will need to be considered if ground-water is too badly contaminated

for wells to be disinfected, or if piped water supplies in a town are interrupted. There are two kinds of alternative source which may be used —sources already developed and normally used for other purposes, for example, by industry, and sources which have not previously been tapped at all. Contingency planning for a disaster should include inventories of both kinds of source, and prior arrangements for emergency access should be negotiated with the owners of private and industrial supplies.

Where no alternative source which has already been developed exists, it may be necessary to use previously untapped but accessible sources, such as rivers, streams, lakes, ponds and springs. It may also sometimes be feasible to sink shallow wells quickly, but in general, water 50 metres below ground requires several weeks of engineering work to be made available. In rainy areas, it may be possible to improvise tanks to collect water directly off large roof surfaces. This may be a particularly convenient form of improvised supply, though it should be remembered that some kinds of disasters lead to large amounts of dust and other dirt being thrown onto roofs, e.g. from collapsing buildings during an earthquake.

3.2.6 *Road tankers, and tank-carrying trucks for transporting water*

After the 1976 Guatemala earthquake, water supplies in several towns were maintained largely by road tankers, many of which brought clean water across the international frontier from Nicaragua. Whenever normal supplies are badly contaminated or piped supplies are interrupted, this is a solution which may be resorted to; either for transport of water over short distances to local distribution points or for hauls over longer distances. If a railway line exists, this may offer advantages for long hauls of large volumes of water. At the other extreme, in Guatemala pack animals were loaded with 20 litre plastic containers to carry water to otherwise inacessible villages. Listed below are three methods of transporting water by road vehicle:

a) Purpose-built water-tank trucks (capacity typically 12,000 litres),

b) Purpose-built water tank trailers,

c) Improvised systems with ordinary trucks carrying tanks.

The feasibility of the latter approach has been greatly enhanced recently by the development of tanks made of light-weight polythene sheeting. The tanks resemble large pillows when full, and can be laid out on any flat surface. They require no structural support, are ready for instant use, and were first introduced as a means of converting trucks into tankers in Ethiopia in 1975.

The purpose-built water-tank truck has a number of advantages over the other possibilities: it usually has a greater carrying capacity, it is easier to use on rough roads, and it is often fitted with a motorized pump for taking on or discharging water. However, it has two major disadvantages —it is too costly to hold in stock in preparation for a disaster, and so will usually only be cost efficient if it has some other use during normal times. The other disadvantage is that if a purpose-built tanker suffers an engine breakdown, the tank is immobilized. A trailer in contrast, could be hitched to any other large vehicle available or a polythene tank could be transferred to another truck. So the purpose-built tanker has serious limitations in a remote area where it may take time to repair a breakdown.

Good contingency planning would involve making an inventory of all tanker vehicles in the area, including any belonging to dairies or breweries. But if it is required to hold materials in stock so that a tanker service can be provided in the event of a disaster, polythene tanks and perhaps some

purpose-built water-tank trailers are clearly desirable.

3.3 *Excreta and waste disposal*

Although earthquakes and floods frequently have the effect of blocking town drainage systems and causing septic tanks and acqua-privies to leak or overflow, excreta disposal in disaster zones is frequently neglected. This occurs when trying to rescue people in immediate danger, restore communications, provide shelter, and maintain electricity and water supplies. The following measures must be considered in formulating plans for excreta and waste disposal in a disaster zone.

3.3.1 *Leakages from sewers and septic tanks*

Containment of leakages from cracked sewers or septic tanks may be possible by digging a hole or an improvised drainage ditch. Where sewers are affected, it may also be possible to by-pass the damaged sections, perhaps by laying temporary pipelines. Leakages also need to be treated with strong disinfectants to prevent the spread of pathogenic material.

In a flood, it is impossible to contain leakages of sewage. However, as mentioned earlier reflux valves can be installed in sewers to prevent a flood causing a back flow of sewage, and the existence of these will serve to contain sewage already inside piped systems.

3.3.2 *Repairs to drainage systems*

Repairs to drainage systems clearly need to be carried out quickly. Ability to do this depends on adequate preparedness, including the maintenance of detailed and accurate maps of drains, underground pipelines, etc., and the existence of suitable equipment and technical staff to make repairs quickly. Measures which may be taken will include the construction of temporary pipelines and drainage ditches as necessary to contain leakage, the cleaning and flushing of blocked sewerage pipes, repair of pumping stations and so on. At an early stage, the engineer in charge of drainage should have marked on a map all damaged sections of pipe and all blocked drainage ditches and should have planned temporary sewage outfalls into rivers, or temporary pipelines as necessary.

3.3.3 *Sewerage treatment*

Where a sewage treatment plant is out of action, the main options may be to by-pass it and discharge raw sewage at the outfall; to divert sewage to another treatment plant, where one exists; to dig out a basin where sewage can accumulate without danger; or to haul sewage by road to a burial site. In *some* flood conditions it may be acceptable to discharge raw sewage, relying on the greater volume of water in the environment to provide adequate dilution. In other cases, however, floods may have reversed the flow of rivers, or may be backing-up side channels, and the result is that discharges of sewage may affect water supplies taken from the river. Serious flooding is probably the most difficult situation to deal with and very often there will be almost nothing which can be done until the floods subside.

3.3.4 *Emergency excreta disposal*

The provision of emergency excreta disposal facilities are necessary when existing household latrines are destroyed during an earthquake, or when water-borne sewage and the water supply are interrupted, latrines cannot be flushed and sewers are broken or blocked. After the 1971 San

Fernando earthquake in California, main water pipelines were badly damaged and people carried water in buckets to flush their latrines while others used chemical toilets supplied as part of the relief operation.

In many of the above circumstances, it is necessary to instruct the population to stop using their household latrines and instead to use improvised public facilities. These are best set up in open spaces such as parks, when the ground is suitable for digging trench latrines, and contingency planning can appropriately allocate suitable sites in advance.

There are four main strategies which can be adopted for providing emergency excreta disposal facilities within a disaster zone, in most cases based on the provision of public or communal latrines. Contingency planning and preparedness should be based on a prior choice between these methods as follows:

a) Packaged sanitation units.

b) Trench latrines, pit latrines, and bore-hole latrines.

c) Mobile latrines.

d) Chemical latrines.

Finally, excreta from emergency public latrines can be disposed of by containment in the ground, or in tanks which are moved elsewhere for emptying. A variation on the latter arrangement would be to improvise bucket latrines, and carry them away for disposal, or empty them into a tank-carrying vehicle designed for this purpose.

In extreme emergencies, bulldozers have been used to clear areas heavily polluted with excreta, if provisions have not been made until some time after a disaster. Then bulldozers are used to scrape the ground surface and bury the waste material. Under some emergency conditions, the military have gathered excreta into a central location and incinerated it using liquid fuels. This is an extreme measure, but it is essential and easily organized when there is a major disease threat.

3.3.4.1 *Garbage and refuse disposal* can be combined with excreta disposal. In general, the problem in towns is to ensure that existing garbage disposal arrangements are maintained and strengthened after a disaster. If this is impossible, plastic sacks should be firmly tied to seal them when they are full. It may be advisable to instruct people to put only organic refuse in the sacks, and to give priority to this.

If a refuse disposal system has to be improvised, trucks of about 10 cubic metres capacity with a crew of three men to each would be ideal; then initial planning can be based on the assumption that 1,000 people produce between 2 and 4 cubic metres of rubbish per day.

In rural areas, particularly, attention may need to be given to the collection of animal manure and the disposal of the carcasses of animals killed in the disaster as these materials provide breeding sites for flies and other disease vectors. The carcasses of large animals may be a particular problem because a large, deep pit is required. This is a slow and laborious dig, and burning large carcasses is also difficult. Carcasses should at least be hauled away from the vicinity of dwellings, and should be sprinkled with kerosene to discourage predators and insects.

3.4 *Sanitation in reconstruction programmes*

The rebuilding of houses in a disaster zone frequently begins very soon after the disaster has

occurred. The need for resources to be absorbed by the operation of temporary camps can be avoided if at least partial rebuilding can be accomplished within a few weeks. Many householders will also be anxious to get back into a permanent home as soon as possible. A recurring problem in the past is that excreta disposal is generally ignored in these reconstruction programmes. It is therefore important to stress to all concerned in the rebuilding phase, the need for provision of excreta disposal.

After the earthquake in Guatemala in 1976, the government aimed to build minimum shelter for 100,000 people in 100 days —before the onset of the rainy season. Efforts were made to re-use original building plots and the existing (damaged) infrastructure, and to avoid using camps and temporary housing. But only a few of the agencies helping with housing required that latrines be provided as an *integral* part of the housing programme. One group which built 400 houses and planned pit latrines for them found that there was not enough time to dig the pits before the houses were built. Another group which fostered latrine-building provided householders with a prefabricated concrete squatting plate, and left the householder to dig his own latrine and build a cubicle round it. But this kind of programme was exceptional.

The reasons why latrines were neglected in many of the other projects in Guatemala seem to have been that:

a) Many agencies responsible were trying to provide "shelter" with funds supplied only for "emergency needs". Sanitation was not considered an emergency need, although clearly it should have been.

b) Many agencies were unacquainted with the technology of excreta disposal, for example, in being unaware of methods which could be used where the water supply was insufficient to operate flush systems with septic tanks.

It is worth noting here that pit latrines and bore-hole latrines are suitable for many situations in which reconstruction must be accomplished rapidly; the use of these techniques is not limited to emergency camp sites. Where the subsoil is unsuitable for these methods, acqua-privies could be used. In an urban area, where there is not room for a soakaway to take water from an acqua-privy, a pipe can be laid to carry the water from all the acqua-privies in one street, and so lead the water into a main sewer or drain, or to some point where the water can be safely discharged into the ground.

Chapter IV

WATER SUPPLY AND WASTE DISPOSAL IN EMERGENCY CAMPS

4.1 *General*

When people leave a disaster-stricken area to seek refuge in a safer place, the provision of water and waste disposal facilities will need to be developed in stages as follows:

a) as people move towards the emergency accomodation or camp site;

b) when the camp is first set up;

c) as the initial emergency arrangements at the camp are replaced by facilities suitable for use over a longer period.

When people are first evacuated, it is important to inform them where the food and water distribution points and emergency accommodation are located. When people have to trek long distances to reach this accommodation, water will need to be supplied to them en route, possibly from tank-carrying trucks. If no water supply exists at the emergency accommodation, tanker trucks will again be needed until a more permanent form of water supply can be provided.

The evacuation of large parts of Managua, (Nicaragua), after the earthquake in 1974 is an example. Some 36 food and water distribution points were set up in the outskirts of the city and in nearby towns, and camps were planned for 150,000 people. Some of these made intelligent use of existing facilities, including a permanent camp site belonging to the Boy Scout Movement which already had some sanitation facilities installed. At first, water supply to some camps was by road tanker, later pipes were laid by the waterworks authority, connecting existing supplies. In one camp, community taps were provided for each group of tents, and showers for bathing and sinks for laundry were installed, but the value of this excellent installation was diminished by the very low water pressures which prevented the facilities from being fully used.

4.2 *Water supply*

4.2.1 *Supply and demand*

The influx of a large number of people from a disaster zone can create many difficulties for the host community, not the least of which may be the extra volume of water needed from the public supply. This can lead to a drop in water pressure, inconveniencing permanent residents in the area (and even leading to social friction). The waterworks may also have to expand their capacity quickly.

For a water source to be suitable for use by an emergency camp, it must not only be accessible, but must be reliable in volume and duration of flow. Information should be sought locally as to whether a stream is likely to dry up. The measurement of its flow at the same time will indicate whether it has sufficient capacity to provide the necessary supply, taking into consideration flow reduction in dry weather. Such data information should include private water supplies for agricultural, industrial and commercial use.

4.2.2 *Access to water*

Problems of extracting and transporting the water also require important consideration. It may be possible to find a river or spring from which water will flow by gravity through a pipeline, but the use of many sources will require a pump, for which thorough maintenance will have to be arranged if it is to be reliable. At wells, it may be sufficient to have hand-pumps operated by the people from the camp as and when they require water, but in many circumstances a motorized pump is necessary.

Emergency pipelines from water sources to the camps can be laid above ground for short distances (up to 5 km), using plastic or metal piping of one of the types designed for easy jointing. Stocks of suitable piping are one of the essentials in any stockpile of emergency equipment which may be maintained as a preparedness measure. Polythene piping, for example, can be obtained either as long legths of coiled, flexible pipe, or rigid pipes in 3 m lengths (one proprietary brand is Polyorc piping). The flexible pipe offers the quickest way of laying a temporary pipeline to a camp site, but lengths of the rigid pipe are easily joined by push-fit connectors which may be secured either by adhesives, or by ordinary wood screws. The rigid piping is a versatile material as it can provide posts and beams in emergency shelters if not required as a water pipe. The push-fit right angle and T connectors make this a very rapid construction. These pipes are relatively inexpensive, and a stock of the 5 mm, 37 mm or 25 mm diameter sizes could be invaluable in laying on water quickly for an emergency camp.

4.2.3 *Pollution*

Source-works must be protected from pollution. Siting is therefore important, especially in relation to latrines, and to animal enclosures and drinking troughs.

4.3 *Water storage*

by pipeline or road vehicle, so that there is always some water on the site if supplies are temporarily interrupted. Where a pipeline is hastily laid, pipes of small diameter will often be used to ease transport to the site and to speed progress of the work. When this happens, a storage tank on the site which can be filled overnight is essential if an adequate amount of water is to be supplied by the pipeline. For example, the water supplies constructed by UNICEF for relief camps in Ethiopia typically included steel tanks of 20,000 litres (20 cubic metres) capacity; this represents the daily consumption of about 1,000 people, and is about the right amount of storage to aim at in a camp containing up to 2,000 people supplied by pipeline. A camp supplied by *tanker truck* would need a larger safety margin, and if deliveries of water were made only twice a week, 100 cubic metres of storage would be needed for 1,000 people. The provision of storage tanks needs also to be planned with needs for water treatment in mind, as this may take place in or near the tanks.

There are several ways of providing the necessary storage tanks:

a) use of prefabricated steel tanks of up to 5,000 litres capacity;

b) construction of larger tanks on site using prefabricated steel sections; these can be quickly built if the necessary components are readily available;

c) construction of large tanks in brick, stone or concrete, water-proofed by applying a cement plaster to the inside; the problem with these is the time needed for construction;

d) use of tanks made of light-weight polythene sheeting, resembling large pillows when full. Typical capacity is 2,500 litres. They can be laid on any flat surface, and need no rigid support;

e) use of plastic or butyl rubber sheeting to line holes dug in the ground or supported above ground with earth embankments or walls made of sandbags. Large tanks can be made in this way, but need careful protection from ingress of dirt, waste water, animals and children.

4.4 *Water treatment*

Although it is vitally important that a water supply should provide clean and "safe" water, a potential source which is polluted may have to be used in an emergency, and this can be safely done if the water is purified. In normal circumstances there are many criteria of the suitability of water for drinking, but in a disaster situation the only criterion of importance is pathogenic contamination —the question of whether pathogenic material is present in the water at a concentration which could be significantly dangerous to the health of a person drinking the water.

4.4.1 *Disinfection*

Thus although water supplied to an emergency camp may be filtered or passed through a settling tank to get rid of any suspended matter, (and on occasion this may be all the treatment that is necessary) in the majority of emergency situations the most important process is disinfection. Usually this is achieved by treating the water with chemicals generally containing chlorine. Chlorination works best if the suspended matter has been removed from the water. So although it may not be possible to improvise sand filters or sedimentation tanks, it is an advantage if these processes can be incorporated in the system to prepare the water for chlorination.

If storage tanks are set up on the camp site, it is inevitable that some sedimentation will take place within them, and it may be possible to arrange the tanks so that maximum advantage is taken of this. For example, if the water is withdrawn from a tank at a point some distance above the bottom, the useful storage capacity of the tank will be reduced, but the resulting "dead" storage at the bottom will provide space into which suspended solids and sediments in the water can settle. Then, if there is a tap at the very bottom of the tank, this can be opened from time to time to draw off the sludge which accumulates. Sedimentation can be encouraged by adding alum cake to the water (i.e. aluminium sulphate; use about 80 grams per 100 litres, preferably dissolved in a small quantity of water before being added to the tank). The first, at a higher level, can be used as a settling tank in the manner described; clarified water can then be extracted and stored in the second tank which chlorinates the water.

Ideally, the water should be allowed to settle for about six hours before passing into the

second tank. If the size of the sedimentation tank is roughly equivalent to the amount of water consumed in the camp during one day, then sedimentation can take place mainly overnight, with the alum being added the previous evening.

4.4.2 *Filtration*

Filtration offers an alternative method of getting rid of suspended matter in water, and sand filters are fairly easy to construct if suitable sand is available near the site. The essential factors for satisfactory working are the depth of the sand in the filter (at least 60 cm) and also the rate at which water flows through the sand (not greater than 3.6 litres per minute for each square metre of the filter).

A simple type of sand filter can be made from an open top steel drum of 200 litres capacity and 75 cm high. This is placed on a stand after a 2 mm hole has been drilled in the bottom to serve as an outlet. Pea-size stones are placed in the bottom of the drum to a depth of 5 cm, and the drum is then filled to within 10 cm of the top with fine sand. A filter of this kind should ideally have a lid to prevent the growth of algae.

Such a filter should be capable of processing 60 litres of water per hour. The rate of flow will become less after a period of use, but the filter is only cleaned when absolutely necessary, as its efficiency depends to a large extent on the formation of a biological growth on the surface. When cleaning becomes essential, the top layer of sand (about 0.5 cm) is scraped off and discarded. The exposed sand surface is then slightly raked to leave it loose, and filtration is recommenced.

4.4.3 *Chlorination*

Although chlorination of water is a complication which cannot be permanently incorporated into small water supplies in many remote rural areas, chlorination becomes both simpler and much more important during a disaster. The process and equipment which may be used for decontamination of various health hazard systems with chlorine include:

a) Where water is stored in large tanks, the chlorine solution is added manually as the tank is being filled, using the inflow of water to stir in and distribute the solution.

b) Where water is supplied continuously via a pipe, chlorinators may be improvised which drip chlorine solution at a steady and controlled rate, mixing it with the flowing water. Burns and Howard illustrate a device of this kind specially designed for chlorinating water raised from a well by an electric or diesel suction pump; other simple chlorinators are illustrated by Cairncross and Feachem and Assar.

c) A simpler method of chlorinating a continuous supply is to use pot chlorinators advocated for disinfecting wells as discussed.

d) Mobile units mounted on trailers have been devised, mainly for use by army camps, which consist of a pump, filter, and chlorinator in a compact but fairly complex piece of equipment. These units can pump water from a contaminated river or any other accessible source and turn it into a portable water supply. A typical unit of this type has an output of 6,000 litres per hour. Disaster contingency plans should clearly take note of any such equipment which may exist in the area.

e) At times it will be convenient to supply chlorinated water to individuals in their own containers. These should be thoroughly clean, but if they are not quite sterile, the supply of chlorinated water will help to ensure this, provided that the water is allowed to stand in the receptacle before being used. After this lapse of time the water can be dechlorinated by the individual concerned, if crystal of thiosulphate for each litre of water is added.

4.4.3.1 *Preparing the chlorine solution.* This is the first step in many of the chlorination techniques likely to be used in an emergency camp. The starting point will be one of the substances listed in Table I, and perhaps more frequently, this will be bleaching powder or calcium hypochlorite. These substances come in air-tight cans or packages and deteriorate on exposure to the air. In making up the solution, the required quantity of powder is placed in a basin or suitable vessel and water is slowly added while the powder is stirred until dissolved. The final steps in preparing the solution are: add more water and dilute to the volume required, allow the sediment to settle, decant, and use the clarified liquid. As already stated, it is best to aim for a concentration of 10 g/l, (or 1 per cent) in this solution; stronger concentrations are unstable and chlorine is lost from them quite rapidly. Some proprietary disinfectants and bleaches come as ready-made chlorine solutions which can be used directly to chlorinate water. It should be noted that all these chemicals are corrosive and can harm the skin. Gloves are needed when handling them, and if they come into contact with the operator's skin he should wash thoroughly and immediately.

4.4.3.2 *Residual chlorine tests.* These tests provide a way of testing water after chlorination to check whether it has been thoroughly disinfected. The principle is that there should be a specified level of chlorine left in the water after the time necessary for chlorination has elapsed; if the chlorine has fallen below this level, it is presumed that the dose used was insufficient to deal with the organisms in the water, and a further dose must then be added. Most versions of the residual chlorine test are carried out by dissolving a special tablet in a small sample of the water; the colour of the resulting solution then indicates the amount of chlorine present.

4.4.3.3 *Dechlorination.* After the chlorine solution and the water being treated have been mixed together for the necessary "contact time", excess chlorine can be removed to improve the taste. This may be necessary because people sometimes reject water with a strong chlorine taste, although a positive taste of chlorine in a water supply is a fair indication that adequate chlorine has been added to effect sterilization. The most satisfactory and stable chemical used to dechlorinate water is sodium thiosulphate (hypo). About 1.0 kg of this should be sufficient to dechlorinate 60,000 litres of water treated so as to contain 5.0 mg/l of chlorine.

4.5 *Water distribution*

The aim in laying out the water supply for a camp site should be to ensure that nobody has to walk more than 5 to 10 minutes to collect water. Laying pipes round the site, should determine the spacing of taps or public standpipes. Where water is distributed by a tank-carrying truck it is possible to install water storage tanks at suitable points. The capacity of these tanks would depend on the number of people served and the frequency of refilling.

Facilities for personal washing and for washing clothes will usually be needed, but details will depend on local customs. A typical arrangement might be to have separate ablution blocks for each sex, containing showers and hand basins, or wash benches on which bowls can be placed. Where ablution blocks are provided, it would be desirable to provide a 5 metre length of bench or 8 hand-

Table I

Chemicals which can be used to chlorinate water, and the quantity of each needed to disinfect 1 000 litres with a dose of 10 mg/l; use half the quantities for a dose of 5 mg/l,.*

Type of chemical	*Examples of proprietary Names of brands*	*Quantity to use*	*Method of use*
Disinfectant (hypochlorite solution)	Milton, Zonite, Javel water	About 1.0 litres	Use direct with the water to be treated
Commercial bleaches	Chlorox, Dazzle, Regina	0.12 to 0.38 litres	Use direct
Bleaching powder	Also referred to as chloride of lime (consists mainly but not entirely of calcium hypochlorite)	30 to 40 grams if fresh from previously unopened can	Mix with one litre of water to make a 10 g/l or 1 per cent solution
Stabilised bleach	Stabochlor	40 grams	Mix as with bleaching powder
High-test calcium hypochlorite		15 to 20 grams if fresh	Mix as with bleaching powder
Sodium hypochlorite		Not suitable for shipment over long distances or in hot climates; specialized uses only.	
Water sterilising tablets	Halazone, Sterotabs, Hydro-chlorazone, Halamid, Chloraine-T, Chlor-dechlor.	Not suitable for treating large volumes of water; follow makers' instructions.	

*After a table given by Burns and Howard.

basins for every 100 people. Arrangements of this kind, with the additional aim of providing 3 showers were set up in emergency camps after an earthquake in Nicaragua.

It should also be remembered that the use of water at camp sites depends on the availability of vessels. In Nicaragua, due to the lack of suitable containers, families at first had difficulty in collecting their supply of water. Eventually 20 litre plastic drums had to be supplied. Soap, towelling, pots, and pans for cooking and boiling water where also in short supply.

4.6 *Excreta disposal*

Existing sewage systems become quickly overloaded during a disaster and arrangements will then have to be made at the treatment plant to by-pass or modify many of the treatment processes. The essential criterion in such a case is to ensure that raw sewage discharged into rivers or elsewhere cannot find its way back into any community's water supply.

In many instances emergency accomodation has to be provided where no excreta disposal system exists. After an earthquake, for example, town dwellers will often be evacuated to a rural area with absolutely no sanitation facilities. In these circumstances, the main consideration will be for people to excrete in private. This must be *contained* so that the disease potential cannot spread around the site. It is important to prevent rats, insects, vermin and birds having access to excreta and spreading it; to prevent excreta from coming into contact with cooking utensils, which may have to be placed on the ground in camp conditions.

Some people from rural areas where there are no latrines customarily defecate on the ground wherever it may be convenient to them. Even when large numbers of people are brought together for shelter, feeding or evacuation they continue this habit. Serious conditions can thus arise, especially if diarrhoeal diseases are prevalent, as so often they are. However, flexibility in providing for defecation is essential; in a dry climate, people excreting on the ground *outside* a camp may be a lesser hazard than pit latrines near to wells *inside*, as was found in an emergency camp in Algeria, where defecation on the ground in specified "safe" locations was allowed to continue.

4.6.1 *Hygiene*

The provisions of places to defecate and containing excreta will entail keeping them clean, convenient to use and importantly, will include educational activities designed to make people aware of the necessity of using latrines and maintaining high standards of hygiene.

4.6.1.2 *Treatment of excreta*

There are a variety of methods for containing and treating excreta to prevent them from being dispersed in the environment and to reduce the load of disease-causing organisms. Three processes are chiefly used: *sedimentation* during which the solid matter will settle to the bottom to form a sludge which will then digest anaerobically; *aerobic treatment* in which liquid sewage is brought into contact with air by holding it in shallow open ponds or by letting it trickle over a bed of broken stones; *anaerobic treatment* in which sewage is held in the absence of air either in deep ponds or in sealed containers. These processes reduce the content of pathogens in various ways and to various degrees and also change the chemical content of the sewage. The products from all are a *sludge* and a liquid *effluent*. The *sludge* will always contain pathogens —especially worm eggs— and must be carefully

disposed of. The *effluent* will also always contain many pathogens unless it has been chlorinated or passed through a chain of not less than four oxidation ponds. The effluent should in general be discharged to a stream or used to irrigate a fodder crop.

4.6.3 *Simple excreta disposal systems*

4.6.3.1 *Depositing excreta* straight into the ground is one of the simplest ways of containing them, and of allowing the anaerobic treatment processes to take place. Thus almost all contingency planning for natural disasters will need to include preparedness for the construction of trench latrines, pit latrines, or bore-hole latrines. Some of these techniques, particularly pit latrines, may also be applicable in areas where permanent housing is rapidly rebuilt after a disaster.

4.6.3.2 *Shallow trench latrines* may be dug very quickly, and are effective for short periods of up to a week. The trench is usually about 0.3 m wide and up to 1.5 m deep. Its length will depend on the number of users, and may be about 3.5 m for every 100 people. The earth from the excavation is left, with a shovel, at the side of the trench, and then users can be asked to cover their excreta each time they use the latrine. One or two people should also be made responsible for visiting the latrine at regular intervals to cover excreta where users have neglected to do this.

4.6.3.3 *Deep trench latrines*, usable for several weeks or even months, consist of a trench up to 2.5 m deep and about 0.8 m wide. Again, it should be about 3.5 m long for every hundred users. However, instead of continually covering excreta with earth, this type of latrine has a fly-proof floor above it for the users to stand on, and the squat-holes or seats have lids to keep flies out. This type of latrine therefore takes longer to construct.

4.6.3.4 *Both types of trench latrine* depend on the availability of timber for shoring up the sides (which are liable to cave in, especially in soft soil), and for bridging the top. With temporary, shallow trench latrines, all that is necessary is to ensure that users have a secure foothold at the point where they crouch to defecate, whereas in semi-permanent deep trenches, the floor with squat-holes and lids must be properly constructed by carpenters; alternatively, concrete squatting plates may be used.

Trench latrines used in refugee camps in West Bengal in 1971, suffered from lack of suitable timber for bridging the top; bamboo poles were tied together to form foot-rests, but these became wet and slippery, and there was a danger of users falling into the trench. As a contrast, one camp set up after the earthquake in Nicaragua had six well-constructed trench latrines. Each of these had cubicles built over them, made from galvanised iron sheeting supported by timber posts, and subdivided to provide 3 holes for men and 3 for women. These were well-maintained and effectively used until camp dwellers began to return to their homes; then it turned out that the people who had done the cleaning were the first to go, and the condition of the latrines deteriorated rapidly.

Both these instances point to the need for a preparedness policy to include access to timber and materials for constructing cubicles.

4.6.3.5 *Bore-hole latrines* are a preferred method in places where the subsoil does not contain rock or large stones. They are not suitable for use in places where the surface soil is waterlogged, but they may penetrate below the water table if this is encountered no more than 2 or 3 m below the surface. Bore-hole latrines are made with a hand-driven earth-auger, having a strong, light blade able to make a hole about 0.3 m in diameter. By adding extra lengths to the auger shaft, and if possible by using a tripod

(sheerlegs) with rope and pulley to lift the auger when it is loaded with soil, holes up to 7 m deep may be dug —though 5 m is usually sufficient for latrines. A concrete, wood, or plastic squatting plate covers the hole at the top. Equipment for making this cover, along with a number of augers, can conveniently be stockpiled as part of a disaster preparedness policy.

An auger is operated by two men who will typically work at the following rates, according to experience in India.

a) In sandy soil, 1.5 m per hour, or 9 m depth per day.

b) In soft clay soil, 1.0 m per hour, or 6 m per day.

c) In wet clay soil, 0.6 m per hour, or 3-4 m per day.

Where local contracting firms use agricultural tractors with hydraulic attachments for boring holes for fence posts, these may be utilized for making bore-hole latrines. The deepest this kind of equipment can dig is about 2.0 m, but this may be sufficient if holes are made quickly and in large numbers. Inquiry of contractors as to whether this equipment exists in the area should take place during contingency planning. When dug in firm soil, bore-holes do not cave in at the sides. But some sort of lining may be needed near the ground surface, and one way of providing this is to use oil drums with the ends knocked out.

4.6.3.6 *Pit latrines* use the same principle as bore-hole latrines, but consist of hand-dug pits, usually about 3 m deep. They may be circular in plan (about 1.5 m in diameter) or rectangular (measuring roughly 1.5 by 2.0 m). They cannot be dug in waterlogged soil, nor, obviously, in rocky terrain. Some sort of lining —timber, concrete or brick— is usually needed, and the top of the pit must be bridged by a timber or concrete floor incorporating a squat-hole or seat, according to local custom.

4.6.3.7 *Cubicles* should be provided to give privacy to users of all these kinds of latrine, as the facilities will not be fully utilized unless privacy is ensured. Poles set in the ground will provide an adequate framework to support walls improvised from rush matting, black polythene sheeting, sacks, boards, or sheet metal. A roof will be necessary to protect users in rainy climates, for which galvanised iron will often be the most convenient material.

4.6.3.8 *Floors and squatting plates* for use with trench, pit and bore-hole latrines will often be the most difficult components to provide in an emergency. In general, trenches can be dug quickly while bore-hole and pit latrines take longer. So it may be useful to construct a type of flooring with squat holes or seats which can be used first on a trench, and can then be transferred to a pit latrine as improvements in sanitation are made. For trenches and bore-holes, the type of floor unit or squatting plate needed would need to be able to span about 1.0 m; the same unit could be used over pit latrines if supported by timber beams. The main options are as flollows:

a) Timber is often the most convenient material to use, but is also the least satisfactory for flooring, since it tends to get sodden and unless well finished, with close joints, is difficult to keep clean. It is probably most satisfactory where seats rather than squat holes are required.

b) Factory-cast reinforced concrete slabs may be a possibility where a manufacturer of sanitary equipment exists, and prior arrangements for emergency production can be made.

c) Reinforced concrete slabs cast on the camp site are an alternative to *(b)*. They should be cast upside down in steel moulds shaped to make the finished slab slope downwards towards the squat-holes, but with flat, slightly raised, foot-rest. This mould can be designed with notches to ensure correct positioning of 8 mm diameter steel reinforcing bars. Various measures may be taken to speed up manufacture and the setting of the concrete, as described below.

d) Squatting plates made from fibre glass, or injection moulded plastic are particularly suitable for holding in stock as part of a preparedness policy. One British relief agency now holds stocks of squatting plates of this type, which are light enough to be transported by air to the site of any disaster. For complete security, they need some support from beams spanning a trench or pit. However, these squatting plates are relatively expensive.

4.6.3.9 *Preparedness for emergency sanitation* using the above systems and techniques is well illustrated by a contingency plan in West Bengal, India. The plan is designed to cater for 10,000 people in an area where the subsoil is suited for bore-holes latrines. It is assumed that trench latrines are to be used in the immediate aftermath of the disaster, when people first move to the emergency camp. But the aim is that everyone should have access to a bore-hole latrine after 20 days. With an estimated 50 users per latrine (rather a high number), this means that 2,000 latrines have to be constructed in 20 days, or 100 every day. With each hole about 5 m deep, this rate of construction can be achieved with 100 earth-augers even in difficult soil conditions.

One steel mould can turn out concrete floor slabs with squat-holes at the rate of 15 slabs per day if following steps are taken to speed up production:

a) The concrete must be vibrated mechanically in the mould.

b) The slabs must be turned out of the mould before initial setting is complete. This was done in India by placing a flat sheet of plywood over the mould and inverting the mould and the plywood together; moulds were lined with newspaper before the concrete was poured for easy turn-out.

c) It will still take a few days for the concrete to set and cure, but this may be speeded up if 3 per cent calcium chloride is added to the cement.

With this production technique, moulds with ancillary equipment can produce 105 concrete slabs per day. Therefore the equipment needed to provide for 100,000 people in 20 days would include 100 earth augers, (complete with handles and extension pieces), 7 mild steel moulds for latrine squatting plates, and 7 form vibrators for use with moulds (or smaller number if one vibrator can be used with two or three moulds).

It would also be necessary to ensure that adequate supplies of the basic materials were available —cement (about 16 tonnes), calcium chloride in air-tight packs (400 kg), steel reinforcing bars (2 tonnes), sand, aggregate, and water. By making prior arrangements with contractors who regularly use such materials and equipment, the authorities responsible for disaster relief could avoid the need to stock most of these items. Earth augers and moulds for squatting plates are desirable items to stock.

4.6.4 The requirements for the successful operation of an emergency public latrine facility, whether

in a camp, or erected as a temporary measure in a disaster-stricken town, are summarised as follows:

a) The latrine must be culturally acceptable.

b) It must provide separate facilities for each sex, and must be usable by children.

c) It must offer adequate privacy.

d) It must be easily reached and visible from where people are living; preferably it should be within 30 - 50 metres.

e) It must be clean, free from smells, and well maintained.

f) It must be lit at night.

g) Water must be available for personal hygiene and cooking.

h) The latrine should offer 5 - 6 seat or squat plates per 100 users.

i) Refuse should be disposed of efficiently and hygienically.

4.7 *Complex systems for emergency excreta disposal*

4.7.1 *Aqua-privies and septic tanks*

Aqua-privies and septic tanks are not normally considered suitable for the use at camps for disaster victims, but over 50 were actually constructed in emergency camps in India in 1971.

The principle of this disposal system is that excreta are contained in a tank of water where anaerobic bacteria slowly digest them. More water is added as latrines are used, and a controlled overflow of water is disposed of via a soakage pit in the ground. In India, the necessary tanks were built of brick above the ground, and waterproofed on the inside. The tanks were then roofed with a reinforced concrete top which had the earthenware squatting pans cast into it. The latrines were thus about 2 m above ground level.

One problem was the water supply needed to operate this kind of installation; in these examples some of the latrines were located alongside a water main, but a well had to be specially sunk alongside one latrine block to provide its supply, greatly adding to the cost. Another problem was that the water table in the ground was very high, so that the soakage pits did not work properly, and tended to overflow onto the ground surface. But given the resources to overcome these problems, aqua-privies of this type could provide a very effective excreta disposal system for a camp site likely to be in use for months rather than weeks.

4.7.2 *Packaged sanitation units*

Packaged sanitation units were conceived partly as a result of this experience with the acqua-privy/septic tank principle in emergency conditions. Suggestions were made about the possible use of butyl rubber or plastic to form a septic tank which could be installed very quickly on the site; research and development carried out since then for the British agency, OXFAM, led to a fully developed and effective packaged sanitation unit which first went into use in camp conditions in Bangladesh in early 1975.

This unit was designed so that it can be crated and transported by normal cargo-carrying aircraft. On arrival at the site, it can be assembled within a few days, and its operation does not depend

on any motive power (though it does require a modest water supply). It provides a communal latrine for 500 people, (with as many as 1,000 people using it, sewage is held in the tanks for a shorter time, and the quantity of the effluent is lower). These latrines have two groups of squatting plates separated by a wooden partition to cater separately for both sexes. The squatting plates connect with 100 mm diameter prefabricated plastic pipework with push-fit joints, all of them feeding into a common excreta pipe running the length of the installation at a slight slope. This pipe is flushed periodically by water supplied at its upper end from a small tank, which can be filled by hand if necessary.

4.7.3 *Containment*

The containment takes the form of air-tight butyl rubber pillow-shaped bags. Normally, two bags are operated in series, but the arrangement is flexible. As would be expected, more sludge collects in the first bag than in the second. When a bag contains so much sludge that its efficiency starts to be impaired, a simple procedure may be followed: the bag can be disconnected and a trench dug along side it. The bag can then continue in use. The trenches are filled with soil to prevent the breeding of flies. When the system is operating normally, the two bags fill with liquid — their total capacity is 36,000 litres — and effluent is then discharged from the tail of the system at the same rate as excreta and water enter it. This effluent is aerated by passing it through a filter of broken bricks, gravel or other suitable material and may be disposed via a soakway into the ground. This can be done by discharging into a river which is large enough to provide reasonable dilution. The quality of this effluent will be acceptable only if the system is not over-loaded with too many users, and if the tanks are desludged regularly.

This sanitation unit can be used in several ways, for different kinds of sanitation, as follows:

a) When used with two tanks and a percolating filter, as described above, the unit provides a long-term communal latrine facility.

b) The unit can be used with one tank only as a short-term measure for sewage containment and storage.

c) The tanks can be connected to existing drains to provide sewage treatment where none was previously provided.

d) The squatting plates can be used separately within existing drainage facilities to improve latrines, or they can be used with bore-hole latrines.

4.8 *Community action*

4.8.1 *Training*

Although a well-prepared government or relief agency will have picks, shovels, earth augers, and squatting plates in stock or otherwise immediately available, this equipment will be of no use unless there are trained personnel. Disaster victims are able to contribute their labour to latrine construction, but will lack knowledge and skills. The training must be given in advance of any disaster to a squad of people able to plan, dig, and construct latrines. These people should be recruited from waterworks staff, the army, or non-governmental organizations (3.8), or should be employees of a contractor with whom there is a prior arrangement to undertake work at specific potential emergency camp sites.

4.8.2 *Maintenance*

Simply to construct the latrines does not solve the problem. If latrines are to be effectively used, they must be well maintained. Cleaning brushes and buckets need to be provided along with construction tools.

4.8.3 *Acceptability*

There are many documented cases from camps in India, Ethiopia, and elsewhere, in which latrines have been provided but have not been used by the camp dwellers. There are two main reasons for this. The first is that cleaning is sometimes neglected and latrines become filthy and smell offensively, so after an initial period of use, they are ignored. The second reason why latrines are not used is that they are culturally unacceptable. When covering seats or squatting plates have to be lifted, there exists a social influence against touching any part of the latrines.

Lighting can be provided by casting a small saucer-shaped depression in one corner of a concrete squatting plate. This will hold a little kerosene; a metal can with one end cut out and a hole in the other end can then be used to hold a cloth wick with one end in the kerosene.

4.8.4 *Self-help*

It also helps people to appreciate the importance of keeping latrines clean if some self-help activity is involved. Often in the past, the daily maintenance and cleaning job has been left to an untrained and unmotivated person causing unsanitary conditions within a short period. If sanitation is a key requisite for a community, then keeping the sanitation facilities in good condition and serviced is a key job and must be made to appear so.

Chapter V

ORGANIZATIONAL AND PLANNING ASPECTS

5.1 *Responsibility for sanitary relief measures*

If disaster relief is to be effectively carried out, there must be some organization capable of co-ordinating the activities of different people and agencies in the disaster zone; and if this organization is to function competently, it must have given some thought to its role in advance of any disaster. Such forethought implies *contingency planning*, at least in outline, and some instruction or training of its staff members in their particular duties during a disaster. Where this kind of preparedness is lacking, there is poor work, danger of wasteful overlapping and inefficiency in relief efforts.

The kind of organization needed will depend on local circumstances. Central and local government may reserve general contingency planning to itself, but most of the matters discussed in *Chapters IV* and *V* will usually be delegated to local sanitary and waterworks authorities (where they exist). However, governments should occasionally inspect the contingency plans of waterworks to ensure that such plans have been made, are adequate, and that the designated people can put them into action.

The army, the police, local associations and non-governmental organizations should all be capable of contributing to sanitary relief measures after a disaster. It is vital that the division of responsibilities between all these bodies should be clearly defined and understood by all concerned, so that no major functions are neglected and duplication of effort avoided.

Any co-ordinating organization of the type envisaged must have authority during disaster relief operations to cut through red tape and ensure that decisions are rapidly made and decisively implemented. However, if contingency planning is intended to go beyond formulating procedures on paper, and if it is to embrace some form of material preparedness, competent bodies will need to be given authority in advance of any disaster to carry out the following functions:

a) To purchase and hold stockpiles of emergency equipment.

b) To pre-arrange access to private reservoirs and industrial plants in the event of an emergency.

c) To make contingency arrangements with manufacturers and suppliers for the supply of materials such as chemicals for water treatment.

d) To make contingency arrangements with contractors capable of constructing latrines, etc.

e) To recruit (possibly on secondment from other employers) suitable relief workers and emergency technical staff.

f) To organize training and require potential relief workers to attend periodic training sessions.

g) To make contingency arrangements for the formation of public health teams responsible for "crowd management" and supervision of water distribution points, vaccination centres, disposal of excreta, rubbish or waste.

h) To maintain liaison with the army and police regarding training for disaster relief, the duties of personnel and the use of army equipment.

The disaster relief organization should have a headquarters suitable for the administration of relief in emergency conditions; it should be in a disaster-resistant building, and should house all files containing information required to operate contingency plans, including plans of water supply, maps of the area, lists of suppliers mentioned in points *(c)* and *(d)* above, and other details mentioned in section 6.2 below. All lists of relief workers, suppliers, and others, should include addresses and telephone numbers where staff may be contacted at night and during emergencies.

5.2 *Planning*

Specially detailed plans should be made for areas within the community where hazard and vulnerability assessments show that risks are particularly high. Contingency planning should include a pre-arranged system for informing the public of measures being taken, including availability of water when supplies are interrupted, evacuation routes, and precautions to be taken in the home.

In trying to foresee what kind of action is required, it will be important for those involved in contingency planning to estimate how long emergency conditions are likely to last after a disaster, and the related question of whether people will need to be evacuated to emergency accommodation. In general, evacuation tends to prolong abnormal conditions, and people usually stay in emergency camps longer than is envisaged at the outset and longer than necessary. Many governments feel with reason, that camps tend to divert resources away from reconstruction, and believe that evacuation adds to the disruption of administration and economic activities. In many ways, it seems better wherever possible to re-house people quickly within the affected zone. It must also be recognized that an important reason for the formation of emergency camps is that they are seen as centres where food, sanitation and drinking water can be conveniently supplied to the stricken population. If people are to be encouraged to stay within the disaster zone and to engage in reconstruction activities as rapidly as possible, an adequate system for on-site distribution of food, sanitation and water must be provided.

Local policy makers must decide whether evacuation of people to emergency accommodation will be necessary, and if so, what will be the optimum size of camps. Policies for emergency water supplies and excreta disposal depend heavily on prior decisions concerning these issues.

5.3 *Technical data requirements*

Effective action in case of disaster is dependent on the availability of relevant information about the water supply and the location of alternative water sources. Much of this information will also be needed in contingency planning, and an important activity relating to disaster preparedness will be the compilation of such material in a quickly accessible form. With regard to sanitation the follow-

ing data will be needed:

a) Accurate maps showing the layout of pipe networks, location of installations, places where damage is especially likely during the anticipated types of disaster (e.g. geological faults in seismic zones), location of alternative water sources, and etc.

b) Plans of installation, especially treatment plant and dams, showing details of construction.

c) Data on the emergency relief organization, including manpower skills, and equipment available.

d) An inventory of the quantity and quality of water available from various sources (section 4.2) including:

- *existing sources,*
- *untapped but accessible sources (ground and surface),*
- *sources available through interconnection with other communities, private supplies, etc.*
- *location of large tanks, cisterns, swimming pools, etc. which contain water,*
- *tanker vehicles available for use from commercial business and industry.*

e) Inventory of installations which may be suitable for emergency storage or treatment of water, including breweries, dairies, soft-drink bottling plant, and swimming pools.

f) Inventory of points where public standpipes can be set up, or other means of distributing water in the event of failure of the ordinary supply.

g) A list of priorities for essential water users (including hospitals, standpipes at key points in residential areas, and fire fighting services) should be compiled, and there should be the possibility, with legal authority, to cut off supplies from non-essential users.

h) An inventory of sites suitable for the establishment of temporary public latrines, including parks and open places (trench latrines), and sites to be served by mobile units with tanker vehicles for removing excreta.

i) Details of potential or existing water supplies and excreta disposal facilities at accommodation which may be used by people evacuated from disaster area, including accommodation in schools, warehouses, public buildings and camp sites.

j) Data on the availability of supplies and equipment from all sources (section 6.4 below), including equipment to:

- *waterworks maintenance crews (6.3 below),*
- *emergency stockpiles,*
- *the army, industry, or private contractors.*

5.4 *Maintenance*

Regular and effective maintenance of water and other sanitation systems provide an important and valuable basis for disaster preparedness and for the prevention of damage during disasters. Thus before specifying what stores and equipment need to be stockpiled for possible use in a disaster, it is important to consider what aspects of disaster preparedness can be provided as part of the routine operations of organizations responsible for maintenance of water supplies and related facilities.

In many countries routine maintenance is inadequate, and it is strongly urged that a first step

in disaster preparedness be the strengthening of day-to-day maintenance procedures, the recruitment and training of an adequate maintenance staff, and the gradual establishment of a stock of spare parts and equipment suitable for maintenance operations.

The suggestions made in *Chapter IV* and *V* concerning disaster preparedness and equipment to be held in reserve could be covered by the following appropriate improvements in maintenance services:

a) Techniques and equipment for quick coupling and plastic patching of pipes (Section 4.2).

b) Tools and fittings, including pipe-laying tools, pipe fittings, jointing materials, excavation tools, pipe wrenches, valves, hose-pipes, welding equipment, protective clothing, boots and working gloves.

c) Tanks for water distribution, up to about 20,000 litres capacity including steel and flexible types, (Section 4.2 and 5.3).

d) Equipment for constructing and repairing wells, including well-head fittings and pumps, (hand-operated or engine-driven according to practice in the area concerned).

e) Pipes, especially of plastic materials, with valves and fittings.

f) Chemicals for water treatment to be stored in a cool, dry place with additional supplies available from the manufacturer at short notice; stocks of bleaching powder and calcium hypochlorite will tend to deteriorate and should be renewed every twelve months. Stocks of alum should also be carried.

g) Sludge pumps for work on sewage disposal facilities.

h) Sewage pipes with jointing materials and equipment, e.g. diameters 100-300 mm.

i) In areas where pit latrines or related types are in regular use, stocks of squatting plates, or moulds and vibrators for casting them in concrete, can be stocked by maintenance organizations rather than in special emergency stores.

j) Reliable access to supplies of cement, calcium chloride, steel reinforcing bars, sand and aggregate.

5.5 *Materials and equipment*

Much of the equipment needed to provide sanitation during a disaster should be available from efficiently-run waterworks maintenance departments, but there is some additional equipment which may be needed. Items of this kind should be held in special emergency stores, if funds are available, or alternatively the supply or loan of equipment from manufacturers, contractors, or other organizations should be arranged in advance of any disaster. Policies with regard to such arrangements can usefully be based on a classification of different types of equipment in categories as follows:

a) Equipment, material, tools, and spare parts stocked by the waterworks maintenance department.

b) Water supply and excreta disposal equipment likely to be needed only in emergencies, which must therefore be stocked in emergency relief stores, or obtained by arrangement at short notice when a disaster occurs; also ordinary articles like water-jugs or empty oil drums which may be in short supply. Examples are:

— *leaflets or printing blocks, for public information*
— *plastic sacks for garbage disposal*

- *equipment for converting ordinary trucks to water carriers*
- *earth-augers for making bore-holes latrines; other tools, brushes and cleaning materials for operating emergency latrines*
- *packaged sanitation units*
- *pot chlorinators*
- *timber for latrine building*
- *family water jugs, cooking pots, soap*
- *empty oil drums (200 litre size).*

c) Equipment for use by relief workers, including equipment for personal use (e.g. camping equipment where necessary water sterilizing tablets) also equipment needed for the work being undertaken (e.g. tablets, colour comparators, and other equipment for making the residual chlorine test. Included in this latter category might be:

- *tape measures (pocket 3 m length; also long 30 m tapes)*
- *clip boards, pencils*
- *standard 500 ml cup or graduated measure jug*
- *hand level*
- *plumb line).*

d) Perishable materials such as vaccines and chemicals for water treatment which are not held in stock. Arrangements with suppliers can often be made so that if an emergency occurs, the materials can be made quickly available in quantity.

e) Specialized heavy equipment and capital-intensive equipment whose cost prohibits purchase and storage especially for emergency use. Efforts should be made before a disaster to discover where the loan of such equipment can be obtained (e.g. from the army). Examples are:

- *mobile units for chlorinating water*
- *mobile latrines, or mobile sludge tanks suitable for improvising them*
- *purpose-built tank-carrying trucks or trailers*
- *large pumps*
- *auxiliary electric power generators*
- *bulldozers and other earth-moving equipment*
- *transport (e.g. trucks for refuse disposal). Assar*[45] *suggests that in an emergency affecting 100,000 people, the requirement of sanitation work would be 5 jeeps or Land Rovers, 2 light trucks (3/4 tonne capacity) and one 4 tonne truck, but this will clearly vary greatly with the terrain, population density, and the nature of the emergency.*

5.6 *Training and personnel*

5.6.1 *General considerations*

Many countries will not have the resources to assemble all the above equipment, and will not be able to finance large emergency stores. However, every disaster-prone nation needs to invest in manpower resources which are, in many ways, much more important. Thus, even if emergency equipment of the kind envisaged does not exist, there is still an urgent need for contingency planning, for the assignment and co-ordination of responsibilities between different organizations and different governmental departments, and for training people likely to be involved in relief operations.

A useful technique in contingency planning is to create disaster scenarios. These should include details of anticipated damage which may be sustained by water supply and waste disposal systems, and on the sanitary needs of the population. Such scenarios can give a fairly clear idea of which organizations, departments and persons will be involved.

5.6.2 *Public information and health education*

If water supplies are interrupted it may be necessary to inform people about the times and places where water tank trucks will call.

The radio should be used to broadcast instructions and give information. It may need to be backed up by loudspeaker announcements in the streets, and by pamphlets and posters. With regard to routine health procedures, such as boiling contaminated water, the text of radio broadcasts can be drafted in advance as part of disaster preparedness. In places where they are likely to be needed, leaflets and posters can also be printed and posted in advance, or if this is too costly, at least the text and illustrations can be prepared, and the blocks can be made.

5.6.3 *Organization of relief workers*

5.6.3.1 Being well prepared for a disaster depends more than anything else on having available potential relief workers who are trained and who know in advance their emergency responsibilities. Some of these relief workers will be trained to do technical work, like installing emergency latrines; others will keep liaison with individual local communities; others will inform the citizens on what they can do to help themselves. Recovery from a disaster is rapid when everyone in the affected area is both informed about precautions he or she should take, and what relief he or she can supply.

Relief workers may be recruited from a number of bodies, including waterworks and waste disposal authorities, the army, the police, and non-governmental organizations (including foreign ones, which can sometimes provide specialized expertise from another country if necessary). Boy Scouts and students can be used very effectively.

5.6.3.2 Waterworks and sewage treatment plant staff will inevitably provide most of the technical expertise needed. They should be given training in emergency procedures, and executive staff should be aware of the detailed provisions of contingency plans. Where the normal waterworks staff seems likely to be too small for the expected type of emergency, further technical personnel may be recruited by arranging with local engineering firms, offices of consulting engineers, or the army, to release suitably qualified employees for periodic training in emergency procedures, and for their temporary employment by the waterworks in the event of a disaster. Dairies, laboratories, universities, railways and airlines may also employ people with relevant experience, and students from technical colleges could also be recruited.

5.6.3.3 In a disaster-prone country the army may be an important source of equipment and expertise, and in many countries, the armed forces should be expected to regard emergency aid and relief as an essential part of their role. In particular, they may lend heavy transport vehicles, bulldozers and pumps, as well as skilled men to operate them; an engineering corps may assist directly in the restoration of water or sanitation system; equipment and personnel experienced in setting up emergency camp-sites could also be provided by them.

5.6.3.4 The police may play a role in informing people of emergency water distributions, public latrines, or precautions to be taken at home. They may enforce emergency regulations, or supervize evacuation. The precise role of the police in a disaster should be determined in advance and disaster training given as appropriate.

5.6.3.5 Non-governmental organizations may be able to provide voluntary workers (including some professionals), particularly for medical and welfare work, but also, increasingly, for specific sanitary activities, such as digging pit latrines.

5.6.3.6 Self-help activity among the disaster victims themselves should be given every encouragement. Squads may be organized to clean public or communal latrine facilities, to dig pit latrines, or to bury rubbish, carcasses and excreta. Reconstruction programmes can also be successfully based on communal self-help, as in Brazil after the floods in 1974, or in Guatemala after the 1976 earthquake. Non-governmental organizations, including church groups and youth movements, have an important role to play in organizing such activities.

5.6.3.7 Sanitarians may need to be specially trained in latrine construction, and engineers will need practical training in the emergency operation of water and sewage plants. During exercises and demonstrations, equipment stockpiled for use in an emergency should be used, and this may be a worthwhile check on its state of maintenance.

Relief workers often have to work long hours in difficult conditions, and may be especially vulnerable to health risks; they should therefore be given priority with regard to immunization. They should be provided with water sterilizing tablets or personal water filters. Care should be taken to see that they have adequate shelter and food. Their training should include instructions on suitable clothing and on any personal items of equipment they may need.

5.6.3.8 This requirement for recruiting and training personnel, as well as the need for contingency planning, implies the existence of a disaster relief organization which has government backing and which operates at all times to keep a country or municipality prepared to deal with such emergencies as arise. This relief organization will need to play a co-ordinating role during normal times, ensuring that the waterworks, the army, the police, and any other body involved, has a defined role to play in the event of a disaster. It will also need the authority to inspect the detailed technical contingency planning carried out by waterworks staff to assure that it is adequate, and authority to arrange with employers for members of their staffs to be seconded for disaster preparedness training when appropriate.

PART B — VECTOR CONTROL

Chapter I

WHY VECTOR CONTROL?

1.1 *General considerations*

Natural disasters lead immediately to major ecological disturbances and during the period of biological imbalance which follows a disaster some arthropods and rodents might be at a selective advantage and, as a result, may dramatically increase in numbers until natural controlling factors halt the rise and restore the equilibrium. The period of imbalance is likely to be lengthy, and associated with the increase in arthropods and rodents may be an increase in the infections which they carry. In disasters areas, therefore, active steps are required to prevent vector and rodent populations from increasing to unacceptable levels.

Unlike micro-organisms, arthropods and rodents require a period of some weeks before their numbers show significant rises, but it does not follow that there will be a period of respite before there is any real risk of arthropod-borne or rodent-borne infections. Many serious infections of man, such as plague, have a primary cycle in animal populations, and owing to the habits of the animal hosts or of the arthropod vectors man is rarely in contact with this cycle. Following a natural disaster, however, the animal populations as well as the human populations are disturbed, and contact between man and both the animals and their vectors may be greatly increased. In Botswana in 1974 for example, there was an epidemic of plague among villagers which had its origins in an unusual animal migration following flooding (Pollitzer, 1954). The flooding caused an unusually large population of multimammate mice to leave their burrows in the swamps, and it is thought that these mice acquired plague from gerbils, which were suffering an epizootic at the time, and then brought the infection into the villages which they invaded during their migration.

In latent disaster areas it is not possible to predict with confidence which of the vector-borne or rodent-borne infections might erupt, and, even if it were, it would still not be practical to take measures to prevent the ecological imbalance which leads, among a few species, to a population explosion or to an abnormal migration. Nevertheless, some steps can be taken to prevent outbreaks of infection among human communities. The first is to establish within each country a unit of trained and adequately-equipped personnel to study the vector and rodent-borne infections of the country and to be prepared to organize and implement vector control in advance of possible outbreaks of infections. A state of preparedness can be achieved, but the requirements are substantial and extensive; they can only be met by early planning, by adequate staff training, and by the provision of the materials required for effective vector control.

In this section the intention is not to provide detailed descriptive or technical matter on vectors and rodents. The objective is to provide practical guidance to the administrator and to the public health official regarding those arthropods and rodents which might constitute hazards in disaster areas, and, equally important, guidance on the methods and the pesticides which are available to help control them.

Some references are given to further sources. These are weighted in favour of publications of the World Health Organization for two reasons: the publications are relevant and often contain helpful detail, and second, they are generally the most readily available in all health departments, and if not so available, can be obtained quickly from the local WHO Office.

Chapter II

ARTHROPOD VECTORS, THEIR INFECTIONS AND THEIR CONTROL

2.1 *Classification*

There are several ways of classifying vectors whose numbers or contact with man might be changed, to the detriment of man, by natural disasters. It is proposed that they be reviewed here according to their habits and habitats. By this means we can arrange them into four groups: first, those which, like the scabies mite and the louse, spend virtually all their life on their host; second, those which, like fleas, live in the home or nest of their host and which spend a limited period on the host for feeding; third, those which are peridomestic, living in or around the house of man, and in this group we need consider only the housefly; and fourth, those which may be said to be field-dwelling and which come into contact with hosts only for feeding.

2.2 *Host-dwelling arthropods*

2.2.1 *The scabies mite*

Although in some respects it is of secondary importance, the scabies mite, *Sarcoptes scabiei*, deserves consideration. The mite is world-wide in distribution, and in addition to the severe skin irritation during the infestation, there may also be associated secondary skin infections which result from scratching the affected area. The mites are concentrated mostly on the hands and wrists, but may be found elsewhere on the body.

Scabies has been described as a familial infection, readily spreading from parent to child and child to child. Transmission and spread are likely to be greatest in autumn and winter, perhaps because people sleep then in closer contact. At these times also they generally wash less often, and although washing does not affect the mite in its burrow, infrequent washing may increase the prevalence of secondary infections. The areas of severe secondary infection do not correspond with the distribution of the mites on the body; nor does the distribution of the scabies rash correspond with the mite distribution.

New cases of scabies are not usually recognized until about 4 weeks after infection; at that time the signs of infestation are easily recognized. In disaster areas, therefore, an increase in scabies may be inapparent for some weeks, but the probability of increased transmission in crowded conditions should be anticipated.

The control of scabies is greatly helped by early and accurate diagnosis of the infection.

Infected individuals require the application of a mite-killing compound over the whole surface of the body, excluding the head. The most widely-used compound has been benzyl benzoate, and "painting" the body with a 25 per cent emulsion, allowing the patient to dry in warm surroundings and discouraging him or her from bathing for 24 hours, will prove most effective. Sometimes a second treatment is required after a few days, but in most cases a single treatment is adequate.

2.2.2 *Lice*

Lice are present in all human communities, and although both the head louse, *Pediculus humanus capitis* and the pubic louse, *Pthirus pubis*, may increase in prevalence in disaster areas, it is the body louse, *P. h. corporis*, which, as a vector of epidemic typhus, trench fever and relapsing fever, is the greatest potential hazard. Body lice are now uncommon in developed countries (though the head louse is still well established), but they are still prevalent under conditions of low standards of hygiene. Where people are crowded and unable to wash and change their clothing regularly, body lice, and their infections, will spread.

Lice multiply rapidly, and for practical purposes those on man cannot live on an alternative host. Under disaster conditions, where facilities for changing and washing clothes are restricted, louse populations might reach abnormal numbers.

The two infections with which lice are primarily associated, typhus and relapsing fever, are regarded as infections only of man.

2.2.2.1 *Louse-borne typhus*

The causative organism of typhus is *Rickettsia prowazeki*, and the infection is transmitted by lice. There is no transmission by bite. The louse's infected faeces contaminate clothing and bedding, and since the rickettsiae can remain viable and infective for at least two months in dry faeces, all clothing and bedding associated with individuals with typhus should be regarded as hazardous and treated with great care. The dry rickettsiae can infect people through cuts and abrasions, or they may be scratched into the skin, and they might also infect through the conjunctiva and mucous membranes.

Vaccines are available against louse-borne typhus, and infected individuals can be effectively treated with some antibiotics.

The epidemics of the past have been associated with such conditions as occur in war, famines, prison camps, and like disasters where people have been crowded together in unhygienic conditions with limited facilities for washing and changing clothing. They have also been associated with temperate countries, as in Europe, or in high altitude regions of tropical areas, where people wear many items of clothing. In more recent times, and associated with a low general level of hygiene, outbreaks are reported mainly from the highlands in tropical zones, for example in Burundi, Ethiopia and Rwanda in Africa and in Bolivia, Ecuador and Peru in South America.

2.2.2.2 *Louse-borne relapsing fever*

Relapsing fever is caused by *Borrelia recurrentis* and transmitted by lice. They do not infect the salivary glands and they are not therefore transmitted by bite. The spirochaetes can only infect man when the louse is crushed, for example between the fingers or between the teeth, and the infected

haemocoelic fluid contaminates scratches and abrasions.

This infection has been responsible for seven major epidemics during this century, all associated with wars or famines, with more than 16 million cases and 5 million deaths (World Health Organization, 1976*b*).

2.2.3 *Control of lice*

Where a community is exposed, the louse population must be reduced as quickly as possible by applying an insecticide in dust form to the inner clothing of all members of the community. These insecticidal dusts include 1 per cent gamma HCH, 1 per cent malathion, 2 per cent Abate, 1 per cent propoxur and 5 per cent carbaryl. Resistance has been reported to HCH and malathion in some louse populations and the pattern is changing with time and insecticide usage. Periodic reviews by the World Health Organization include up-to-date statements on the spread of resistance and on recommended vector control measures.

For the treatment of individuals, about 30 g of the dust or powder should be applied from sifter-top cans to the underclothing, with particular attention to treating the inner seams. The seams of outer garments should also be dusted, as should socks.

Large groups of people can be treated without removal of their clothing by the use of hand-operated dusters or by means of motor-driven compressors with a series of duster heads. About 50 g of powder is applied to clothing through neck and waist openings and through sleeves. In treating women, the application around the waist is usually omitted and an extra quantity of powder is introduced down the neck of their garments. Treatment of socks, head-wear, spare clothing and bedding should not be neglected.

As a further prophylactic measure, clothing can be soaked in insecticide, such as 1 per cent DDT emulsion, or washed with soap containing 3-7 per cent DDT.

A thorough treatment of individuals and their clothing and bedding is often sufficient to eliminate the louse population. If some lice persist, retreatment may be required after 3 or 4 weeks.

If HCH or pyrethrins, whose residual life is short, are used, weekly applications are recommended until the infestation is eliminated.

The possibility of resistance of the lice to the insecticides available should always be kept in mind. It is likely that DDT-resistance is now widespread, and perhaps also HCH-resistance. Malathion may still be effective in most areas, but there have been reports of resistant strains.

2.3 *Nest or burrow-dwelling arthropods*

2.3.1 *General considerations*

Under this heading are included those vectors which live mainly in association with vertebrates other than man, more especially rodents. There are four groups: sandflies, bugs, ticks and fleas. These vectors are all responsible for the maintenance of infections among their primary hosts, and when for one reason man intrudes into their environment there is a possibility of the vectors transmitting to him the animal infections. In disaster situations, when large numbers of people may have to move from their homes into adjoining undeveloped areas, there is very real risk of the vectors turning

to man as an alternative host for blood meals, and of transmitting such infections as plague and leishmaniasis. The most important potential danger lies with fleas and plague; the other vectors are either more restricted geographically or their infections are less severe.

2.3.2 *Fleas*

As adults, fleas spend part of their time on their host and part free-living in the home or burrow of the host. The species of most concern to man is *Xenopsylla cheopis*, the tropical rat flea, which associates with commensal and with wild rodents. It is a major vector of plague and murine typhus, and if given the opportunity it feeds readily on man. There are many other fleas which are found living with wild rodents but which, following an intrusion of new hosts into their environment, will readily adapt to these hosts for blood meals.

2.3.2.1 *Plague*

The bacilli of plague, *Yersinia pestis*, multiply in fleas which may infect several hosts during their efforts to feed.

The permanent reservoirs of plague are different species of wild rodent, such as rabbits, ground squirrels, gerbils and voles. During natural disaster the contact between these animals and commensal rodents and man may be greatly increased. In many of the plague epidemics of the past the infection has passed in the first instance from wild rodents to commensal rodents via the flea vectors. Thereafter, since domestic rats usually die of the infection, the fleas (often *X. cheopis*) leave their dead or moribund hosts and readily pass to man, in whom the infection is severe and often fatal. The contact between wild rodents and man may at times be more direct. In 1974, there was an outbreak of plague in Namibia also associated with a mass migration of rodents. In this case the rodent migration followed a brush fire and the outbreak, with 102 cases and 5 deaths, was ascribed to the subsequent close contact between man and the rodents and their fleas (World Health Organization, 1975*a*).

Although plague has declined as a major public health problem during this century, except in Vietnam from which the great majority of human cases and deaths are reported, the number of foci of wild or sylvatic plague has probably changed very little. There are still many human cases reported annually from the Americas and Asia which have their origins in sylvatic foci, and such foci should be recorded and mapped in all areas susceptible to natural disasters.

2.3.2.2 *Murine typhus*

Murine typhus (*Rickettsia mooseri* or *R. typhi*) is another infection of rodents which is transmissible by fleas to man. However, it is more sporadic than the related louse-borne form, and it is less dangerous than plague.

Murine typhus occurs in many parts of the world, from Manchuria, China and South-east Asia to South and West Africa and the Americas. The vector to man is most commonly *X. cheopis;* however, *R. mooseri* has been recovered from many kinds of wild rodent and no doubt several species of flea play a part in its transmission. It has been associated primarily with the commensal rat, *Rattus norvegicus*, and where populations of this rat are high there is always a risk of transmission to man. Where high flea indices occur, there is a great risk of transmission to man, particularly if there is any ecological disruption in the area.

2.3.2.3 *Control of fleas*

Surveillance of plague and murine typhus foci is a primary requirement in areas subject to natural disasters and an important part of surveillance concerns the vector fleas. The organization and requirements for plague surveillance have been described in detail by the World Health Organization (1973*a*).

Since fleas quickly leave dead hosts and transfer to living animals, a campaign against rodents may result in an initial increase in the numbers of fleas attacking man. Consequently, in a plague outbreak, or where one may threaten, it is essential to attack the flea population first.

The generous application of insecticidal dusts to rodent runs, to the entrances of burrows, and to all possible resting and foraging areas is the best method of flea control. The dust is picked up on the feet and fur of the rodent and carried to its nest where it is transferred, during grooming, over its body.

Dusts of 10 per cent DDT or 3 per cent HCH have been used most successfully in the past. However, resistance of *X. cheopis* to DDT and to HCH has been reported from many parts of Asia, Africa and the Americas, and in emergency situations 2-5 per cent carbaryl (Sevin) dust is the most certain to be effective.

If 2 per cent diazinon, 3 per cent fenthion or 5 per cent malathion dusts are available, these should prove satisfactory.

Hand-carried dusters specially designed for dusting are available, but in an emergency any form of tin-can with a perforated lid can be used. The aim is simply to apply a liberal layer of dust on all rodent pathways. If the burrows can be detected, about 30 g of dust should be blown into the entrance; some of this may penetrate sufficiently to reach the flea larvae in the nest.

The period of efficacy of a single treatment is influenced by the amount of exposure to sunlight, wind and rain, but one treatment will commonly be effective in holding the flea population at a low level for two or more months.

Control measures against fleas of domestic or commensal rodents present fewer difficulties than those against fleas of wild rodent populations. In the latter circumstances, besides dusting the burrow entrances and any recognizable pathways, it is useful to treat bait-boxes with about 100 g of powder. The boxes should have an ample supply of easily accessible bait, and when the rodents visit the bait their feet and fur are contaminated with the insecticidal powder.

2.3.3 *Sandflies*

2.3.3.1 Sandflies of the genera *Phlebotomus* (in the Old World) and *Lutzomyia* (in the New World) are the vectors of cutaneous and visceral leishmaniasis, of sandfly viral fever, and of Oroya fever *(Bartonella bacilliformis).* As a group, they range in distribution from tropical rain forest to semi-arid desert areas. They are associated primarily with rodents, dogs and wild canines, but some species are peridomestic and feed readily on man. The infections they transmit are not usually high on the list of public health priorities; nevertheless, both cutaneous and visceral leishmaniasis are widely distributed and readily transmissible from their animal reservoirs to man. The presence of absence of sandfly-transmitted infections in an area is a matter to be established by local health authorities.

It is often possible to show an association between the distribution of the infections and the terrain and ecology of the endemic areas.

2.3.3.2 *Leishmaniasis*

Cutaneous leishmaniasis is associated with rodents and dogs. It is widely distributed in Central Asia, the Indian subcontinent, the Eastern Mediterranean and Middle East, Southern Africa, parts of the Ethiopian region, and in most of tropical Central and South America.

Visceral leishmaniasis or kala-azar has a reservoir in dogs, wild canines, sometimes rodents, and in man himself. It occurs in Central Asia and India, the Mediterranean basin and in Sudan and East Africa, as well as in many of the countries of Central and South America.

The interrelationships of the various vectors and forms of leishmaniaisis are most complex. Sandflies are not likely to be a major cause of concern in disaster areas since the signs of leishmaniasis appear after a long incubation period. However, if displaced people in endemic areas of the tropics or sub-tropics have to live outdoors for a time in proximity to rodent colonies and wild canines there will be an increased risk of transmission. Sandflies and leishmaniasis should therefore be kept in mind as a possible hazard, and account should be taken of them in designing a vector surveillance system.

2.3.3.3 *Sandfly fever and Oroya fever*

Sandfly fever is a mild viral infection occurring in the Mediterranean basin, the Near and Middle East, Central Asia and South China. It may occur in epidemic form, but it is unlikely to be of major concern in disaster situations.

Oroya fever, known as Peruvian verruga or Carrion's disease is limited to foci between 800 and 3,000 metres in Andean valleys of Colombia, Ecuador and Peru. The only known host is man.

2.3.3.4 *Control of sandflies*

Sandflies are among the most susceptible of insects to contact insecticides, and resistance has not yet been reported. DDT has been very effective, and in those areas where DDT has been used to control malaria vectors, the sandfly population has been reduced to a point of near extinction. Sandfly control has rarely been high among priorities of public health programmes, but effective control can be quickly achieved by spraying houses with 0,25 g gamma HCH/m2 or 1-2 g malathion/m2. Where resources and manpower are limited, it may well be sufficient to spray only in and around entrances to houses and the sleeping areas. It is desirable to spray also any nearby animal sheds. If the sandflies have their origin in rodent burrows, the application of an insecticidal fog or dust into the entrance should prove effective.

2.3.4 *Bugs*

2.3.4.1 Although bedbugs can be a source of irritation and discomfort, they do not merit serious consideration as a potential major problem in disaster areas. They are not vectors of disease. Organophosphorus compounds and carbamates are often effective, but resistance has been recorded in some areas.

2.3.4.2 Triatomine bugs are vectors of Chagas' disease (*Trypanosoma cruzi*) and they are especially

prevalent in South America, living in the homes of man and animals. However, their importance is most unlikely to increase in the short-term as a result of any natural disaster.

2.3.5 *Ticks*

Nest-dwelling ticks are principally soft ticks of the genus *Ornithodoros*. They are vectors of relapsing fever (e.g. *Borrelia duttoni*), but owing to their slow rate of multiplication they will present no immediate hazard in disaster situations, except if displaced people make use of caves as temporary homes, as in refugee situations in much of Central Asia, the eastern Mediterranean countries, northern and Central Africa, and North and South America. The application of insecticidal dusts, e.g. DDT or HCH, on the floors of caves which are being used as temporary shelters is recommended.

2.4 *Peridomestic arthropods*

2.4.1 *Houseflies*

2.4.1.1 The only arthropod of major concern in and around human settlements, be they permanent or temporary, which might be called peridomestic is the housefly. Within this commonly-used name is a group of closely-related species, differing in detail in several aspects of their ecology, but for most purposes they can be considered together as those flies which depend upon man and his domesticated animals for their food and which readily enter dwellings. Although the evidence is weak, there is no doubt that houseflies may be involved at times in the transmission of a range of pathogens, including viruses, bacteria, protozoa and helminths. Many pathogens can pass through the housefly's alimentary tract undamaged.

There is good evidence that many enteric infections, including bacillary dysentery, and eye infections, such as trachoma and epidemic conjunctivitis, are the result of housefly transmission. The role of flies when present in large numbers in the transmission of amoebic dysentery, poliomyelitis and related viruses, and of infectious hepatitis is less certain.

Because of their very wide distribution throughout the world and their adaptiveness to different climatic conditions, it is unlikely that flies will be absent from any area suffering a natural disaster. Their presence in large numbers can most often be related to inadequate or inefficient waste disposal, and both human and animal excrement and ordinary household refuse provide favourable habitats for the immature stages.

2.4.1.2 *Housefly control*

The elimination of the breeding sites is the best measure for fly control. However, since houseflies can breed in a wide range of organic matters, the prevention of breeding is never an easy task. Under disaster situations it is usually only practical to apply control measures against the adults, and these measures are all based on the use of insecticides. Unfortunately, houseflies have the capacity to develop resistance to insecticides relatively quickly, sometimes within months of a compound being introduced, and, as a result, many of the commonly-available insecticides are now no longer effective. The pattern of resistance varies from country to country according to their history of insecticide usage. Nevertheless, the following compounds and methods of application are still effective over most of the range of the fly:

a) *Residual sprays* are applied by hand-or power-operated sprayers and all indoor or outdoor

surfaces where flies may rest are treated. In disaster situations it is unlikely that extensive residual spraying will be practical, but it may be desirable and feasible in selected communal buildings. According to the toxicity of the compounds applied, the target dosage commonly ranges from 0.5 g to 2.5 g/m^2. The organochlorine insecticides are as a whole no longer effective for housefly control; resistance is widespread. However, there are still several effective organophosphorus (OP) compounds which can be used. Dimethoate at 1 g/m^2 has given excellent results in many areas. Trichlorphon is also still an effective contact poison, but perhaps its chief merit is as a stomach poison, and sugar at 1-2 g/m^2 may be mixed with the insecticide to give an enhanced effect; it has also given good results as an insecticidal paint containing 4 per cent trichlorphon. Naled (or dibrom) at at 1 g/m^2 has a short residual life, but it is recommended in the United States. Several of the carbamate group of compounds are usually effective, and propoxur and bendiocarb at 1 g/m^2 can be mixed with sugar to provide a kill both by contact and by feeding.

In some countries there are restrictions on the use of organophosphorus and carbamate compounds, especially where foodstuffs may be contaminated or where livestock may be exposed to the spray.

b) *Tapes or cords impregnated with insecticide*, usually mixed with sugar, are often effective indoors. They are easy and quick to distribute and hang, whereas a residual spraying programme is more difficult to organize and implement. The OP and carbamate compounds mentioned above can be used at concentrations of 10-25 per cent to impregnate the tapes or cords. The handlers should take precautions with all compounds against personal contamination.

c) The *toxic bait* most commonly recommended is trichlorphon in liquid form (0.1-0.2 per cent) mixed with a sugar solution. The mixture can be painted on any surface where flies congregate, for example on window ledges.

d) *Space-spraying* with pyrethrins or synthetic pyrethroids is the best measure for reducing fly populations quickly. Although relatively expensive, these compounds give at low doses an immediate kill with no toxic hazards to man. Pyrethrins (0.1-0.4 per cent) are usually mixed with a synergist (0.5-2.5 per cent) such as piperonyl butoxide for an enhanced effect, and the synthetic pyrethroid bioresmethrin is usually combined with another, S-bioallethrin, and the synergist piperonyl butoxide to provide a mixture which gives a very rapid knockdown.

The synthetic pyrethroids can be applied indoors or outdoors, as a thermal fog or as an ultra-low-volume (ULV) formulation, and using hand-held, vehicle-mounted or aircraft-mounted equipment.

Many OP compounds can also be used for indoor or outdoor space-spraying *(Table II)*, though some countries have restrictions on indoor spraying. Dichlorvos (0.1-0.5 per cent) and malathion (2-4 per cent) have been used indoors (but malathion resistance is becoming widespread), and dimethoate and naled are effective outdoors at dosages of 200 g/ha applied from the ground; diazinon and dichlorvos at twice this dosage are also effective. Naled, applied in a ULV formulation from the air, is effective at 60 g/ha.

e) *Slow-release formulations* of dichlorvos are effective in rooms which are adequately

Table II

Insecticides suitable for outdoor space spraying against houseflies

Insecticide	*Dosage (g/ha)*	*Remarks*
Bioresmethrin	10	Usually combined with piperonyl butoxide and bioallethrin to enhace the effect.
Diazinon	400	In thermal applications it is usual to apply 5-10 1/ha of diluent + insecticide. Assuming an effective drift of 50 m, and in vehicle-mounted equipment a speed of 10 km/hr 25-50 1 will be used in 1 km or 6 mins. In ULV applications, volumes as low as 0.2-0.5 1/ha are used since the insecticide is much more concentrated.
Dichlorvos	400	
Dimethoate	200	
Fenthion	450	
Naled	50-200	
Ronnel	450	

ventilated. Resin or plastic strips are impregnated with dichlorvos and these strips hanging near the centre of a room can be effective for several months. In some countries their use may be prohibited in rooms where foodstuffs are exposed or where people spend much of their time.

2.5 *Field dwelling or sylvatic arthropods*

2.5.1 *Mosquitoes*

2.5.1.1 When natural disasters are accompanied by flooding, or following heavy rains, mosquito populations are likely to multiply in the expanded range of habitats made available for breeding. For example, a season of very heavy rainfall in 1950 in Sudan, led to a rapid spread of malaria transmitted by *Anopheles gambiae*, amd within weeks some thousands of people were infected, hundreds died, and apart from this loss of lives, there was an economic loss because of the loss through unharvested crops of about 10 million dollars.

It is during the period after flooding, when residual pools are left behind as the floods recede, that mosquito populations may rise to abnormal levels.

The best documented account of malaria epidemic resulting from a natural disaster is that of Mason and Cavalie (1965). A hurricane swept across the southern peninsula of Haiti on the evening of October 3, 1963, and in addition to the devastation caused by the winds there was great supplementary damage caused by the floods which followed the hurricane. There were two periods of heavy rainfall, the first immediately associated with the storm on October 3 and the second several days later when the hurricane passed to the north of Haiti. This second period of heavy rainfall, in particular, caused extensive flooding since the water table was already high and many of the water courses were

blocked or damaged as a result of the first storm. It can be taken that the vector mosquito, *Anopheles albimanus*, built up in numbers during October and November, since rises in malaria reports were apparent by mid-December. By the end of that month an epidemic was well established. This epidemic continued until March 1964, and by that time some 75,000 people had been infected. Fortunately, there was apparently no associated increase in mortality; though it should be noted that the mortality reporting system was unreliable.

But it is not only malaria vectors whose numbers might be greatly augmented following the provision by floods of extensive new breeding areas; vectors of virus infections may also exploit these habitats. Temperature also has an important effect on the probability of virus epidemics, but, in general, heavy rainfall and flooding in an endemic area, for example in the Central Valley of California, is followed by an outbreak of western encephalitis. Both in 1952 and in 1958, for example, floods were followed by epidemics.

There are many countries with flood water vectors of virus infections, and flooding following a natural disaster will always bring with it a risk of mosquito-borne infections. There is little that can be done to prevent mosquito populations utilizing the habitats created by flooding; on the other hand, quick action against the larval stages can obviate the risk of an epidemic of mosquito-borne disease.

2.5.1.2 *Mosquito control*

a) Larvae

In disaster situations involving flooding, surveillance of larval mosquito populations is essential. Prompt treatment of larval habitats will greatly reduce the risk of outbreaks of mosquito-borne infections. It will usually not be practical to eliminate the larval sites by filling or draining so that dependence must be placed on insecticides or oils. Petroleum oil fractions have proved their value over the years and the most effective as larvicides are diesel and gas oils. Such oils by themselves have to be applied at high dosages, for example about 150-200 l/ha of surface area, but when spreading agents are incorporated the dose can be reduced to 20-50 l/ha. Nowadays, commercially available larvicides have insecticides added to the oil and dosages of less than 20 l/ha can often be used. Paris green in dust or granular formulations is also satisfactory for use in emergency situations. Many organochlorine and organophosphorus insecticides are available as larvicides but the former are less used because of the wide prevalence of resistance to these compounds; the formulations include solutions, emulsions and granules. The dosages of larvicides commonly applied are illustrated in *Table III.*

Larvicides may be applied by hand-carried, vehicle-mounted, or aerial equipment. Applications may need to be repeated at intervals of 7-14 days according to local circumstances and to the efficacy of the larvicide. If the dosages shown in *Table III* are increased 10-20 fold, a longer residual effect will be obtained, but generally such large dosages are not to be recommended because of the probable adverse effects on other components of the environment. Lesser dosages than shown may be effective against some species; for example, the Tennessee Valley Authority in the United States has successfully applied aerial spraying against *Anopheles quadrimaculatus* larvae using only 350 ml/ha of 43 per cent Abate, equivalent to 4.5 g Abate/ha.

b) Adults

The control of adult mosquitoes by residual spraying of houses is sufficiently well known

Table III

Insecticides suitable for use against mosquito larvae

Insecticide [a,b]	*Dosage (g/ha)*	*Remarks*
Abate	50-100	Use oil or water emulsion formulations in areas with minimum vegetative cover. Granular formulations are suitable for penetration of heavy vegetative cover.
Chlorpyriphos [c]	10- 15	
DDT	220	
Dieldrin	110	
Fenthion [c]	20-110	For use as residual larvicides or pre-hatch treatments higher dosages are necessary.
Fenitrothion	220-340	
Heptachlor	110	
Lindane	110	
Malathion	220-680	
Paris green	850	Apply Paris green pellets (5 per cent) at a rate of 17.0 kg/ha with ground machines or aircraft.
Fuel oil		Apply to cover water surface in catch basins or at a rate of 150-200 l/ha in open water courses. With a spreading agent the volume can be reduced to 20-50 l/ha.
Larvicidal oil		Apply at 20-50 l/ha.

a) As there may be regulations restricting the use of these compounds, the user should consult the appropriate authorities. He should also read the label carefully for any mention of restrictions on the types of persons approved for handling the compound or of hazard to non-target animals.

b) Where insecticides are to be applied to croplands, pasture, range land, or uncultivated lands, the agricultural authorities should be consulted regarding acceptable application procedures.

c) Chlorpyriphos and fenthion should not be applied to waters containing valuable fish.

to require no detailed description. In disaster situations this approach requires too much preliminary organization and time to merit further consideration. Emphasis is therefore given to the application of indoor and outdoor space-spraying designed to achieve a quick reduction of adult populations.

In recent years there have been great developments in the use of thermal fogs and aerosols, either by ground or by aircraft equipment. Thermal fogging with 2-5 per cent malathion or 3 per cent fenthion (outdoors) or with the recently-developed synthetic pyrethroids will give significant though not complete suppression of adult populations. Thermal fogs are usually applied by ground equipment, such as the hand-held Swingfog SN10 or the vehicle-mounted Swingfog SN100 or TIFA or Leco 120 machines. Malathion has been most widely used, but such synthetic pyrethroids as bioresmethrin and bioallethrin combined with the synergist piperonyl butoxide have proved effective against a number of species. Thermal fogging is spectacular to the populace, but several applications at intervals of 5-7 days are usually required to have a reasonably lasting effect on the mosquito population.

Although thermal fogging can be applied from the air, it is more common to apply what has become known as the ultra-low-volume, or ULV, method. In this method small volumes of concentrated insecticide are applied, commonly less than 1 l/ha. The insecticides most often used are malathion and the synthetic pyrethroids, but others may be used (see *Table IV*). Both ground and aerial equipment have been developed, there is no doubt that in emergency situations involving any group of mosquitoes ULV applications offer the best promise of quick control.

Satisfactory conditions for aerial ULV spraying are usually restricted to an hour or two in the early morning before rising temperatures and thermal currents cause excessive dispersion of the insecticide.

Table IV

Insecticides suitable for outdoor space spraying against mosquito adults

Insecticide	*Dosage (g/ha)*	*Remarks*
Bioresmethrin	2- 3	Usually combined with piperonyl butoxide and bioallethrin to enhance the effect.
Carbaryl	220-1120	The treatments are applied as thermal or non-thermal fogs, mists or dusts. Applications are most commonly made by ground equipment, but may be made from the air. Environmental conditions, particularly wind movement, affect the efficacy of space treatments. In ground applications, effective swath widths are usually from 30 to 90 m (100-300 ft.)
DDT	220	
Dichlorvos	50- 250	
Fenthion	110	
Lindane	110- 220	
Malathion	110- 560	
Naled	50- 200	

Both single and multi-engined aircraft, and helicopters, can be adapted for ULV spraying, and Lofgren *et al.* (1970), for example, have described an insecticide-spraying system that can be mounted easily and quickly on C-47 aircraft. In most countries aircraft are used for spraying crops, and these could often be utilized for combatting mosquito populations.

Ground equipment can also be utilized for ULV spraying. The vehicle-mounted Leco HD, for example, has been used widely in south-east Asia to control mosquitoes in towns, where there is a satisfactory road system. There are also several hand-held or knapsack sprayers which are designed for ULV treatments, and these, too, would be of value in emergency conditions.

2.6 *Other field-dwelling species*

It is unlikely that outdoor groups of arthropods other than mosquitoes will require controlling during disaster situations, but in the event of people having to move into areas where there are large populations of, say, tsetse flies or horseflies or biting midges, control measures are best directed at the adults by outdoor space spraying. The compounds and methods suggested for use against adult mosquitoes will be most appropriate.

Chapter III

SOME INSECTICIDES IN COMMON USE FOR PUBLIC HEALTH

3.1 *General provision*

A wide range of insecticides is in common use in almost all countries. Generally, more compounds are applied by agriculturists than by public health workers and in disaster situations it should be kept in mind that large stocks are often more readily available from this source, together with expert advice, than from medical stores. Whenever possible, *only materials which comply with the specifications recommended by the WHO Expert Committee on Insecticides (World Health Organization, 1973b) should be used.* All containers with pesticides should carry clear statements on the contents, their formulation and the precautions which should be taken by those persons handling the compound.

The following notes on compounds in common use are intended to provide guidance on the situation in which they are most often applied. Since resistance to one or more insecticides has evolved in many arthropods of public health importance, and each year additional resistant populations are being reported, it is seldom possible to make unequivocal statements on the most effective compound for a particular vector. However, the World Health Organization regularly geographically reviews the resistance status of the major vectors.

Table V gives a selected list of compounds, some of which are likely to be available in areas where disasters occur, and the vectors against which they can be applied.

3.2 *Table of selected insecticides*

Table V

A table of selected insecticides for use against vectors of public health importance

Insecticide	*Vector groups*						
	Mosquitoes	*Sandflies*	*Houseflies*	*Lice*	*Fleas*	*Bugs*	*Ticks*
Arsenical							
Paris green	X						
Natural pyrethrins							
Pyrethrum	X	X	X	X			
Synthetic pyrethroids							
Bioresmethrin	X	X	X				
S-bioallethrin	X	X	X				
Organochlorine compounds							
Benzene hexachloride	X	X		X	X	X	X
DDT	X	X			X		X
Dieldrin	X	X					
Lindane	X	X		X	X	X	X
Organophosphorus compounds							
Abate	X	X					
Chlorpyriphos	X	X					X
Diazinon			X		X		X
Dichlorvos	X	X	X		X	X	X
Dimethoate			X				
Fenitrothion	X	X					
Fenthion	X	X	X		X		
Malathion	X	X		X	X	X	
Naled	X	X	X				X
Parathion	X						
Trichlorphon			X			X	X
Carbamates							
Carbaryl	X	X		X	X	X	X
Propoxur	X	X		X	X		X

Chapter IV

VECTOR CONTROL EQUIPMENT AND TECHNIQUES

4.1 *General considerations*

In disaster situations there is seldom a choice of equipment for vector control. Improvisation may be necessary to utilize whatever is available from whatever source. This section covers the main methods of applying pesticides and the types of equipment which can be utilized. It is worth repeating that agriculture departments often have a good selection of spraying equipment, much of which can be adapted for public health measures. A valuable reference text which gives guidance on ground equipment and on the use of aircraft in vector control operations is *Equipment for Vector Control*, published by the World Health Organization, 1974.

Successful vector control requires first of all the identification of the vector; secondly, a decision on where it is to be attacked; next, the selection of the most suitable pesticide available, the formulation and the dosage; and, lastly, the selection of the equipment. The availability of appropriate equipment may prove the main constraint to a successful control operation.

Table VI summarizes the basic control methods and the equipment required for use against groups of arthropods (and rodents) which are likely to present problems in one or other disaster situation. The *Table* can be used in conjunction with *Table V*, which gives guidance on the most suitable insecticides for each group, and, in the case of rodents, with *Tables VII* and *VIII*.

4.2 *Ground equipment for applying liquid pesticides*

4.2.1 *Sprays*

Liquid sprays are classified according to the volume median diameter (VMD) of the droplets produced by the spraying equipment. Three commonly-used terms are aerosols, mists and sprays. The WHO Expert Committee on Insecticides has given the following guide to usage based on droplet VMD:

Aerosols	50 μm
Mists	50-100 μm
Fine sprays	100-250 μm
Medium sprays	250-400 μm
Coarse sprays	400 μm

The term "fog" denotes an aerosol spray with a droplet VMD in the range 5-15 μm.

4.2.2 *Equipment for sprays*

Equipment for sprays may be manually or power-operated. The most simple sprayer is the hand-sprayer, which is available in most countries for domestic and garden use and which is operated by a simple pump, liquid being drawn from the reservoir on the backward stroke and expelled through a fine nozzle on the forward stroke. A more refined version is the compression hand-sprayer, in which the air above the liquid is compressed by means of a small plunger-type air pump. The liquid is expelled under pressure from the nozzle by the operation of a trigger valve. Although such manually-operated hand-sprayers have limited use in normal vector control operations, they may well have value in emergency situations, for example, for spraying rodent runs against fleas.

A wide range of larger manually-operated sprayers has been used for vector control. These include the stirrup pump sprayer and several kinds of knapsack or back-pack sprayers, some of which have lever-operated plunger pumps, others of which are compression sprayers with the container acting as a pressurized air chamber as well as holding the presticide. Some of the latter type have been used extensively in mosquito control programmes, especially for indoor residual spraying.

Larger sprayers which require two or more men to carry and operate are sometimes encountered. Although not generally recommended for vector control because they are unwieldy, some large manually-operated sprayers may still be used in farming areas, and they should be utilized in emergency control programmes.

The power-operated sprayers are also available in different sizes and designs. The designs are essentially the same as in the previous group except that power-driven pumps are incorporated. Although power-operated sprayers are little used for vector control in normal circumstances, they can be adapted for, for example, mosquito larviciding. The larger machines can be mounted on vehicles or moved by wheel-barrow or by means of stretcher poles.

4.2.3 *Equipment for mists*

Small manually-operated, hand-carried, mist sprayers are commonly used domestically and in gardening. The liquid from the reservoir is expelled as a mist after being sheared into droplets by the high velocity stream of air from the pumping of the piston. The quality of sprayers varies widely, from cheap units for domestic use with a short life to well-constructed, robust units with a long life. Such hand sprayers are useful for indoor space spraying.

Power-operated mist-blowers have a wider range of usefulness. The small hand-held machines are generally only satisfactory for indoor space spraying, and often they are too heavy for prolonged use, but the knapsack machines can be used effectively for indoor and outdoor vector control. They can often be converted and used for ULV applications, which makes them most valuable in disaster situations. Still larger machines are available for mounting on vehicles or boats and these are required for extensive outdoor space spraying or for applying larvicides. By fitting small jets, these also can be adapted for low-volume applications, although for technical reasons only a relatively small change in droplet size is possible. The coverage achieved by the units can be increased by making use of light winds to carry and disperse the insecticide.

Table VI

Recommended methods and equipment for control of arthropods and rodents in emergency situations

Target	*Control method*	*Equipment*
MOSQUITOES		
Adults		
Indoors	Residual treatment	Hand-sprayers, stirrup pumps, compression sprayers
	Space spraying	Aerosol dispensers or generators
Outdoors	Space spraying	Power-operated mist-blowers, thermal foggers or ULV equipment
LARVAE		
Containers	Larviciding	Hand granule applicators, manual or compression sprayers
Ground water	Larviciding	Hand or power-operated sprayers or granule applicators
SANDFLIES		
Indoors	Residual treatment	Hand-sprayers, stirrup pumps, compression sprayers
	Space spraying	Aerosol dispensers or generators
Outdoors	Space spraying	Power-operated mist-blowers, thermal foggers or ULV equipment
HOUSEFLIES		
Indoors	Space spraying	Aerosol dispensers or generators
	Baiting	None required
Outdoors	Space spraying	Power-operated mist-blowers, thermal foggers or ULV equipment
FLEAS		
Indoors	Residual treatment	Hand or power-operated dusters and sprayers
Outdoors	Residual treatment	Hand or power-operated dusters
BUGS		
Indoors	Residual treatment	Hand or power-operated sprayers
LICE		
Head	Body treatment	Hand-operated dusters
Body	Clothing treatment	Hand or power-operated dusters
TICKS		
Indoors	Residual treatment	Hand or power-operated dusters or sprayers
MITES		
Scabies	Body treatment	None required
RODENTS		
Indoors	Baiting and trapping	Bait containers and traps
Outdoors	Baiting and fumigation	Bait containers, bait dispersing equipment and fumigant equipment

4.2.4 *Equipment for aerosols*

Equipment for aerosol production may be carried and operated by one man or it may be vehicle-mounted. The aerosols are produced by mechanical, thermal or by gaseous energy devices, and since the small droplets are emitted at a comparatively low discharge velocity best results outdoors are obtained by making use of light wind to disperse the insecticide. The time of day when applications are made is most important; to be most effective, treatments should be made in the early morning or in the evening, when there is a temperature inversion. Otherwise the insecticide is dissipated by thermal currents. Under ideal conditions the aerosol will lie like morning mist over the treated area.

The aerosols produced by thermal fogging machines are emitted as dense white fogs; the insecticide is in oil-solution or a water emulsion and it is vapourized by being injected into a stream of hot gas. On discharge, the vapour condenses as a fog. In the thermal fogging technique it is usual to apply 50-75 litres/ha of the solution. There is a fire hazard with thermal fogging machines, and care should be taken to ensure that the equipment is properly maintained and operated.

In the ULV technique insecticide concentrate is used and the output volume is reduced to about 0.5 l/ha. The insecticide is atomized by an aerosol generator based on gaseous energy, and it is emitted as a very fine aerosol, dispersal of which is much less obvious than that of a thermal fog. The so-called cold aerosol generators present fewer problems of maintenance or operation than thermal fogging machines.

The simplest aerosol dispenser is the household container in which the insecticide is under pressure in solution or mixed with liquefied gas. These dispensers will commonly contain one or other of the synthetic pyrethroids and they are useful for indoor space spraying.

4.3 *Ground equipment for applying solid materials*

Pesticides in solid formulations may be applied as dusts, granules or pellets. Dusts are used primarily against lice and fleas, but they may also be useful against ticks; granules or pellets are used mainly for larval mosquito control.

Equipment for appying both groups of materials may be manually or power-operated.

The simplest dusting equipment is a tin with fine holes punched in its lid. More commonly, the dust is expelled in a small cloud in a jet of air; the duster may be of the hand-held bellows type or, like a hand-held sprayer, the air is introduced by a simple plunger into the dust reservoir and expelled, with the dust, through a narrow opening. Larger dusting units can be carried; some have a hand lever operating a bellows and the dust is expelled through a long lance, and another design has a fan which is operated by rotating a crank by hand, the dust is fed into the fan and dispersed by the airstream through an outlet.

Power-operated equipment is also available, either hand-held, or of knapsack design, or for mounting on a vehicle. Knapsack mist blowers can often be modified for dust (and granule) application.

Granules and pellets can similarly be applied by manually-operated or by power-operated equipment. In general, the range of usefulness of granules and pellets is rather restricted. They are mostly used for mosquito larviciding, especially where there is thick vegetation which would obstruct the penetration of liquid formulations, and they are useful for dispersing over an area as a pre-flood

semi-residual treatment. Granular formulations are generally applied from the air, but where the terrain is suitable for vehicles, power-operated ground equipment will be effective for treating flood waters and residual pools.

4.4 *The use of aircraft*

Aircraft are now used successfully in control programmes against a number of vectors, and they offer a means of covering extensive areas quickly. With the development of the ULV technique, in which small amounts of insecticide concentrate are applied, aircraft can carry sufficient insecticide to cover large areas without returning to base for further supplies; for example, commonly only 0.5 l/ha need be applied. Thermal fogging or dusting or the application of larvicidal oil can also be carried out by aircraft.

Both fixed-wing aircraft and helicopters may be utilized for control operations. Some have been specially designed for insecticide applications, especially for agriculture, but application equipment can be adapted for use with several types of aircraft. Single, twin and four-engined aircraft can all be used, though the former has been most common for routine usage.

For efficiency and safety, there are a number of operational and technical requirements to be fulfilled during aircraft spraying. These are dealt with fully in the publication by the World Health Organization (1974*a*) on vector control equipment.

Although in disaster situations various types of aircraft may be available to assist relief organization, the necessary insecticide application equipment may well be lacking. In view of this likely constraint to rapid action in emergencies, the WHO Expert Committee on Vector Biology and Control has recently recommended the development or adaptation of simple and inexpensive application equipment for attachment to a variety of types of aircraft, both fixed-wing and helicopters, and proposed that this equipment be stockpiled and kept available for use in readily accessible places (World Health Organization, 1977).

Chapter V

RODENTS AND THEIR CONTROL

5.1 *General considerations*

Rodents are among the most adaptable and numerous of mammals, and apart from the huge economic losses which they cause throughout the world they probably form the most important reservoirs of infections which are transmissible to man. As with all wild animals, there is a delicate balance between their numbers and natural regulatory forces, but during any disruption within the environment rodents are among the first to respond and adapt to new circumstances. In many areas their total numbers far outweigh those of all other mammals, and it is wise to assume that one or more species may present a health hazard during natural disasters.

Rodent-maintained infections may be transmitted to man in several ways; for example, rat-bite fever, caused by a spirochaete is transmitted by bite; leptospirosis is transmitted by rodent urine contaminating water frequented by man, as in rice-fields; tularaemia may be passed to man when he handles the carcasses of infected rodents; and typhus and plague are passed to man by infected fleas. The virus causing Lassa fever in West Africa has been isolated from the widely-distributed multi-mammated rat, and a related virus responsible for Bolivian haemorrhagic fever is maintained by another small rodent and man may be infected through direct contamination of his foodstuffs.

In this Section, emphasis will only be given to control methods commonly used against rodents.

5.2 *Domestic or commensal rodents*

Three species of rodents have become so adapted to living with man that they are now almost world-wide in distribution. These are the house mouse, *Mus musculus*, the Norway rat, *Rattus norvegicus*, and the roof rat or black rat, *Rattus rattus*. The house mouse is established in cities, towns and villages throughout the world and in some areas, where competitors are absent, they form outdoor colonies. The Norway rat is most widely distributed in temperate regions, and in the tropics is more confined to seaports and some of the inland towns. The roof rat is, on the other hand, more successful in the tropics, and most of the towns and larger villages have been colonized. Several other species may also be found in association with man but have not spread so widely. For example, in much of South-east Asia and in most of the Pacific Islands, the Pacific Island rat, *Rattus exulans*, is the main commensal rodent, in the Nile valley and parts of the Middle East the spiny mouse, *Acomys cahirinus*, is very common; and throughout much of Africa the multimammate rat, *Mastomys natalensis*, the species linked with the maintenance of Lassa fever, is associated with human settlements and agricultural areas.

5.2.1 *Control of domestic or commensal rodents*

5.2.1.1 There are many recognized methods of restricting the numbers of rodents on premises, including, for example, environmental improvements and various means of rodent-proofing. In emergency situations when rodent populations have to be reduced quickly trapping is the immediate method of choice, but poison baits will probably prove to be necessary. Since the baits provide a choice with the normally available foodstuffs, every effort should be made to reduce the latter. Poisons are of two main kinds: acute or single-dose poisons and chronic or multiple-dose poisons. The chronic or multiple-dose poisons are slow to act, and several meals may be required over a period of a few days before they take effect. The only poisons in this group currently used widely are the anticoagulants and one of these should always, for reasons of safety and effectiveness, be the first choice. The best known is "Warfarin" but others are equally effective. The choice of compounds can be based on their availability from reputable manufacturers. *Table VII* shows four commonly-used compounds and the dosages recommended for mice and rats. Many anticoagulants are already mixed with food materials. If the baits have to be prepared locally, meat, fish, grains or nuts may be found satisfactory. The most simple preparation is a dry medium-ground or crushed cereal to which the concentrate is added. The addition of a vegetable oil may make the bait more attractive for a time until the oil turns rancid. Sugar added to give a concentration of about 5 per cent is also a useful additive.

The anticoagulant bait should be placed in piles of 100-200 g for rats and about 25 g for mice where the rodents may find it easily and before they reach alternative food. Although usually prepared as solids, the poisons are also available in liquid form or as soluble formulations; these can be added to water and made available to the rodents. Alternative supplies of liquids should, of course, be eliminated as far as possible. A reduction in feeding by the rodents should be apparent after about a week, when numbers begin to die, and feeding on the bait should have stopped after 3-5 weeks depending on the rodent involved and the general circumstances. If there is evidence of continued feeding on the bait, indicating that some of the rodents have not been killed, there is a need to extend the area being baited, or to change the bait or change the anticoagulant. An on-the-spot assessment is required to establish whether there are regular fresh introductions of rodents from outside the treated area or whether the rodents are resistant to the anticoagulant.

5.2.1.2 Acute poisons are effective after a single feed by the rodent. Their action is rapid, and death can occur within 30 minutes. However, such rapidity can be a drawback, for the rodent must be enticed to eat a sufficient quantity of the poisoned bait quickly before it beings to be affected by the poison. The bait must therefore be attractive and acceptable. It is usually advantageous, when time permits, to pre-bait with unpoisoned food so that the animals become accustomed to feeding at the same sites on the same foodstuff. The bait is best damp to allow quick feeding.

Acute poisons are chosen when speed of action is essential, but it should be emphasized that these poisons present more hazards to man and his domestic animals than do anticoagulants and strict precautions should be observed in handling and preparing the bait. *Table VIII* shows the compounds which have been most often used as acute poisons and, following the recommendations of the WHO, they have been divided into three groups according to the relative hazards to man. These acute poisons are generally made available for only one or two nights, particularly if there has been a period of pre-baiting.

5.2.1.3 Mice are often more difficult to control than rats. Since they have the habit of sampling small amounts of food from different sources, a large number of bait points should be provided, and since

Table VII

Multiple-dose rodenticides used against Mus musculus, Rattus rattus and Rattus norvegicus

Compound[a]	Dosage in parts per million[b]		
	M. musculus	*R. rattus*	*R. norvegicus*
Diphacinone	125-250	50-100	50-100
Coumafuryl / Pindone	250-500	250-500	250
Warfarin	250-500	250-500	50-250

[a] May be used in dry or liquid bait

[b] Dilution factors:

500 ppm (0.05%) = 1 part of 0.5% concentrate to 9 parts of bait
250 ppm (0.025%) = 1 part of 0.5% concentrate to 19 parts of bait
100 ppm (0.01%) = 1 part of 0.5% concentrate to 49 parts of bait
50 ppm (0.005%) = 1 part of 0.5% concentrate to 99 parts of bait

they can live for some days without water, the use of liquid formulations of poison may be less effective than solids. A mixture of warfarin and calciferol (vitamin D_2) is most effective against mice; a suitable mixture would contain 0.025% warfarin and 0.1% calciferol.

5.3 *Field rodents*

Several different kinds of field rodents are reservoirs of infections which might be transmissible to man. Many of these live in colonies which form foci of infections, such as plague and leishmaniasis. Contact between man and such foci is usually limited, but it may be increased greatly during natural disasters when displaced people move temporarily into the habitat of field rodents, or, conversely, when the rodents migrate into human settlements.

5.3.1 *Control of field rodents*

Poison baits will generally provide the most satisfactory means of combatting field rodents. Since a quick kill is required, and since the use of anti-coagulants requires several retreatments of an infested area, most reliance is placed on acute poisons (see above). Fluoroacetamide, socium fluoracetate and zinc phosphide (*Table VIII*) can be recommended when mixed with an acceptable bait, such as barley, wheat or other grain. The poison bait can be spread by hand, or mechanically, in and around the rodent foci, but when the area involved is very extensive, aerial applications might prove necessary. The bait can be provided at doses of 200 g to 2 kg per hectare. A judgement can be made locally as to whether and when retreatment is required, perhaps using a different bait.

Table VIII

Single-dose rodenticides used against Rattus norvegicus and Rattus rattus

Compounds	*Acute oral dose (mg/kg)*[a]	*Percentage commonly employed in baits*
Requiring ordinary care:		
Norbormide [b]	12	1.0
Red squill [b]	500	10.0
Zinc phosphide	40	1.0-2.5
Requiring maximal care:		
Fluoroacetamide	13-15	2.0
Sodium flouroacetate	5[c]	0.3
Not recommended:		
Antu (1-naphthylthiourea) [b]	6	1.5
Arsenic trioxide	13	1.5
Phosphorus (yellow)	1.7	0.05
Thallium sulphate	25	0.3-1.5

[a] Based on laboratory strains of *R. norvegicus*

[b] Not used against *R. rattus*

[c] 2 mg/kg for *R. rattus*.

In addition to poison baits, gassing powders or tablets are effective if the burrows and their entrances can be identified, and if the colonies are not too diffuse. Powders that release hydrogen cyanide gas when moisture comes into contact with the powder are effective in well-constructed burrows in damp soil. About a teaspoonful of the powder is placed inside the burrow entrance, which is then well sealed with soil. Tablets of aluminium phosphide have also proved effective against colonies of field rodents. Two 0.5 g tablets are placed in the burrow, which is then sealed. Entrances which are re-opened by the rodents should be retreated on the following day.

5.4 *Rodent poisons*

All rodent poisons must be handled with great caution; they are usually toxic to man and his domestic animals. The anticoagulants are less hazardous than the single-dose, acute poisons since they must be ingested for several days to be effective; whenever practical, anticoagulants should be used for rodent control.

The main features relating to safety are summarized below:

5.4.1 *Norbormide* is one of the safest rodenticides, though not the most effective. It is most useful against the Norway rat, less so against other rats and against house mice. It has a low toxicity to other mammals.

5.4.2 *Red squill* has a bitter taste and is unlikely to be eaten by man accidentally. It causes vomiting in man and most domestic animals and is accordingly less hazardous than some other compounds. It has a strong irritant effect on the skin and handlers should wear gloves. It is relatively ineffective against *R. rattus*.

5.4.3 *Zinc phosphide* has a good safety record and has been widely used for many years. When moistened, zinc phosphide releases phosphine gas, which is repellent to man and most domestic animals; however, chickens find the poison bait acceptable and it is highly toxic to them. Bait preparation should always be done outdoors.

5.4.4 *Sodium fluoroacetate*, owing to its high toxicity to all mammals, should be used only by trained personnel. There have been a number of fatal cases of poisoning attributable to this chemical. It should not be used in domestic surroundings. Liquid baits are preferable to solids, as the rodent cannot move them from the bait point; all bait points should be recorded.

5.4.5 *Fluoroacetamide* is less toxic than sodium fluoroacetate and probably a little safer to man. Nevertheless, it is still a highly dangerous compound and strict precautions should be observed by those handling it.

5.4.6 *Antu* has had a good safety record as far as man is concerned, but it is highly toxic to cats, dogs and pigs. However, owing to the presence of about 2 per cent of 2-naphthylamine as an impurity, there is a possible risk to man of bladder tumours, and for this reason antu is not now recommended.

5.4.7 *Arsenic trioxide* has a very long history as a rodenticide, but in many countries the sale of arsenicals is now severely restricted. Although most effective against rats (but not mice) arsenic trioxide is also highly toxic to man, other mammals and birds, and it is now no longer recommended.

5.4.8 *Phosphorus* (yellow) is highly toxic, and though available in many countries in a paste form, its sale in other countries is banned. It has been the cause of poisoning among children who have eaten the paste and since there are effective and safer alternatives, phosphorus is not recommended.

5.4.9 *Thallium sulphate* can penetrate the skin and accumulate in the body. Although highly toxic, it is slow-acting, and symptoms may not appear until some time after exposure. There is no unpleasant taste or smell, nor is there any irritation of the skin. Because of the hazards it presents to man and other non-target animals, its use in rodent control is not recommended.

5.5 *Safety precautions*

As a general rule, only personnel trained and experienced in the use and misuse of rodenticides should be permitted to apply poison baits and gassing powders. Most are poisonous to man if they are

inhaled and the wearing of dust masks is recommended during the preparation of poison baits. Since some of the poisons can penetrate the skin, plastic or rubber gloves should be worn when the baits are handled.

When a poisoning campaign is completed, as much as possible of the remaining uneaten bait should be collected and destroyed by burning or by deep burial. The same applies to rodent corpses. Finally, although rodent destruction will in the long term reduce the health hazards to man, the death of rodents can result in their flea parasites searching for alternative hosts, including man, and in plague foci there may be an increased health hazard following rodent destruction. In such areas it is essential to attack the flea population before or at the same time as the rodents.

BIBLIOGRAPHY

PART A — WATER SUPPLY AND WASTE DISPOSAL

M. Assar, *Guide to Sanitation in Natural Disasters*, WHO, Geneva, 1971.

Building Research Establishment, Overseas Building Notes No. 143, *Building in Earthquake Areas*, Garston, England, 1972 (clear and brief introduction to earthquake-resistent design).

R.H. Burns and Jim Howard, *Safe Drinking Water: Information and Practice when Treatment of Drinking Water Supplies is necessary*, Oxfam, Oxford, 1974, (useful short booklet on emergency water treatment).

A.M. Cairncross and R.G.A. Feachem, *Small Water Supplies*, Ross Institute Bulletin No. 10 (new edition), London, 1977.

Canada Department of National Health and Welfare, *Environmental Health in Disaster*, Ottawa, 1967.

E. Chamorro, "Participative planning as a process of reconstruction after the Managua earthquake", *Conference on the Managua Earthquake*, Earthquake Engineering Research Institute, San Francisco, 1973.

D.J. Dowrick, *Earthquake-resistant Design: A Manual for Engineers and Architects*, John Wiley, London, 1977, (has a chapter on services with a section on plumbing).

Earthquake Engineering Research Center, University of California, Berkeley, *Abstract Journal in Earthquake Engineering*, volume 1, 1972 to date.

R.G.A. Feachem, "Appropriate Sanitation", *New Scientist*, London, 8 January 1976; also R.G.A. Feachem, M. McGarry and D. Mara, *Water, Wastes and Health in Hot Countries*, John Wiley, London, 1977.

R.G.A. Feachem and A.M. Cairncross, *Small Excreta Disposal Systems*, Ross Institute Bulletin No. 8 (new edition), London, 1977.

H.K. Gupta and B.K. Rostogi, "Will another earthquake occur in Koyna?", *Nature*, London, 248, (March 15, 1974), pp. 215-16.

Jim Howard and James Fraser, "Water and Sanitation Appropriate for Disaster Situations", *Agua*, Pergamon Press, Oxford, No. 1, 1977, p. 59.

N.W. Hudson, *Soil Conservation*, Batsford, London, 1971.

International Association of Earthquake Engineering, *Earthquake Resistances Regulations — A World List*, Tokyo, 1973, (summarizes building regulations from many countries).

International Association of Earthquake Engineering, *International Journal of Earthquake Engineering and Structural Dynamics*, John Wiley, London.

Henry Lansford, "Prediction, the negative aspects", *Nature*, London, 265, January 6, 1977, p. 4; also "Don't rush them to predict earthquakes", *Nature*, London, 257, September 11, 1975, p. 77.

F.W. MacDonald and J.E. Trygg, *Environmental Health Practices in Disasters*, U S Department of Health, Education and Welfare, Washington D.C., 1968.

H.T. Mann, *Sanitation without Sewers — The Aqua Privy*, Building Research Establishment Overseas Building Notes No. 168, Garston, England, 1976.

Duncan Mara, *Sewage Treatment in Hot Climates*, John Wiley, London, 1976.

Nathan M. Newmark and Emilio Rosenbluth, *Fundamentals of Earthquake Engineering*, Prentice Hall, Engelwood Cliffs, New Jersey, 1971, (more theoretical than Okamoto's book).

Shunzo Okamoto, *Introduction to Earthquake Engineering*, University of Tokyo Press, 1973, (the best general book; good sections on services, buried pipes, dams, etc.).

Arnold Pacey (ed.), *Water for the Thousand Millions*, Pergamon Press, Oxford, 1977, (booklet reviewing issues).

C.B. Raleigh, "Investigation of seismic activity related to reservoirs", *Bulletin of the Association of Engineering Geology*, 9, 1972, pp. 177-83.

G.O. Schwab, R.K. Prevert, K.K. Barnes and T.W. Edminster, *Soil and Water Conservation Engineering*, John Wiley, New York, 2nd edition, 1966.

W.E. Strope, J.F. Denavey and J. Nehnevajsa, "The importance of preparatory measures in disaster evacuations", *Mass Emergencies*, vol. 2, March 1977.

P.H. Stern, *Opportunities for the Application of Intermediate Technology to the Development of Water Resources in Disaster Situations*, cyclostyled report, Intermediate Technology Group, London, 1977.

Alan J. Taylor, *Observations on the problems of providing emergency sanitation in Eastern India — May to December 1977*, cyclostyled report, Oxfam, Calcutta, January 1972.

U.K. Ministry of Defence, *Handbook of Army Health*, School of Army Health, Keogh Barracks, Ash Vale, Aldershot, 1976, (useful on water/excreta disposal at camp sites).

United Nations Educational, Scientific and Cultural Organization, *Iran: Dasht-e-Bavaz Earthquake 1968;* also *Iran: Ghiv Earthquake 1972;* (reports on consequences of earthquakes, UNESCO, Paris 1968 and 1972).

United Nations, Office of the Disaster Relief Co-ordinator, *Guidelines for Disaster Prevention*, 3 volumes, United Nations, Geneva, 1976.

United Nations, Office of the Disaster Relief Co-ordinator, *Disaster Prevention and Mitigation: A Compendium of Current Knowledge*, volumes 1 to 10.

United Nations, Office of the Disaster Relief Co-ordinator, *Natural Disasters and Vulnerability Analysis*, Report of Expert Group Meeting, Geneva, 1979.

U.S. Department of Health, Education and Welfare, *An Outline Guide covering Sanitation Aspects of Mass Evacuation*, Public Health Service Publication No. 498, Washington D.C., 1956.

E.G. Wagner and J.N. Lanoix, *Water Supply for Rural Areas and Small Communities*, World Health Organization, Monograph 42, Geneva, 1959.

E.G. Wagner and J.N. Lanoix, *Excreta Disposal for Rural Areas and Small Communities*, World Health Organization, Monograph 39, Geneva, 1958.

S.B. Watt and W.B. Wood, *Hand Dug Wells and their Construction*, Intermediate Technology Publications, London, 1977.

G.F. White, D.J. Bradley and Anne U. White, *Drawers of Water: Domestic Water Use in East Africa*, Chicago University Press, 1972, (an evaluation of social, economic and health aspects).

PART B — VECTOR CONTROL

Brown, A.W.A. and Pal, R. 1971. Insecticide resistance in arthropods. *World Health Organization, Monograph Series*, No. 38.

Gratz, N.G. 1973. A critical review of currently used single-dose rodenticides. *World Health Organization Bulletin* No. 48, pp. 469-477.

Greenberg, N.G. 1973. *Flies and disease.* II. *Biology and disease transmission.* Princeton University Press, New Jersey.

Kilpatrick, J.W., Tonn, R.J. and Sujarti Jatanasen. 1970. Evaluation of ultra-low-volume insecticide dispensing systems for use in single-engined aircraft and their effectiveness against *Aedes aegypti* populations in south-east Asia. *World Health Organization Bulletin*, 42, pp. 1-14.

Pollitzer, R. 1954. Plague. *World Health Organization Monograph Series*, No. 22.

Self, L. S., Ree, H.I., Lofgren, C.S., Shim, J.C., Chow, C.Y., Shin, H.K. and Kim, K.H. 1973. Aerial applications of ultra-low-volume insecticides to control the vector of Japanese encephalitis in Korea. *World Health Organization Bulletin*, No. 49, pp. 353-357.

World Health Organization. 1973. *Vector Control in International Health*, Geneva.

World Health Organization. 1973[a]. Technical guide for plague surveillance. *Weekly Epidemic Rec.* 48, pp. 149-160.

World Health Organization. 1980[b]. *Specifications for pesticides used in public health.* Geneva.

World Health Organization. 1973[c]. Safe use of pesticides. Twentieth Report of the WHO Expert Committee on Insecticides. *World Health Organization technical Report Series*, No. 513.

World Health Organization. 1974[a]. *Equipment for Vector Control.* Geneva.

World Health Organization. 1975[a]. Plague in 1974. *Weekly Epidemic Rec.*, 50, pp. 317-319.

World Health Organization, 1976[b]. Imported louse-borne relapsing fever. *Weekly Epidemic Rec.*, 51, pp. 269-270.

World Health Organization. 1976[c]. Resistance of vectors and reservoirs of disease to pesticides. Twenty-second Report of the WHO Expert Committee on Insecticides. *World Health Organization technical Report Series*, No. 585.

World Health Organization, 1977. Engineering aspects of vector control operations. First Report of the WHO Expert Committee on Vector Biology and Control. *World Health Organization technical Reports Series*, No. 603.