MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

World Health Organization
Eastern Mediterranean Regional Office
Centre for Environmental Health Activities

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 1 - Part 1
HEALTH, WATER AND SANITATION

The aims of this teaching module are to introduce the topic of health (social, physical and mental) and its interrelations with water, sanitation and housing provision in particular and social, financial and political structure in general.

The methods / topics used to acheive these aims are :

- relating mortality rates and life expectancies in less developed areas of the world to water and sanitation provision
- classification of diseases related to management of water and excreta
- consideration of transmission routes for specific diseases (and methods to interrupt these routes)
- investigation of engineering as well as medical, social and educational methods to control disease incidence and spread
- illustration of the need to integrate inputs from many disciplines to maximise health improvements

Water, Engineering
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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE ONE - PART ONE
HEALTH, WATER AND SANITATION

1. WATER SUPPLY AND EXCRETA DISPOSAL

Water use and supply

Water is life, without it humans die within days whereas they can survive for longer periods without food. Water has many uses other than for drinking, these include bathing, cooking, washing clothes and cooking utensils, industries (ranging from small cottage industries up to large scale national ones), power generation, agriculture (livestock and irrigation of crops) and leisure activities.

Yet many people in the world, and especially the developing countries, have water but still die because of its poor quality or the irregular quantity available to them. Many people, especially women and children, spend a large percentage of their day and of their daily calorie intake in fetching and carrying water for family as well as for crops and livestock. Often the water they fetch is polluted and the cause of disease, yet it is the only source available to them. Provision of water, particularly if it is clean, potable and reliable all year round, should lead to improvements in health. These may be linked to the quality and quantity of water available, and to the ways in which the time saved by having more accessible supplies is used. However, provision of clean water may reduce time and energy expended in water collection without having a marked affect on health if people are living in otherwise insanitary conditions and remain unaware of the health values of good personal and domestic hygiene practices.

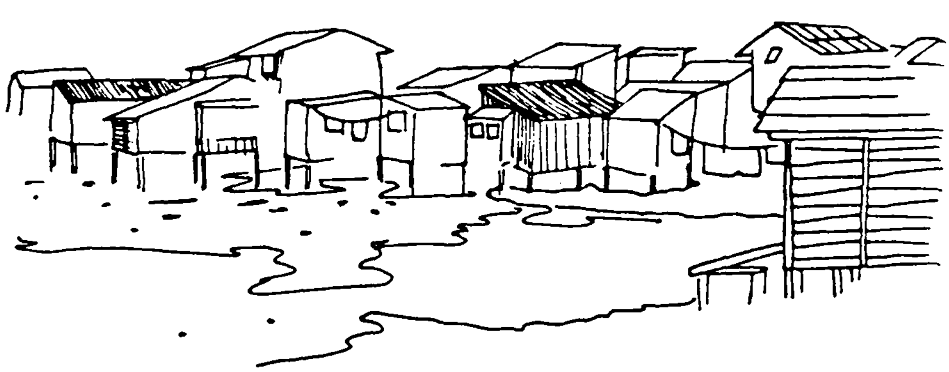

Figure 1. Improvements in health are less likely in over-crowded areas with poor facilities for water and waste disposal and poor drainage.

Sullage, solid waste and excreta disposal

Unhygienic excreta and sullage disposal, solid waste accumulation and poor domestic and personal hygiene practices contribute greatly to the spread of disease. The poor environmental conditions arising from these practices encourage vermin and insects to multiply and may lead to contamination of food and water supplies, either at source or in the home.

Water and sanitation coverage

Although the International Drinking Water Supply and Sanitation Decade (1981-1990) has resulted in increases in the numbers with regular access to safe drinking water, over half of the people in the developing world are still without all year round access to potable water, and the majority are without hygienic methods for excreta disposal. Communities in the rural areas are often the most populated yet the least well provided for in terms of water supply and excreta disposal services (see Table 1).

Table 1 - GLOBAL WATER AND SANITATION PROVISION (1983)

Region	Population		Water Supply		Sanitation	
	% urban	% rural	% urban	% rural	% urban	% rural
Africa	24	76	61	26	68	25
Americas	67	33	85	40	80	18
S.E. Asia	24	76	66	43	31	7
Mediterranean (eastern)	32	68	86	26	64	7
Western Pacific	40	60	70	45	80	57
Totals	34	66	74	39	52	14

Source:-WHO (1986)

2. HEALTH INDICATORS

Mortality and life expectancy

There is a tendency for countries with poor water supply and sanitation coverage to have high infant and child mortality rates and correspondingly lower life expectancy than an otherwise comparable country. The infant mortality rates (IMR) for individual countries vary considerably, from 7 deaths per 1000 in some developed countries to over 200 deaths per 1000 in a few developing countries. Similarly, life expectancy at birth can be over 70 years or less than 40 years. The differences between life expectancy at birth in industrial and developing countries is illustrated in figure 2. For example, at birth the chance surviving to the age of 40 years is about 98% in a developed industrial country but is only about 50% in a developing country.

The average values for the IMR (no. per 1000 births) in developed and developing countries are 19 and 93, respectively with corresponding values for life expectancy at birth (years) being 73 and 58. Among many factors contributing to these differences are the deaths, in developing countries, of over 5 million children every year, mainly as a result of diseases related to water and sanitation provision. At least half of these deaths could be prevented by simple low cost techniques such as immunisation and oral rehydration therapy plus the provision of village/rural-based workers trained in preventive and simple curative medicine. More lives would be saved and unnecessary suffering relieved by the use of appropriate or alternative technologies in both water and sanitation (solid waste, sullage and excreta disposal).

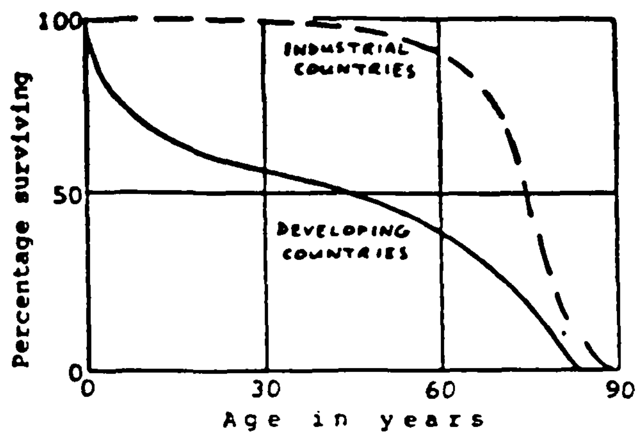

Figure 2.
Survival curves for industrialised and developing countries.

Knowledge of the diseases endemic in a particular area, as well as the local taboos and preferences related to water and excreta, is an important factor in the selection of water sources and sanitation provision. For instance the method of anal cleansing (water or solid material) must be considered when selecting the type of sanitation. Other factors, such as affordability and the ability to maintain and operate the systems chosen, are also very important factors to consider prior to final selection.

3. WATER, EXCRETA AND DISEASE

Infectious and non-infectious disease

The diseases caused or related to water and excreta can be non-infectious chemical-based, such as fluorosis from high fluoride levels or cyanosis (methaemoglobinaemia) associated with high nitrate levels, especially in infants under 6 months of age, and infectious such as cholera and others dependent on disease-causing organisms (pathogens). In developing countries the cases and deaths attributable to infectious diseases far outnumber those that are chemically-based (excluding malnutrition) so these will be looked at in more detail. Deaths from malnutrition, which may or may not be related to water availability, will be considered separately.

Disease-causing organisms (pathogens).

The types of pathogens and examples of the infections that they cause in humans are:

- viruses (influenza, measles and enteric disorders)
- bacteria (cholera, diarrhoeas, typhoid, and tuberculosis)
- protozoa (malaria and amoebic dysentery)
- fungi (ringworm and athlete's foot) and
- helminths (guinea worm infection, river blindness, schistsomiasis or bilharzia, roundworm and hookworm infections).

Most of these organisms or their eggs/larvae are microscopic, i.e. not visible to the naked eye, so water that looks clean may in fact contain a multitude of disease-causing organisms (pathogens). After release from the infected host, pathogens may be immediately infective or may need to undergo development before becoming infective. Pathogens also have different survival times outside of a host, depending on the pathogen, the temperature and the environment (water, sludge, soil etc.).

4. CLASSIFICATION OF WATER AND EXCRETA RELATED INFECTIONS

Water-related infections

The infectious diseases related to water are frequently divided into four major categories, depending on the way by which the pathogen is spread or transmitted. The main transmission routes/categories of infection are:

- water-borne* where the pathogen is present in drinking water,
- water-washed (water-scarce) where disease transmission may be reduced by increasing water availability for personal and domestic hygiene,
- water-based where pathogens must spend part of their life cycle in an aquatic intermediate host (or hosts) and
- water-related insect vector where the pathogen is carried by an insect that breeds/feeds/bites near to water.

* Although water-borne infections may be spread through water, the majority are spread by other routes, i.e. on hands, clothes, food, eating and drinking implements etc. As the faeces reach the mouth by one of these routes the transmission is often called faecal-oral. Water-washed infections come into this category when the source of pathogens is excreta, e.g. pinworm infection, however some water-wasded infections, such as scabies and trachoma, are not related to excreta but rather to personal hygiene and hence quantity of water rather than quality.

Excreta-related infections

Excreta-related infectious diseases are those that are dependent on disposal or treatment of both urine and faeces. For almost all of these diseases the pathogen is present in the excreta, the exceptions being insect vector diseases where the vector preferentially breeds/feeds/bites in or near 'dirty' water. Most of the transmission routes for these diseases are the same as those for water-related infections i.e. faecal-oral (water-borne and water-washed), water-based and water- and excreta-related insect vector; an additional transmission route for excreta-related diseases is:

- soil-based where the excreted organism remains (and may develop) in the soil and enters another host through the skin (hookworm infections).

Classification

Water and excreta related diseases can be classified, therefore, according to their transmission routes as faecal-oral, water-washed (other than faecal-oral), water-based, insect vector, and soil-based. Examples of diseases in these classes and environmental conditions/water and sanitation provisions that can affect disease incidence are shown in Table 2: non-infectious diseases related to water are also included.

Table 2. Classification of excreta- and water-related diseases.

Class	Basis and examples	Preventive measures
Water-borne	- pathogen in water - cholera, typhoid	- improve water quality - change the source
Water-scarce Water-washed	- dependent on personal and domestic hygiene	- improve water quantity - improve access - hygiene education
Water-based	- pathogen spends part of life cycle in aquatic host - penetrating, schistosomes - ingested, guinea worm	- reduce water contact - control aquatic host - excreta disposal - improve water quality
Insect vector	- insect breeds or bites in or near water - malaria, river blindness	- reduce breeding sites - reduce site access - use insecticides
Sanitation-based	- pathogen in soil (or in pit latrine contents)	- improve excreta disposal - control re-use of pit contents
Chemical-based	- chemical in water - fluorosis (fluoride) diarrhoeas (sulphate) methaemoglobinaemia (nitrates)	- remove chemical - prevent chemical entering water - change water source

5. COMMON WATER- AND EXCRETA-RELATED DISEASES AND THEIR CONTROL.

Outlines of some of the more common or high morbidity diseases and infections are given below and in figure 3.

Malaria

This disease is caused by protozoa (Plasmodium species) which are carried by anopheline mosquitoes. When taking a blood meal, before laying eggs, female mosquitoes may also take pathogens from an infected host or may inject pathogens into the host's bloodstream. The disease cycle is water-related as mosquito larvae live in and are dependent on surface water.

Removal of pools of surface water by good drainage helps to reduce the incidence of malaria by reducing the mosquito populations in the area. However if people leave containers (cans or bottles etc.) that can catch rain or dispose of waste water on to impervious surfaces then this will provide sites where mosquitoes can breed. It is essential, therefore, that engineers invoved in water supply schemes make adequate provision for drainage of spilled water, removal of water around standposts and wells and disposal of waste water, otherwise the health benefits of water provision could be outweighed by the increases in mosquito borne disease such as malaria.

Additional measures for controlling malaria, including use of larvicide and insecticide sprays and use of antimalarial prophylactics, need to be considered in areas with high malaria incidence and for large engineering projects, e.g. dam construction sites. Recent development of mosquitoes and malaria pathogens (Plasmodium species) resistant to these chemicals has led to dramatic increases in the disease and the need for more care in the use and selection of chemicals.

Helminths (Worms)

These may be visible to the naked eye but the eggs and larvae may not be or are only just visible.

Cleanliness of latrines, together with good personal hygiene, is of particularly importance in relation to intestinal worms. Dirty latrines, especially communal ones, contribute greatly to the spread of these infections. Organised cleaning of communal (and household) latrines and provision of smooth, impermeable and easily cleaned squatting slabs are essential. The importance of health education on matters such as hand washing after using the latrine and before preparing and serving food also needs to be stressed.

Ascariasis (Roundworm infection)

Roundworm eggs (Ascaris species) are very persistent, being able to live outside the human gut for over a year. The eggs are passed out in the stools. After development in moist ground (or pits) or in water they can infect hosts who swallow them. The larvae hatch in the gut and then pass into the lungs; they are coughed up and swallowed then develop into adults in the small intesine. Sludge from sewage works, septic tanks, and pit latrine contents less than one year old are, therefore, potential sources of roundworm infection.

Hookworm infections

Hookworms (Ancylostoma and Necator species) are a particular health hazard where open defaecation on damp ground is commonly practiced. The eggs, after being excreted, hatch and mature into infective larvae in damp earth. These larvae enter through the skin, usually on the feet, and move to the lungs, are coughed up and swallowed. The adult worms, about 1 cm long, attach themselves to the gut wall and suck blood a heavy load can lead to anaemia. The wearing of shoes is effective in preventing infection. It is, however, customary and often economically necessary for children to go barefoot in many tropical countries, especially in rual areas where open defaecation is common. The provision and use of clean latrines is the best way to reduce infection.

Bancroftian filariasis (Elephantiasis)

This very unpleasant and debilitating, but not fatal, disease is transmitted by culicine mosquitoes (Culex species), which prefer to breed in polluted water, such as that found in wet pit latrines. The organism causing the disease is a filarial nematode, Wuchereria bancrofti. This causes long-term chronic infection, usually associated with swelling, inflammation and blockage of the lymphatio system, especially in the legs.

Engineers must give paricular attention to the removal and disposal of sullage waer and to ensuring that surface drains are kept free of refuse and debris so that water is always free flowing. Any ponding in open drainage channels or at poorly located soakpits, for example, will increase the number of sites for mosquito breeding. Design and maintenance of latrines is another important consideration in the control of culecine mosquitoes.

Onchocerciasis (River Blindness)

In this filarial disease the parasitic worm, Onchocerca volvulus, is transmitted by blackfly (Simulium) bites. Heavy infestations affect the skin and eyes, with blindness being the most severe effect. The larvae or microfilariae of the worm live mainly under the skin causing nodule formation and thinning and loss of elasticity of the skin; some larvae may enter the eyes, initially causing inflammation and eye watering but, if untreated leading to permanent blindness.

The flies breed in fast flowing water: removal or reduction in such sites plus reduced access to them should help control the disease. As such sites are usually adjacent to fertile areas, control is difficult. Control of flies using insecticides is of limited use as the flies occur worlwide and without continued treatment are soon reintroduced. Screening people for infection followed by drug treatment is presently one of the better methods of control.

Dracunculiasis or Draconitis (Guinea-worm infection)

This parasitic worm (Dracunculus mediensis) is transmitted by a microscopic fresh water animal (Cyclops). The larvae are released by the female worm when an infected person stands in water eg when drawing water. The larvae are eaten by cyclops and develop into the infective stage in about 2 weeks. People drinking untreated water containing infected cyclops swallow them; the larvae are released in the stomach and move into the body. After approximately a year the worms are about 70 cms long and able to reproduce. Although not fatal, guinea-worm infection can be very painful and crippling; it is often accompanied by other infections as the blister caused by the adult releasing larvae allows pathogens, especially bacteria to enter the body.

This disease is one that could be controlled and possibly eradicated by improvements in water supply. Filtering out the cyclops through finely meshed material or through ash etc or disinfection of water supplies should prevent infection.

Schistosomiasis (Bilharzia)

Diseases caused by the presence of these parasitic worms (Schistosoma species) in the bloodstream or lymphatic system of the host are acquired through repeated contact with surface water contaminated with infected excreta. Transmission of the parasite is water-based, being dependent on aquatic or amphibian snails acting as intermediate hosts. Schistosoma eggs passed in the urine or faeces must enter water before they can develop into miricadia, the stage that enters snails. If the snail is of the type able to act as the intermediate host, the larvae develop and multiply, producing cercariae which are released by the snail. The cercariae seek out and penetrate the skin of a host, entering the bloodstream or lymphatic system. On reaching maturity the worms mate and eggs are released so that the cycle starts again. People can become infected therefore when they use the water for washing, laundering, fishing or swimming, or when they are in contact with water such as in irrigation channels and at water crossings.

Schistosomiasis affects over 200 million people in tropical and sub-tropical areas, with 500-600 million more running the risk of becoming infected. Those infected suffer weakness and lethargy, decreasing their inclination and ability to work. Heavy infestations, over prolonged periods are fatal.
The main controls of Schistosomiasis are:

- excreta disposal which prevents eggs entering water sources
- water supply which provides cercariae-free water
- snail control by reduction of snail habitats, discouraging snail growth and use of chemicals to kill snails (molluscicides)
- reduction of water contact
- drug treatment of those infected which reduces excretion of eggs
- health and hygiene education.

Diarrhoeal diseases

These diseases, including dysentery, cholera and typhoid, are very common and frequently a major cause of infant and child mortality in developing countries. Ample quantities of water for washing, good family hygiene and use of latrines by children as well as adults are all important in reducing morbidity of diarrhoeal disease. Careful handling and disposal of infants' excreta is esssential. Although often neglected, it should receive engineers' and health workers' attention. Hygiene education and Primary Health Care have vital roles to play in the reduction of diarrhoeal infections and deaths, especially where water supply and sanitation provision is concerned.

Deaths from diarrhoeas are usually from dehydration and the effects of mineral depletion from loss of body fluid. The introduction of simple oral rehydration therapy (ORT) that uses substances found in most homes (salt, sugar and water) has become increasingly common during the 1980's. Administration of ORS (oral rehydration solution) in the early stages of infection replaces lost fluid and minerals and can avoid the need for more expensive and less readily available intravenous rehdration. The composition and dosages for ORS are given in Figure 4. There are many variations on the solution including a rice-based soup but for all of them the balance between the salt and sugar in retained to ensure rehydration and remineralisation occur. The advantage of rice-based preparations is the potassium content which is absent if salt and sugar alone are used.

Malnutrition

Malnutrition covers a wide variety of non-infectious diseases that may be affected by the availability of water (for irrigation or livestock) and acute or cumulative effects of water and excreta related infections. The diseases range from deficiencies of specific vitamins (vitamin A deficiency causes impaired vision or blindness - Xerophthalmia) through protein and calorie deficiency to starvation. The three protein-energy malnutrition disorders are:-

Starvation - lack of all nutrients thus causing poor growth and development, weight loss, skin thinning/peeling and mental disorders.

Marasmus - insufficient protein and energy intake causing stunted growth and slow/poor development and weight loss. This occurs with early weaning and as a result of frequent diarrhoeal attacks.

Kwashiorkor - lack of dietary protein causing slow or poor growth, muscle wasting, swelling of face, hands and feet and general apathy. This often occurs on weaning onto a high carbohydrate diet (yam, cassava and plantain) after prolonged breast feeding.

The variety of disorders associated with malnutrition together with the harmful effects that malnutrition has on susceptibility to infections contribute to high IMRs. The more malnourished a child (or adult) is the more susceptible they become to infectious diseases, as loss of weight is often associated with infection then the child (or adult) becomes more malnourished and hence the vicious cycle of malnutrtion and infection continues. At its worst this leads to a downward spiral of ill health, culminating in death.

In addition, nutritional disorders often cause decreased rates of child growth and development (mental as well as physical). The effects may be quite mild or severe, the more severe they are in early childhood the more likely it is that they will be permanent.

The importance of nutritional deficiencies in relation to child health should not be disregarded and, whenever possible, provision to monitor child development should be included in water and sanitation programmes.

Monitoring child development

The regular weighing and recording of the age and weight of infants and children can give an early warning of nutritional disorders. This allows for measures to be taken to prevent serious and possibly permanent damage developing. For example, a village may select one or more of its people to be trained in child health care, which could include skills such as the organisation and management of growth charts and nutrition classes for the other villagers. Regular measurement of infant's weight and growth can highlight the effects of repeated diarrhoeal attacks or of acute infection (eg measles) on weight. A child of above average weight can lose 25% of body weight during one period of illness; this is serious in itself but the consequences for an already malnourished child would be much more serious and may even be fatal.

6. INTEGRATION IN WATER AND SANITATION PROGRAMMES

Health impacts of water and sanitation programmes

The inaccessibility or poor quality of water together with inadequate sanitation, including excreta and solid waste disposal, poor literacy and insufficient health awareness continues therefore to result in millions suffering from or dying as a result of water and excreta associated diseases. The impact of different measures on disease varies as is illustrated in table 3.

Table 3. Differential effects of improvements in water supply, excreta disposal and hygiene practices on infectious diseases.

		Improvements: - possible effects on disease if the only improvement made.		
Transmission mechanism	examples of infection	water supply	excreta disposal	personal hygiene
Faecal-oral	Cholera	high	low to medium	medium
	Diarrhoeas	medium	low to medium	medium
	Typhoid	high	low to medium	medium
	Roundworm	low	high	medium
Water-washed not faecal-oral	Scabies	high	very low	high
Water-based	Schistosomi- -asis	medium	medium	very low
Water-related insect-vector	Malaria	very low	medium	very low

The table only gives a guide to the potential impact of improvements if made alone. This rarely happens; most changes in either water or sanitation provision alter peoples health awareness. However the impact on health is normally increased when more than one improvement is made at the same time. For instance increasing water supply may not have a positive effect overall on health if people do not change their personal and dometic hygiene practices and if no provision is made for disposal of the extra water made available. Similarly, if schistosomiasis is the major disease in an area, then improving the water supply without providing adequate excreta disposal will not have much effect on people's health.

By providing health and hygiene education (and soap) at the same time as improving the water supply or sanitation facilities, the benefits to the health of the community is likely to be greater than that with water or sanitation changes alone.

To reduce successfully the incidence of these types of disease requires not only multidisciplinary approaches, from the areas of education, planning, technology, medicine, sociology and finance, but also action at many different levels, from the individual and family through the local and national communities to the international organisations. These different inputs lock together to form a whole system of factors affecting health as it relates to water supply and sanitation.

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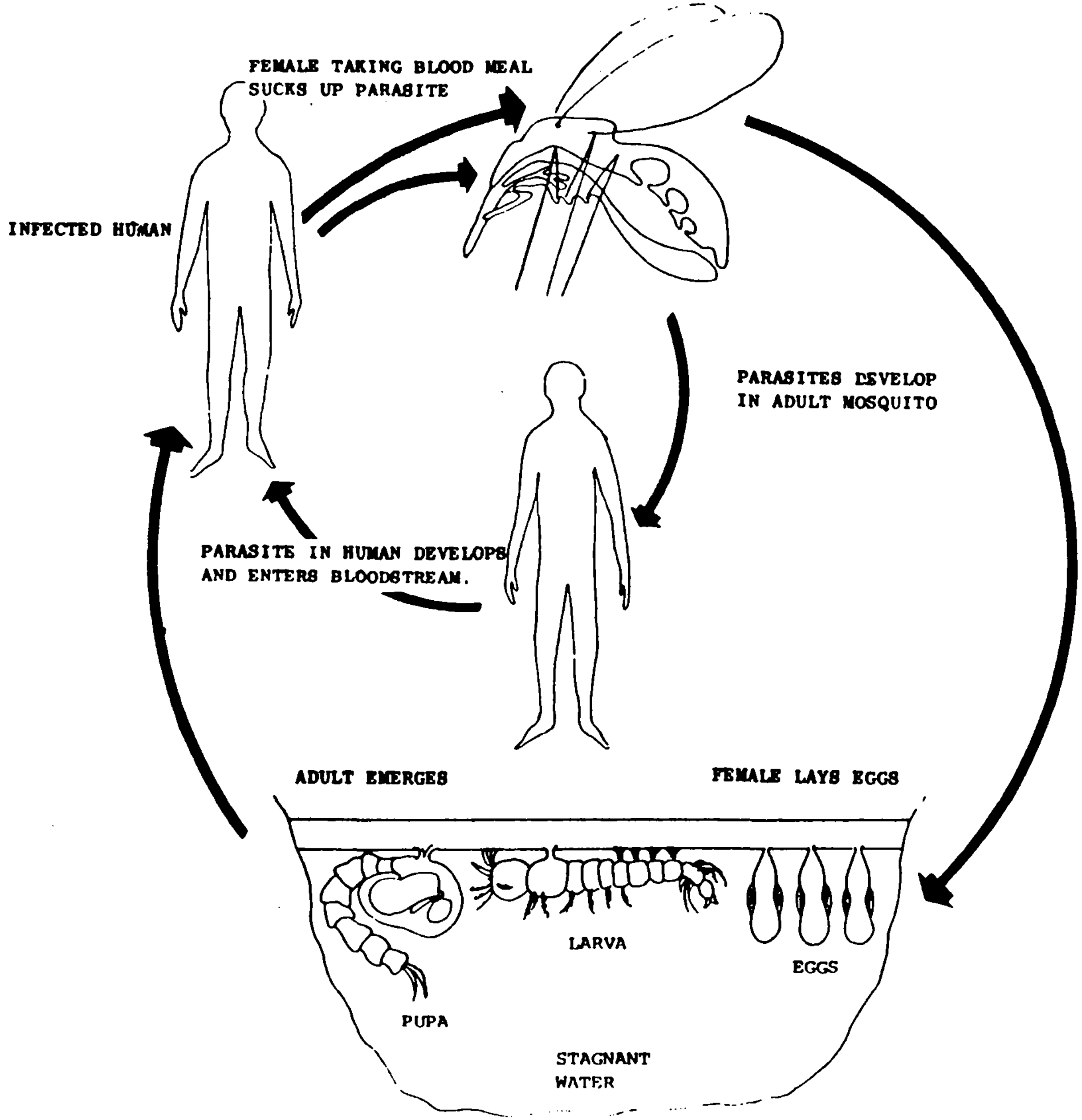
FIGURE 3 : TRANSMISSION CYCLES FOR WATER AND EXCRETA RELATED DISEASES

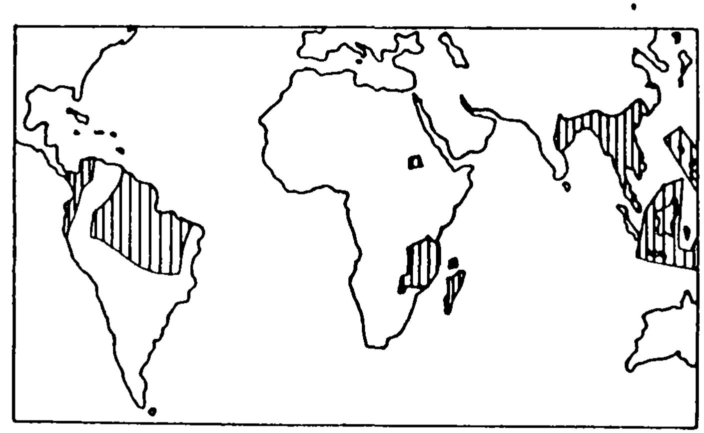
A. TRANSMISSION CYCLE FOR MALARIA (PLASMODIUM SP.)

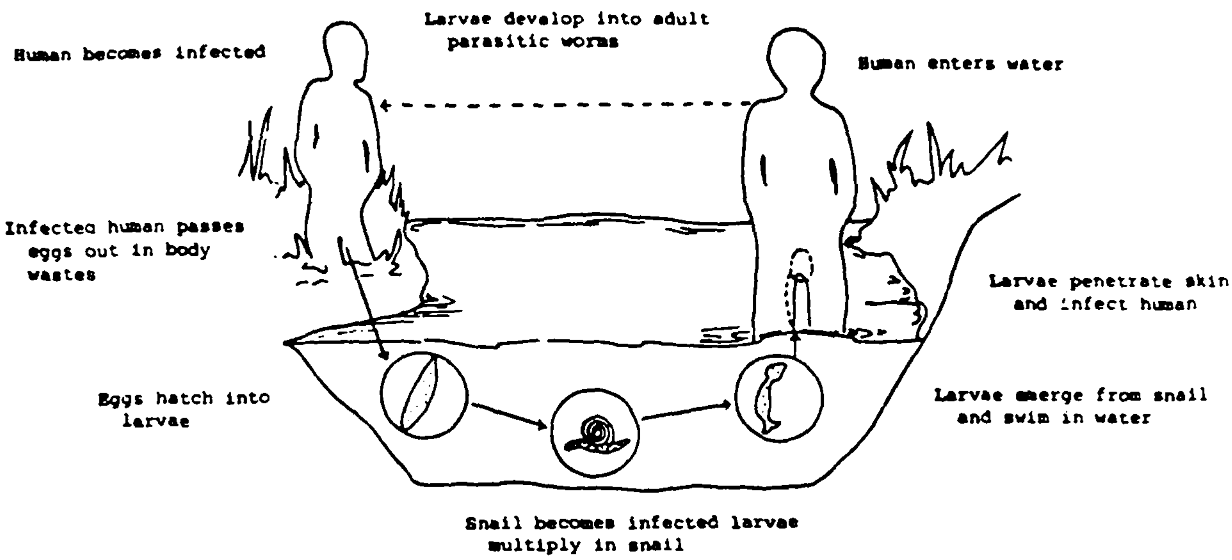


AREAS OF THE WORLD WHERE MALARIA IS A RISK

MALARIA

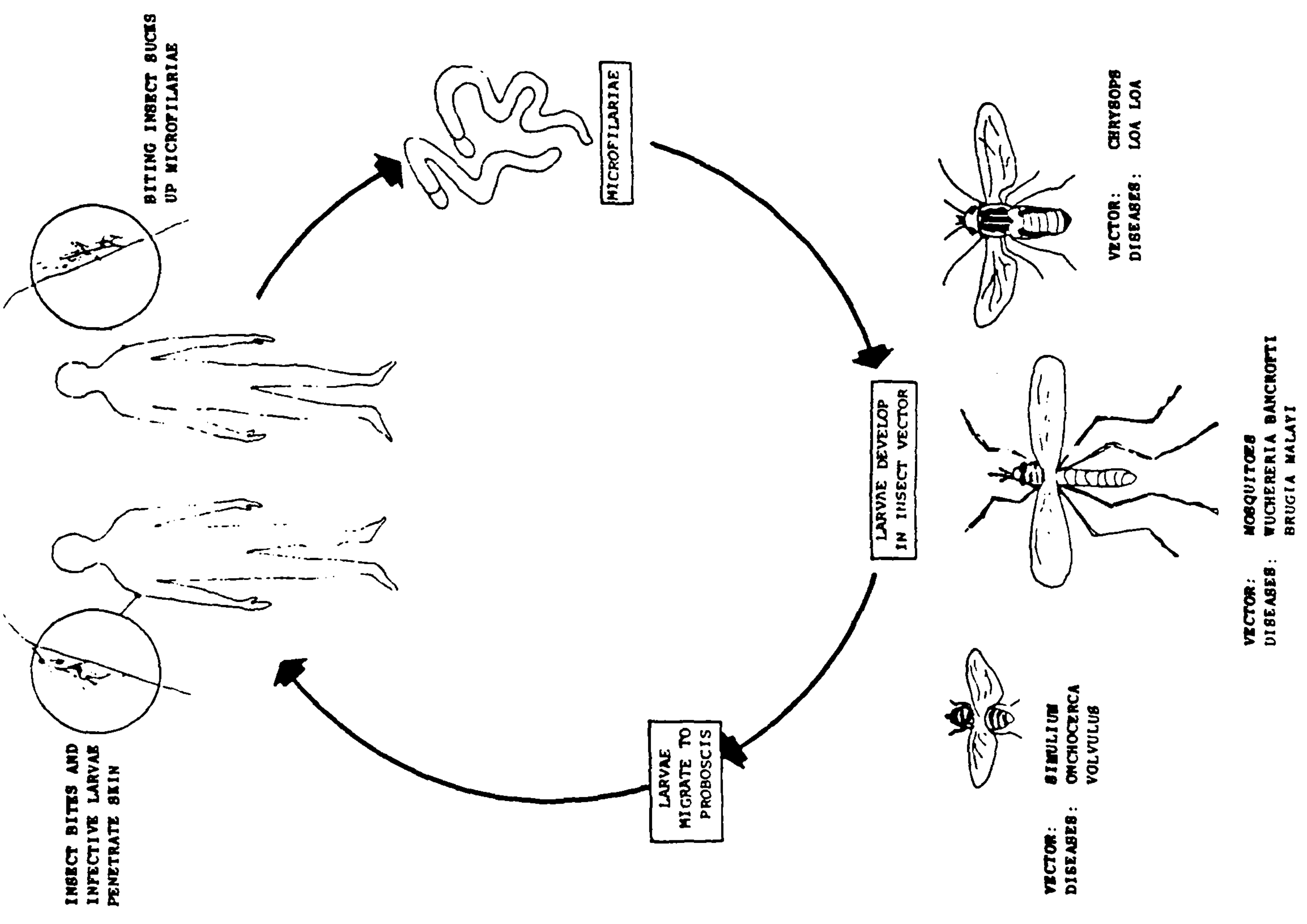
Parasite resistance to chloroquine





B. CYCLE OF TRANSMISSION FOR SCHISTOSMIASIS

C. TRANSMISSION CYCLES FOR FILARIAL DISEASES



CHILD-to-child PROGRAMME

SUGAR, SALT AND WATER FOR DIARRHOEA

Most people with diarrhoea can be safely treated at home.

What is diarrhoea?
When you have diarrhoea your stools are not normal. Your stools are different because they:

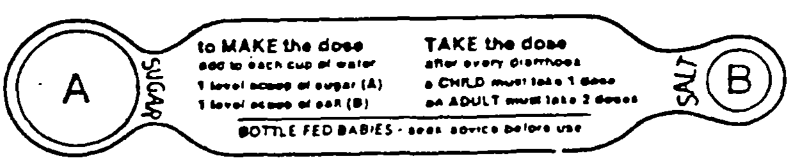
1. have more water
2. come more often
3. usually, they smell different.

When you have diarrhoea your body loses salt and water. This makes you ill.

Taking salt and water
Eating salt and drinking water will not help. Because of the diarrhoea, your body cannot take and use the salt.

Sugar
Sugar can help. Taking sugar and salt with water together helps your body use the salt.
How much sugar and how much salt is important.
You must use the correct amount.

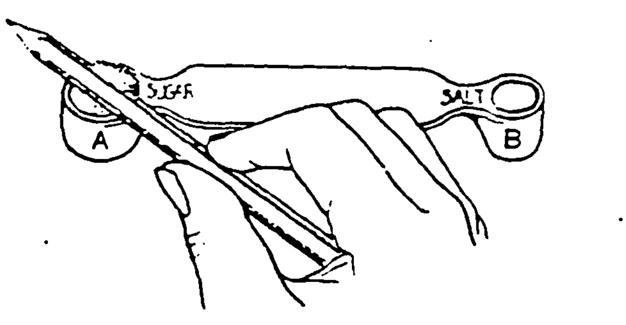
THE SPECIAL SPOON



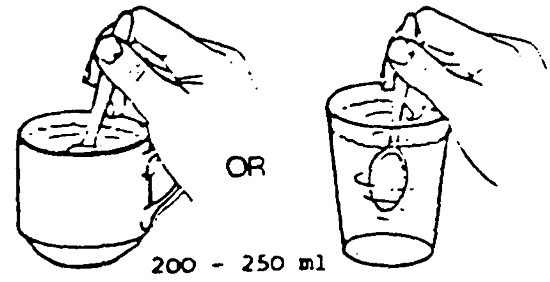
This is a picture of the spoon, it has two ends. The spoon is for measuring sugar and salt. The large end (A) is for sugar. The small end (B) is for salt.

Using the spoon

1. Fill the small end with salt.
2. Make the salt flat. Use a pencil, a knife or anything straight.



3. Put the salt into a cup or glass of water.
4. Fill the large end of the spoon with sugar.
5. Make the sugar flat.
6. Put the sugar into the glass of water with the salt.
7. Mix the water, sugar and salt. Mix until you cannot see the sugar and salt.



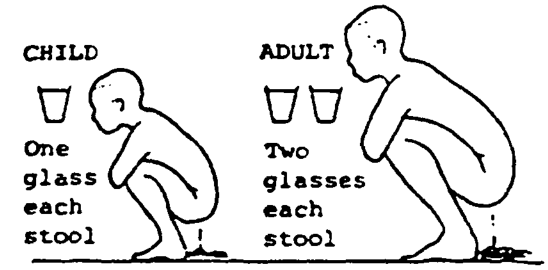
8. Taste before drinking. If it is *very* salty throw it away and start making the drink again.
It should not be more salty than tears.

IMPORTANT: *Too much salt is dangerous. Use only one small spoon of salt in one glass of water.*

Drinking the salt, sugar and water

Drink the salt, sugar and water slowly.
Take about 10 minutes to drink it.
Men and women must drink 2 *glasses* after *every* diarrhoea stool.
Children must drink 1 *glass* after *every* diarrhoea stool.

STOOL AND VOMIT VOLUME



Vomiting
After drinking, the child or adult may vomit the sugar, salt and water. Do not worry. Continue giving the drink. Give a little more to replace what has been vomited.

Get help when the person with diarrhoea:

1. is a very small baby;
2. has green in their vomit;
3. becomes more ill;
4. does not answer clearly when spoken to.

Continue using the salt, sugar and water until help comes.

IMPORTANT: *When the child with diarrhoea is bottle-fed (formula-fed) and not old enough to take food SEEK HELP*

Until help comes, give a glass of plain water instead of every second glass of salt and water.

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE ONE - PART ONE
HEALTH, WATER AND SANITATION
INSTRUCTOR'S NOTES

1. INTRODUCTION

The student's notes introduce health issues relating to water and sanitation provision. The aim is to promote such provisions as essential for health, rather than regarding provision of water and sanitation only as methods to reduce disease.

Health in this context involves social, physical and mental wellbeing. In many countries greater emphasis on infectious is dictated by their high incidence, much of which is attributable to water, sanitation, hygiene and housing conditions and hence poverty. Diseases such as measles and respiratory infections, responsible forup to 30% of child deaths in some countries, are not included as they are not related directly to water and sanitation. The impact of malnutrition on health , however, is included as food availability (variety and amount) is often directly related to provision of sufficient water for agriculture and to sanitation and hygiene practices.

Health should be related to:
- housing (design, ventilation, light, room size and number of occupants).
- personal hygiene (washing of skin and hair, laundering clothes)
- food hygiene (disposal of wastes, preventing access by flies etc.).
- waste disposal (collection, site or method of disposal).
- water supply (well/standpost/home connexions, storage in the home, protection of source and supply points.
- excreta disposal (latrines, design, siting; treatment methods.
- maintenance and operation of all facilities.
- health education/health awareness.

3. ADDITIONAL INFORMATION

The slides that accompany these notes can be used to illustrate points in the student's text. Not all slides will be appropriate for every country or for all groups of students. It may be preferred to add or substitute slides with those available locally. In addition, not all health issues covered in the notes are universally applicable. Emphasis should be given to local or national issues; these could be expanded as suitable for the area or student group.

Additional material in the form of slides and films/videos can be obtained from the sources listed at the end of this text or could be put together from local resources.

For personnel from the health sector more detailed information on disease symptoms and treatments and on health care systems would be necessary. The TALC slide sets cover a wide range of appropriate topics.

2. ACCOMPANYING SLIDES

1. Scene with water.

This scene looks idyllic but the lake water contains many pathogens, especially schistosomes and enteric pathogens. It also provides good breeding sites for disease-carrying insects.

2. A poor water source.

There are many pathogens in the water in this drainage channel. The dumping of solid waste into the water increases the food available to pathogens and to insects. The reasons that people use such unpotable water include easy access, proximity (relative to potable water source) and ignorance of the dangers.

3. Carrying water.

It is usually women's work to fetch and carry water for the family. Apart from the physical stress involved, or probably because of it, the volume of water carried decreases greatly as the distance between the source and the family dwelling increases.

4. Poor environmental conditions.

In many areas, but particularly in urban/periurban areas poor drainage, solid waste collection, sanitation provision and over-crowding lead to poor health. Water becomes contaminated and flies and rats etc. increase, leading to further deteriorations in health.

5. Uses and misuses of water.

Some of the many uses of water are illustrated:- bathing, washing, excreting, fishing, solid waste disposal and leisure activites.

6. Survival curves.

This is the same as figure 2 in the student's notes.

7. Organisms in water.

The range of organisms in water, from microoganisms to animals, is illustrated (enlarged). An indication of water quality can be deduced from the types of aquatic organisms present.

8. Transmission routes for water- and excreta-related diseases.

9. Water-washed disease:- scabies.

10. Places where malaria is a risk.

11. Faecal-oral disease:- roundworm infection.

12. Insect-related disease:- Bancroftian filariasis.

13. Water-based disease:- guineaworm infection (ingested)

14. Transmission cycle for guinea worm infection.

15. Water-based disease:- Schistosomiasis (penetrating).

Areas where the disease occurs. The different types of schistosomes are included.

16. Faecal-oral diseases:- diarrhoeas.

Children are more likely to have repeat attacks which lead to malnutrition. Children who are malnourished are even more susceptible to infection. Dehydration is a major cause of deaths in diarrhoeas.

17. Dehydration - the skin pinch test.

In healthy children the skin rapidly returns to normal after pinching whereas in dehydration the return to normal is much slower as the skin loses its elasticity. (Loss of skin elasticity also occurs with ageing).

18. Dehydration - signs and symptoms.

19. Protein malnourishment.

The peeling skin is a result of insufficient dietary protein; the skin thins, being made of protein, and is easily damaged.

20. Infant growth chart 1.

This chart shows early weight gain, whilst on breast milk, is lost by repeated infection on being weaned.

21. Infant growth chart 2.

This shows the dramatic effect of measles on weight in a chlid that had shown high weight gain in its first 18 months. The loss of 26% of body weight in a malnourished child is often fatal: as this child was wellnourished before the measles attack it was able to recover.

22. Water kiosk.

Provision of water points close to dwellings is of benefit to health, however the design at this site has not allowed for drainage. The standing water around the kiosk is a possible health hazard.

23. Refuse collection 1.

This slide shows good practice in a market area. The rubbish is collected in skips which are empied frequently. The presence of an attendant ensures that no spillage occurs.

24. Refuse collection 2.

Household collection of solid waste may be carried out by private enterprise.
Note the bottom line on the advertising board:-

"HEALTH IS WEALTH - KEEP YOUR COMPOUND CLEAN"

4. SOURCES FOR ADDITIONAL MATERIALS.

Slides

Teaching Aids at Low Cost (TALC)
PO Box 49
ST. ALBANS
Hertfordshire
AL1 4AX, UK.

A list of material available from TALC (including books) is attached.

The World Bank
1818 H Street
N.W. WASHINGTON D.C.
20433, USA.

A series of Training Modules (Information and Training for Low-cost Water Supply and Sanitation) available as tape-slide sets include a module on health and hygiene in relation to water and sanitation.

Films/video tapes

Concorde Films Council Ltd.
201 Felixstone Road
IPSWICH
Suffolk, IP3 9BJ, UK.

IRDC
Box/BP 8500
OTTAWA
Canada, K1G 3HG.

'Prescription for health' and 'A handle on health' are two good examples of films available. They may be obtainable (on free loan) from the local Canadian Embassy.

Shell Film Unit
PAC/11, Group Public Affairs
Shell Centre
LONDON SE1 7NA, UK.

'Malaria' and 'The threat in the water' are two examples.

The World Bank
1818 H Street
N.W. WASHINGTON D.C.
20433, USA.

Three films are included in the 'Information and training for low-cost water supply and sanitation' package.

UNICEF Geneva Office
Information Division
Palais des Nations
CH 1211
GENEVA 10
Switzerland.
or via the regional offices or UNICEF commitees.

'The good news is water' is an example.

WHO
CH 1211
GENEVA 27
Switzerland.

5. CONCLUSION.

By using this module, instructors should be able to give an overview of health aspects of water supply and sanitation, covering mainly the infectious diseases related to the provision of these facilities. The prevention or control of disease, or the promotion of health, by adopting measures to interrupt the transmission cycle of pathogens (or their vectors) through water supply and sanitation provision, in association with health education and other forms of community development.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 1 - Part 2
HEALTH, WATER AND SANITATION

This module sets out to explain the importance of maintaining the bacteriological quality of drinking water by regular testing and sanitary surveillance.

Testing procedures using the membrane filtration and MPN multiple tube techniques for faecal indicator organisms and chlorine testing are discussed. Sampling procedures are outlined and the chemical and physical parameters of water quality are briefly summarized.

Water, Engineering
and Development Centre
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World Health Organisation
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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE ONE - PART TWO

HEALTH, WATER AND SANITATION

1. WATER QUALITY

The relationship between water quality and health has been described in the first section of this module and more details can be found in 'Guidelines for Drinking-Water Quality, Volumes 1 - 3' (WHO, Geneva, 1983-85)

The basic quality requirement for drinking-water is that it should:

1) be free from pathogenic (disease-causing) organisms;
2) contain no compounds that have an adverse effect, acute or in the long term, on human health;
3) be fairly clear (ie, low turbidity, little colour);
4) not be saline (salty);
5) contain no compounds that cause an offensive taste or smell;
6) not cause corrosion or encrustation of the water supply system, nor stain clothes washed in it or food cooked in it.

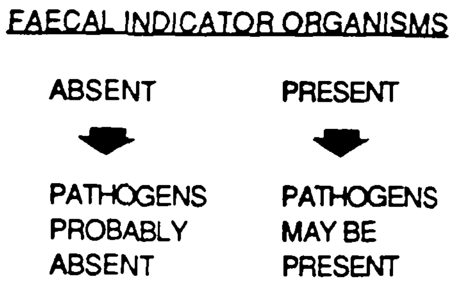
2. SANITARY INSPECTIONS

In many rural areas the supplies will not be regularly tested by a laboratory for bacteriological quality, but an alert operator can often spot potential pollution problems by carrying out regular sanitary surveillance. Sanitary inspections are among the essential elements of an effective drinking-water quality-surveillance and control program. If possible, samples for bacteriological and chemical analysis can be taken during the inspection, especially after any rectification work has been carried out. For details of how to carry out sanitary inspections the 'Guidelines for Drinking-Water Quality, Volume Three (WHO, 1985) or 'Surveillance of Drinking-Water Quality (WHO, 1976) should be consulted. An example of a checklist is given in Appendix 1. After checking this and the references, operators can draw up their own checklist for a particular supply and distribution system.

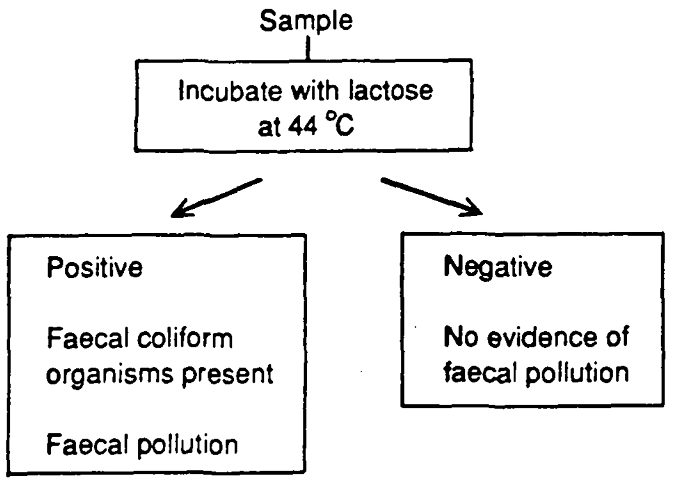
3. MICROBIOLOGICAL ASPECTS OF WATER QUALITY

By far the most important parameter of water quality is its freedom from pathogenic organisms. At present it is not possible to identify pathogens in drinking-water quickly. The pathogens may only be present occasionally in the water, although pollution by faecal matter may be occurring continuously.

Normal bacteriological procedures to test for pathogens in water determine if faecal pollution has occurred. If faecal bacteria are present, then pathogens may be there too.



The most useful indicator organisms for surveillance of bacteriological water quality are the faecal coliform group of organisms.



Faecal coliform organism determination

The number of organisms excreted into the environment each day by every living creature is enormous. Table 1 illustrates some typical figures for some mammals.

	All bacteria	Viruses(if infected)	Vibrio Cholerae (if infected)
HUMANS	20-100 million	1 million	1million

FAECAL INDICATOR ORGANISMS

	FAECAL COLIFORM ORGANISMS	FAECAL STREPTOCOCCI
HUMANS	13 million	3 million
SHEEP	16 million	38 million
CATTLE	0.23 million	1.3 million
PIGS	3.3 million	84 million

TABLE 1: Typical average number of organisms excreted each day per gram*

* Note units. Mass of excreta for man varies 500-1500 gram, depending on diet; cattle 24kg etc.

What is the total number of faecal coliform organisms you will excrete today?

With good techniques it is possible to detect and measure the number of faecal indicator organisms in drinking-water, even if they are there in small numbers. It is also possible to detect their absence.

4. DETECTION AND MEASUREMENT OF FAECAL INDICATOR ORGANISMS

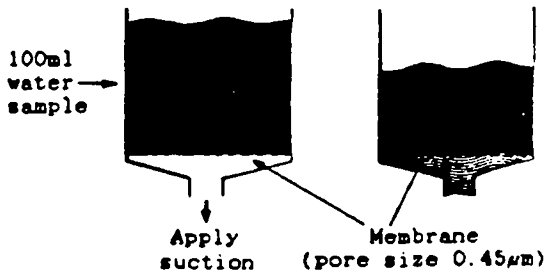
There are two main methods used to detect and measure indicator bacteria in water:

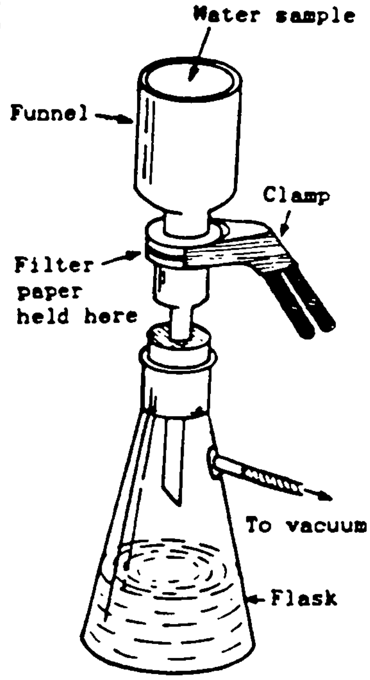
1) the membrane filtration method; and
2) the most probable number (MPN) multiple tube method.

a) Membrane filtration

The most useful method for testing faecal indicator bacteria in drinking water is by membrane filtration. This procedure involves filtering a measured volume of sample (100ml), or an appropriate dilution of it, through a membrane filter which has a pore size of 0.45μm. Micro-organisms are retained on the surface of the filter. It is then placed on an absorbent pad soaked in a suitable selective growth medium (containing lactose) in a glass, plastic or metal petri dish and incubated at 44^{o}C for faecal coliform detection. Any bacteria able to grow will multiply to form visible colonies on the membrane filter surface. The number of colonies counted is expressed in terms of the number present per 100ml of original undiluted sample.

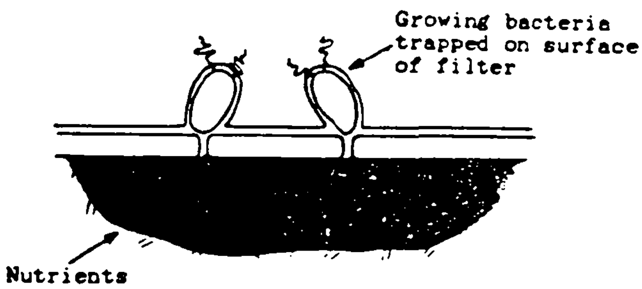
The determination of microbiological water quality by membrane filtration

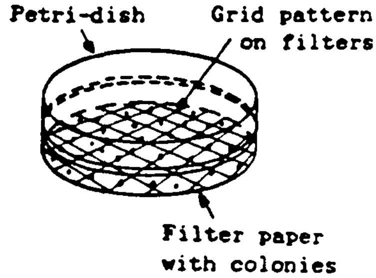




Membrane filtration assembly

1. Filter water sample
2. Supply the bacteria with nutrients





3. Incubate at 44°C in an incubator.
4. They grow and individual colonies can be counted after 24 hours.
5. Assume each colony arose from a single bacterium. Calculate number of colonies per 100ml.

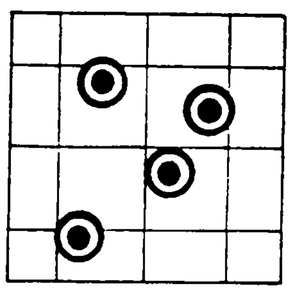


Figure 1. Membrane filtration

b) Most probable number (MPN) multiple tube method

The multiple tube method involves adding measured volumes of sample to sets of sterile tubes or bottles holding a suitable liquid culture medium (containing lactose). Faecal coliform organisms produce acid and gas when incubated at 44°C. The gas production is detected by its appearance in a Durham Tube inserted into the tube or bottle.

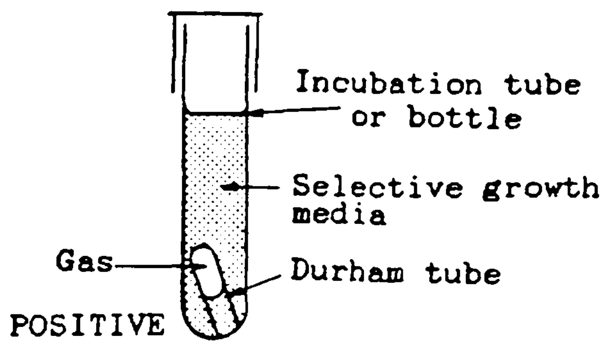


Figure 2. Gas production detected by Durham tube

Acid is detected using various pH indicators. The number of tubes showing positive reactions is recorded at the end of the incubation period and an estimate of the most probable number (MPN) of organisms present in the original sample obtained from statistical tables. A range of different dilutions should be used to ensure that both positive and negative reactions are obtained.

The multiple tube fermentation or MPN technique is applicable to waters of all types and especially those with high turbidity. The equipment required is relatively cheap and simple (positive reactions being easy to read).

One of the simplest procedures using 5 x 10ml of sample is described in detail by Mara in 'Environmental Health Engineering in the Tropics', by Cairncross and Feachem, published by Wiley, London.

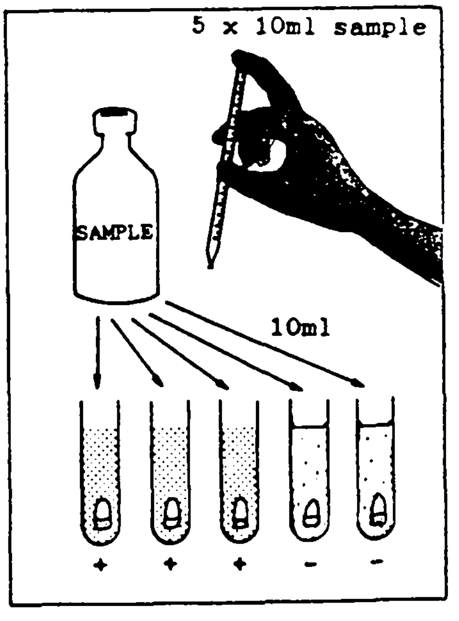


Figure 3. Multiple tube method

c) Incubators

The most difficult problems in operating bacteriological procedures in developing countries occur with incubators. Incubation at temperatures of 44°C±0.5°C for up to 48 hours is difficult if the power supply fluctuates or is subject to interruptions. Battery powered incubators have been developed in the past few years particularly for use with the membrane filtration technique. It is important to keep the batteries in a charged condition and it is best if the incubator can be run from batteries which are connected through a charger to a mains supply or generator. For field use the incubators can be connected to car or truck electrical system, but it is important to have a spare battery, otherwise the vehicle could be left with a flat battery.

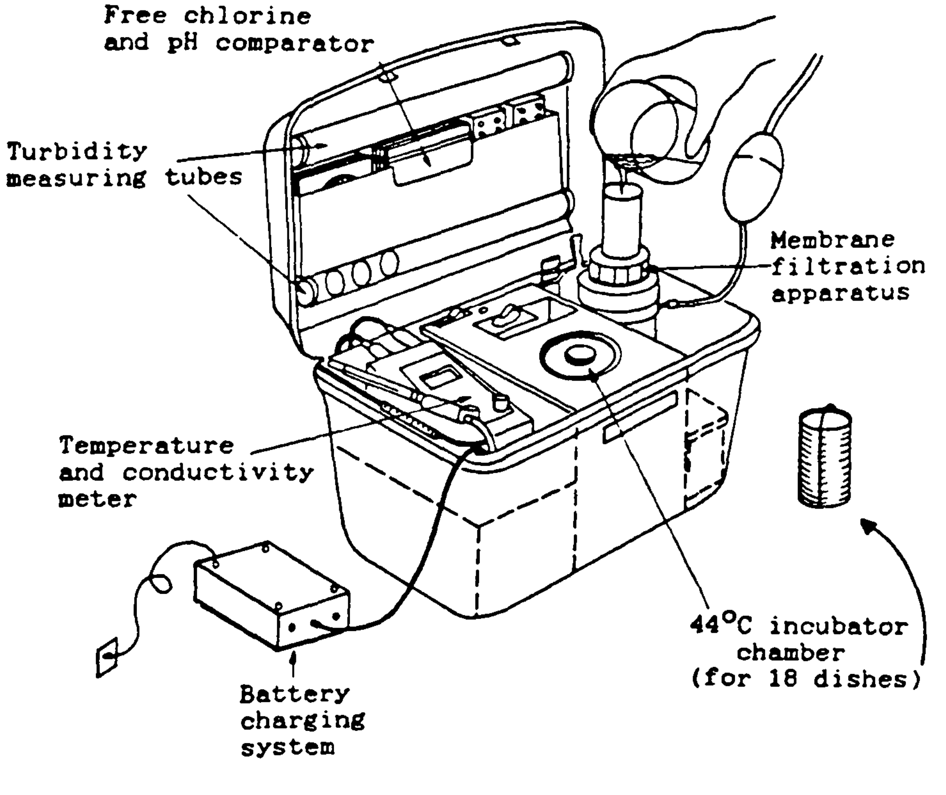


Figure 4. The DelAgua Portable Water Testing Kit Components

d) Autoclaves

Autoclaves are another essential part of a bacteriologist's equipment. In the absence of a commercial autoclave, ordinary domestic pressure cookers are suitable for sterilizing sample bottles, screw-capped bottles, measuring cylinders, pipettes, petri dishes, tweezers, dilution and rinsing fluids, and membrane filtration apparatus prior to use. They should also be used to destroy bacteria developed after the testing procedures have been carried out.

e) <u>Sampling for bacteriological testing</u>

The sampling procedures are as important as the analysis. Samples for bacteriological analysis should only be collected in sterile bottles. Hands should always be washed before and after sampling and analysing.

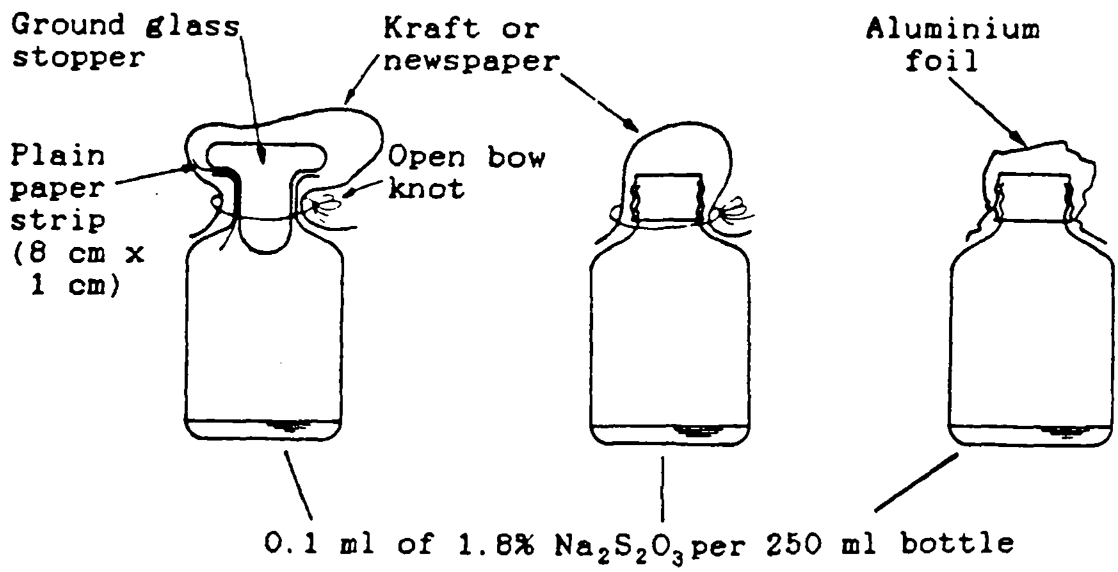


Figure 5. Sterile bottles and protected tops

Sterile bottles are prepared by using glass bottles of at least 200ml capacity with a ground-glass stopper or rubber-lined aluminium or plastic screw-cap. They should be cleaned and washed thoroughly, then rinsed with distilled or de-ionised water.

If the water to be examined is likely to contain chlorine or other disinfectant, then 0.1ml of 1.8% sodium thiosulphate ($Na_2S_2O_35H_2O$) per 100ml of bottle capacity should be added to neutralise any residual disinfectant.

For ground-glass stoppered bottles only a small strip of clean paper should be placed in the neck of the bottle with enough protruding to allow its easy removal prior to sampling.

A piece of paper, preferably Kraft paper or aluminium foil (although any thick paper, even newspaper, may be used) should be fastened over the top and neck of the bottle and tied with string. It should be fastened with an open bow knot which can be released by a single pull.

Screw-tops should only be loosely fastened prior to sterilizing and then only tightened when cooled following sterilization.

The sample bottles can then be sterilized (all micro-organisms on the glass or in the bottle killed) by:

1) autoclaving in a pressure cooker or autoclave for 20 minutes at 15 psi steam pressure at 122°C; or

2) heating in a dry oven at 170°C for two hours.

After cooling and tightening the tops, sterile bottles can be stored for about one week in the refrigerator. It is useful to have a few ready just in case an urgent sample needs to be taken. It is also recommended that samplers take extra sample bottles with them in case some bottles are contaminated or extra samples need to be collected on site.

5. SAMPLING PROCEDURES FOR MICROBIOLOGICAL ANALYSIS

In collecting samples for bacteriological analysis, the following requirements must be satisfied:

a) sampling should be properly planned and, ideally, carried out with sufficient frequency to enable any temporal (seasonal) variations in the quality of the water to be detected;

b) samples should be collected, stored, and dispatched in suitable sterilized bottles;

c) the volume of water collected should be large enough to permit an accurate analysis;

d) the sampling points in the water-supply system should be selected such that the samples obtained are as representative as possible;

e) great care should be taken during sampling to prevent contamination of the sample being collected;

f) in order to prevent any significant change in the composition of a collected sample prior to its analysis, it is important to ensure that it is collected properly, and dispatched as soon as possible;

g) the sample details should be adequately described and the sample bottle properly labelled to avoid errors.

Although it may seem a simple matter to collect a sample of water, errors can occur, and special care is therefore needed. Problems can also arise independently of the sampling technique used. Unless valid samples are collected, the careful work that is carried out in the subsequent analysis could be a complete waste of time.

Water can be divided into three basic types for the purposes of sampling:

1) water from a tap in a distribution system, or from a fixed hand pump, etc;

2) water from a watercourse, or reservoir (river, lake, tank);

3) water from a dug well, etc, where sampling is more difficult than from an open water source.

6. CHEMICAL ASPECTS OF WATER QUALITY

a) Free Residual Chlorine

As mentioned in Module Six on SIMPLE DISINFECTION, chlorine in one form or another is the main disinfecting agent employed in most countries. When chlorination is carried out the most important parameter to be determined is the free residual chlorine concentration. If free residual chlorine is found in a sample it may be assumed that, provided sufficient contact time between chlorine and the water has been allowed, the water will be bacteriologically safe at the point and time the sample is taken. This is no guarantee that contamination has not occurred elsewhere in the distribution system. The presence of free residual chlorine therefore needs to be checked in all parts of the system to ensure that safe water is being distributed.

We can consider the presence of free residual chlorine to be a negative bacteria test. The test has the major advantages of being quick (two minutes) and cheap.

Two reagents are now used to detect free residual chlorine:

1) DPD (Diethyl-para-phenylene diamine);

2) Starch-potassium iodide.

Another reagent called ortho-tolidine was used, but it did not react very well and has been found to cause cancer of the bladder. DPD has been found to be much safer and more accurate. In the presence of free residual chlorine, DPD reacts to give a pink colour.

The test is easily carried out. When taking bacteriological samples from a treated water system it is normal to test for free chlorine at the test site.

If samples are from raw water which has not received any chlorination, do not test for free chlorine. It does not occur naturally.

7. CHEMICAL QUALITY AND HEALTH

Chemical contaminants are not normally associated with acute effects and thus are in a lower priority category than microbial contaminants, the effects of which can be immediate and massive. Consideration of chemical contamination of drinking-water is almost irrelevant where water-borne infections and parasitic diseases are rampant in a society.

Chemical contamination of drinking-water may be due to natural geological sources (eg, fluoride, selenium, total dissolved solids), use of agricultural chemicals (pesticides and nitrates), treatment and distribution of water (chloroform, lead, copper and aluminium) and industrial wastes such as those from textile or paper mills, tanneries, or the petroleum industry (eg, chromium, phenols, trichloroethylene). [Gorchev, 1986]

a) Fluoride and dental health

Fluoride levels of about 1 mg/litre provide substantial protection against dental caries, but the margin between the beneficial and toxic effects of fluoride is small. In areas where geological rifting is occurring or groundwater is drawn from igneous rocks, then high fluoride values may appear. Higher concentrations and increases in water consumption may lead to adverse health effects ranging from mottling of teeth to crippling fluorosis.

b) Total Dissolved Solids (TDS)

Very low TDS water (less than 30 mg/litre) such as those from distillation or desalinated supplies can cause gastric disorders and also tend to dissolve metals from the distribution systems. These waters should have calcium and magnesium salts added to stop their corrosive action.

Waters with a TDS above 1200 mg/litre can be objected to on taste grounds. However, there is no evidence to say that the water is unhealthy.

c. Pesticides

Pesticides are widely used in agriculture and public health. In addition to their direct toxic effects on humans, numerous fish kills have been caused by industrial and agricultural runoffs or by direct application of pesticides to water bodies.

The levels of pesticides are often very low: the guideline level for DDT is I Mg/litre, which indicates how toxic these chemicals can be. The 'Guidelines for Drinking-Water Quality, Volume Two', has many more details of individual pesticide hazard levels.

d. Petroleum products

Industrial wastes from the petroleum industry or even spillages from tankers and petrol stations can easily pollute surface and groundwater.

e. Nitrate and nitrite

Excessive levels of nitrate and especially nitrite in drinking water can cause methaemoglobinaemia (blue-baby) in infants. The problem affects bottle-fed infants and is not of any concern where infants are breast-fed. The high levels of nitrate may serve as a warning indicator of pollution from unsewered sanitation or fertilizer leaching.

8. PHYSICAL PARAMETERS

a. Turbidity

Particles in water are aesthetically objectionable and can serve as a location and shield for pathogenic micro-organisms. Additionally, many toxic chemicals such as pesticides and heavy metals are adsorbed by suspended particles.

Disinfection cannot be totally effective unless the water is free of particles. The disinfectant is unable to kill the target organisms because of a physical barrier or chemical reactions with the particles themselves. Regrowth of organisms deep inside the particles can easily occur when the disinfectant has passed.

As a result, consumption of turbid water may be a serious health risk.

9. CONCLUSIONS

1. The most important water quality parameter is the freedom from pathogenic micro-organisms contained in faecal material.

2. Regular sanitary inspection and water analyses are both important in maintaining safe drinking-water supplies.

3. A clear water is potentially much safer to drink than a turbid water and allows chlorination to be effective.

4. In disinfected water always check for free chlorine in all parts of the system.

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE ONE - INSTRUCTOR'S NOTES

HEALTH, WATER AND SANITATION

PART TWO

1. INTRODUCTION

The module will be taught as a lecture with demonstrations. Class participation is to be encouraged. The lecture should be followed by practical exercises in which the students take water samples and test for micro-organisms and residual chlorine. These tests are described in the Student's Notes and in Appendix Four. Visits to typical sites to sample water, and sanitary inspections will help to consodiate what is taught in the lecture.

2. TEACHING THE MODULE

Slides may accompany the module but are not essential.

If possible, local resources in terms of a laboratory, water testing kits and chlorine testing kits should be utilised.

Demonstrations should be carried out in class.

The students should be asked to carry out the following exercises:

1. compile their own sanitary inspection survey sheets and conduct a survey;

2. test for free chlorine using DPD or starch / KI

3. sample at different types of site.

3. EQUIPMENT REQUIRED

1. Slides of typical faecal indicator bacteria and sequence of membrane filtration (if available).
2. 100 DPD No. 1 quick dissolving tablets. A little bleaching powder to ensure positive reaction.
3. Some sealed petri dishes showing faecal coliform organisms.
4. Positive and negative MPN tubes and tables.
5. Field test kit (OXFAM Del Aqua or Millipore).
6. Test strips for Nitrate and Nitrite
7. Conductivity meter.
8. pH dip-stick electrode.
9. Turbidity tube.
10. Bottle of muddy water.

4. FURTHER READING

Cairncross S. and Feacham R. - Environmental Health Engineering in the Tropics (Wiley, London, 1983)

Gorchev H. G. - Drinking Water Quality and Health, Notes for Seminar on Drinking Water Quality Standards, Baghdad (1983)

Hutton L. G. - Field Testing of Water in Developing Countries (WRC, Medmenham, UK, 1983)

Mara D. D. in Cairncross S. and Feacham R. - Small Water Supplies, Bulletin 10 (Ross Institute, London, 1978)

WHO - Guidelines for Drinking-Water Quality, Volumes 1-3 (WHO, Geneva, 1983-85)

WHO - Surveillance of Drinking-Water Quality, WHO Monograph 63 (WHO, Geneva, 1976)

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 2
SOURCES OF WATER

The aim of this module is to supply those who have to operate and maintain simple water supply sources with background information on groundwater occurance together with maintenance of hand dug wells, spring boxes and small earth dams.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

SOURCES OF WATER

1. HYDROLOGY AND HYDROGEOLOGY

Hydrology is the study of the natural circulation of water.

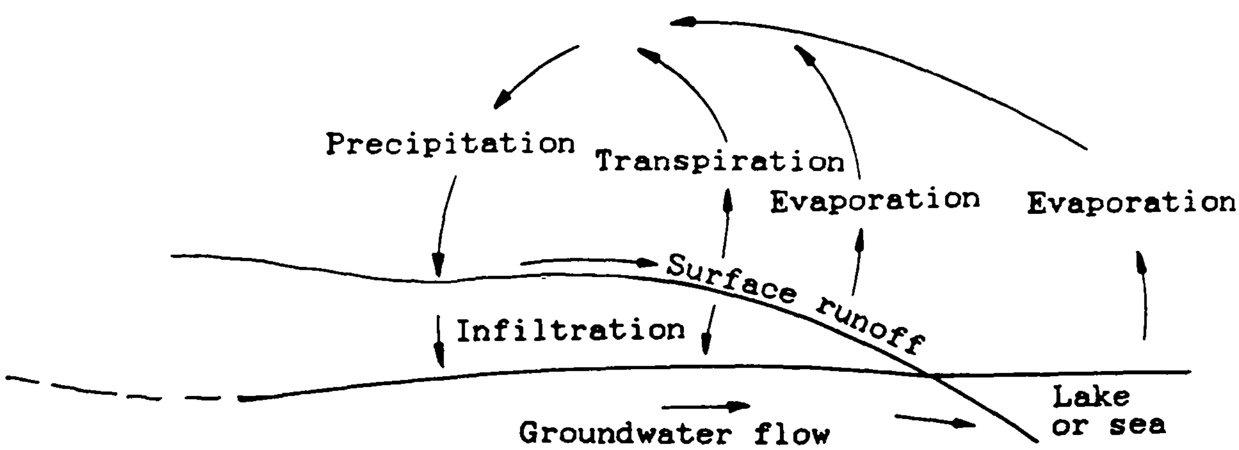

Figure 1. The natural water cycle

The major components of this cycle are:-

precipitation	- rain, snow;
evaporation	- water loss from the ground surface or from open water surfaces to the atmosphere;
transpiration	- water loss from plants generally through their leaves;
infiltration	- water which infiltrates through the upper layers of the soil to reach the water-table (the water below the water-table is called groundwater);
surface runoff	- water flow on the ground surface in rivers and streams.

Within a surface catchment a water balance can be calculated. A surface catchment is defined as all the land within a line following the hill crests surrounding a river valley.

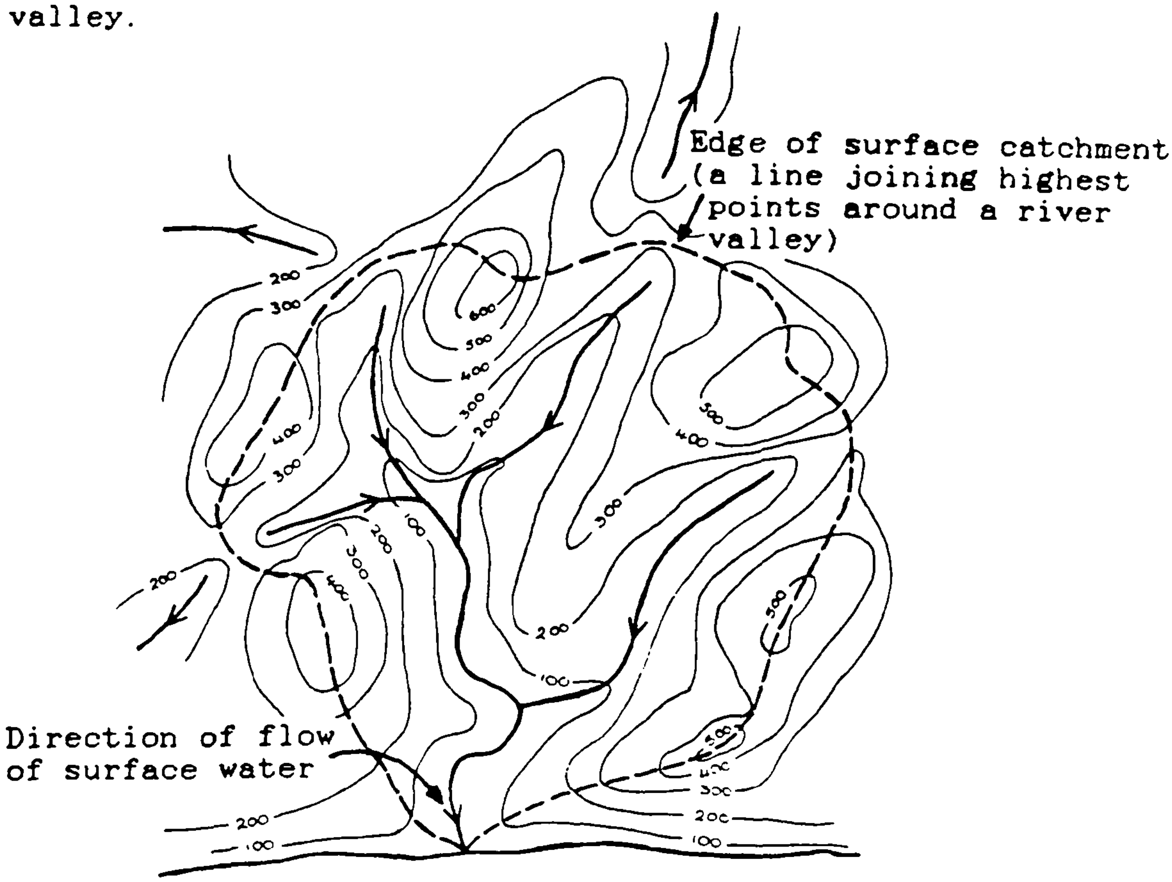

Figure 2. Surface catchment area

A water balance can be expressed as a simple equation.

Precipitation = surface runoff + evaporation + transpiration + infiltration + any water retained in reservoirs.

The volumes on each side of the equation should be equal, so if the precipitation, surface runoff, evaporation and transpiration are known, the infiltration can be calculated. Infiltration is important since it is the recharge for all groundwater supplies - that is, the groundwater supplies are replenished by water which infiltrates through the soil.

Once water has reached the water-table it will flow horizontally through the aquifer until it appears as springs or contributes to river flow by seepage through the river bed. The volume of this seepage is called the base flow. Most rivers in dry spells or in the dry season obtain their water from base flow. When rivers dry up it means that the water table has fallen below the level of the river bed and so the flow of water ceases.

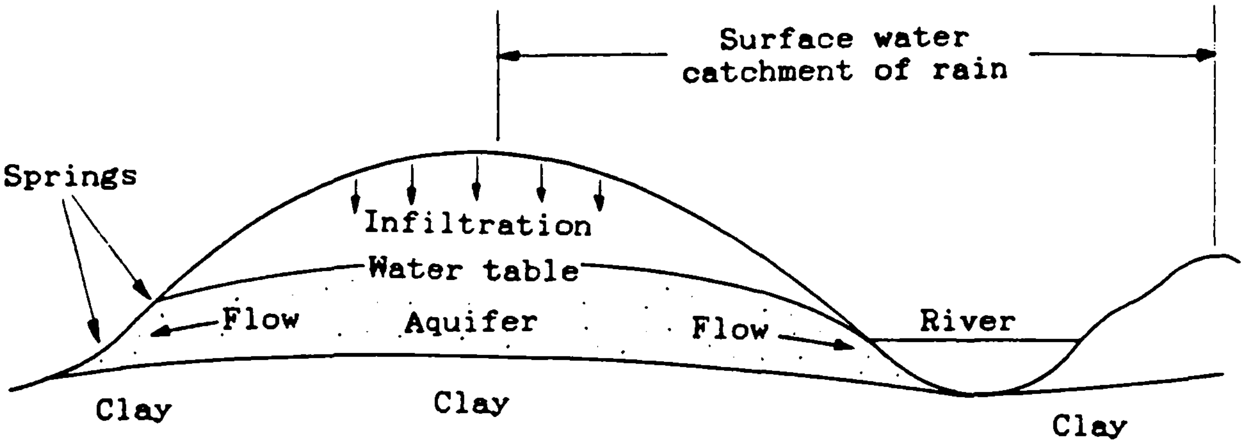

Figure 3. Water table aquifer

All aquifers are not like that shown in Figure 3 which is a water-table aquifer (ie., it can receive recharge by infiltration from all the land surface above it).

Other aquifers are confined between two impermeable layers (ie, layers that water cannot pass through) and they can only be recharged from the area where the aquifer outcrops at the land surface (see Figures 3 and 4). This means that the water in a confined aquifer is often at pressure (the pressure head is called the pietzometric surface). If this aquifer is intersected by a well, water may flow to the surface and overflow because of the pressure in the aquifer.

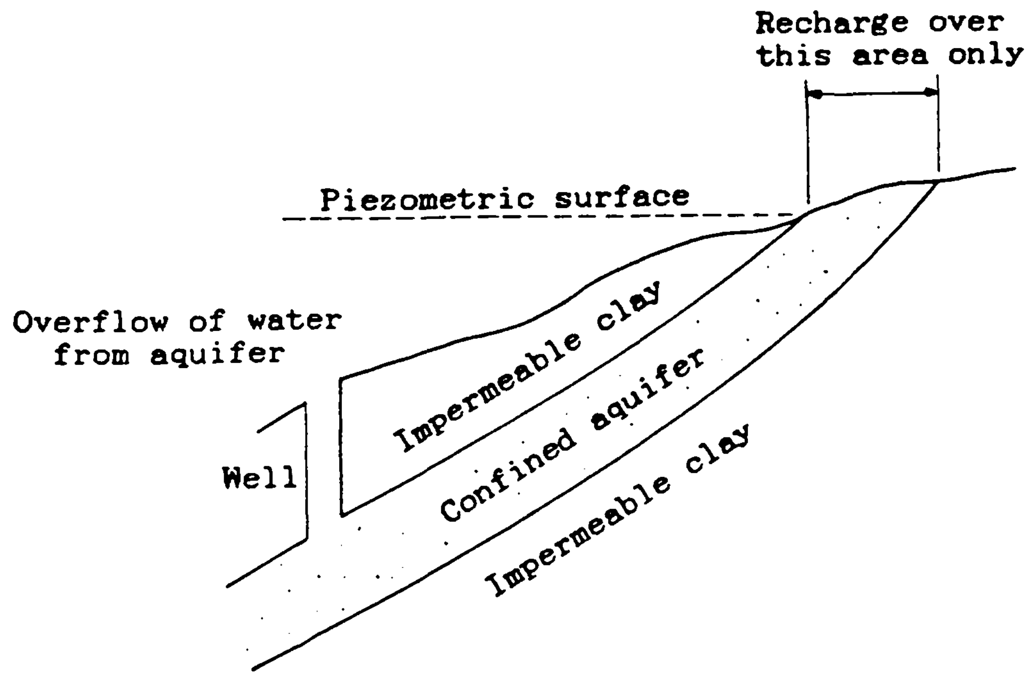

Figure 4. Confined aquifer

In Figure 4, if a well was constructed and water was removed from the aquifer this would result in less water being available for springs or for dry river flows. If many wells are constructed, springs and rivers may dry up very rapidly. If many wells are dug into a confined aquifer, the over-flowing water will get less and may stop due to the lowering of the pietzometric surface.

It is very important to understand that both surface and ground water receive their recharge from precipitation which is limited, so if groundwater is heavily exploited river and spring flow will become less.

2. HAND-DUG WELLS

A properly constructed hand-dug well should include the following items.

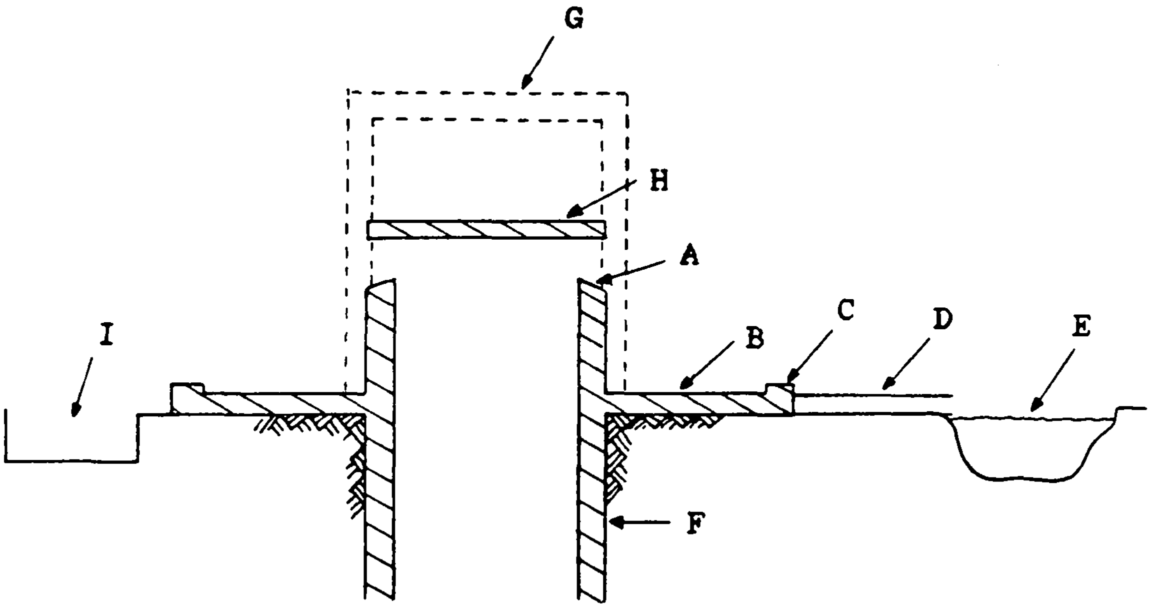

Figure 5. A well head

A - A wall to prevent litter, animals and people from falling into the well. The top should be made uncomfortable to stand upon so that no debris from feet will fall into the well. The height should be convenient for the method used to collect water by people in that area.

B - A stone, brick or cement platform surrounding the well-head to prevent the area surrounding the well becoming muddy.

C - A lip on the edge of the platform to direct water spillages into the drain.

D - A drain taking water spillages away from the well and into a soakaway.

E - A soakaway to prevent a wet area developing where water insects such as mosquitoes could breed.

F - A sealed lining outside the top 1 metre of the walls of the well to prevent any contaminated surface water draining into the well.

G - Some structure to assist with the drawing of the water and to minimise the introduction of pollution from the outside of the bucket. Hand pumps are dealt with in Module 4.

H - A cover to keep out the sunlight and to protect well

I - If animal drinking troughs are used they should be some distance from the well head to minimise the pollution risk.

A properly constructed well needs little maintenance to ensure good quality water. The following maintenance should be carried out annually. The best time to do this work is at the time of the year when the water level is at its lowest.

a. Daily or weekly maintenance

Daily or weekly maintenance should be carried out by a representative of the people who use the well.

1. Cleaning and sweeping the immediate well surround.
2. Making temporary repairs to any large cracks or damage to the parapet and surround.
3. Inspecting the lifting mechanism used to draw water out of the well and repairing or renewing it if necessary.

b. Monthly

1. Ensure that no latrines are constructed too close to the well as effluent from the latrines could pollute the groundwater (see Module 7, Section 5).
2. Check that any fence built to keep animals away from the well is kept in good condition.

c. Annual Maintenance

To be carried out by a maintenance team provided by the organisation (government or non-government) responsible for the well.

1. Clean out all rubbish from the bottom of the well and remove all weeds that have grown on the side of the lining. This will involve someone entering the well and great care must be taken that he does not fall. The safest way of lowering someone down a well is in a bosun's chair.

2. Repair and clean the platform and parapet by sealing all cracks which might allow polluted water to leak into the well. It is particularly important to repair cracks where the surrounding platform meets the head wall.

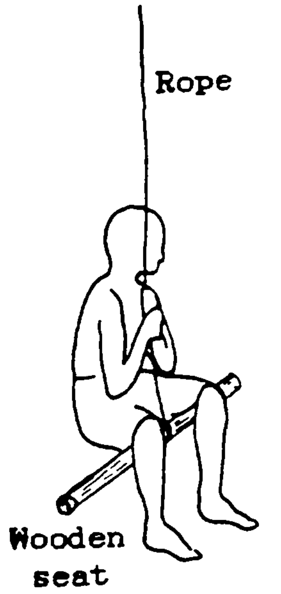

Figure 6.
A bosun's chair

3. Clean out the drain and inspect the soakaway to make sure that a wet area is not forming.

4. Check the outside of the apron to ensure that no erosion has taken place which might undermine it.

d. Other maintenance procedures which need to be carried out

Disinfect the well whenever it is suspected that the water may have become contaminated, eg, after a person has been down the well to clean it. Use bleaching powder at a rate of 100gms of bleaching powder per m^3 of water in the well. 100gms of powder should be pre-mixed in a bucket of water and then poured into the well. The water in the well should be thoroughly mixed with the bleaching powder solution and allowed to stand unused for at least 12 hours. Then the water should be pumped or bailed out of the well until the odour of chlorine disappears.
If no bleaching powder is available, mix 2 litres of household bleach in 35 litres of water and use instead.

3. SPRING BOXES

A well designed spring box should include the following items but there are many different designs of spring box and varieties in detail to allow for local conditions.

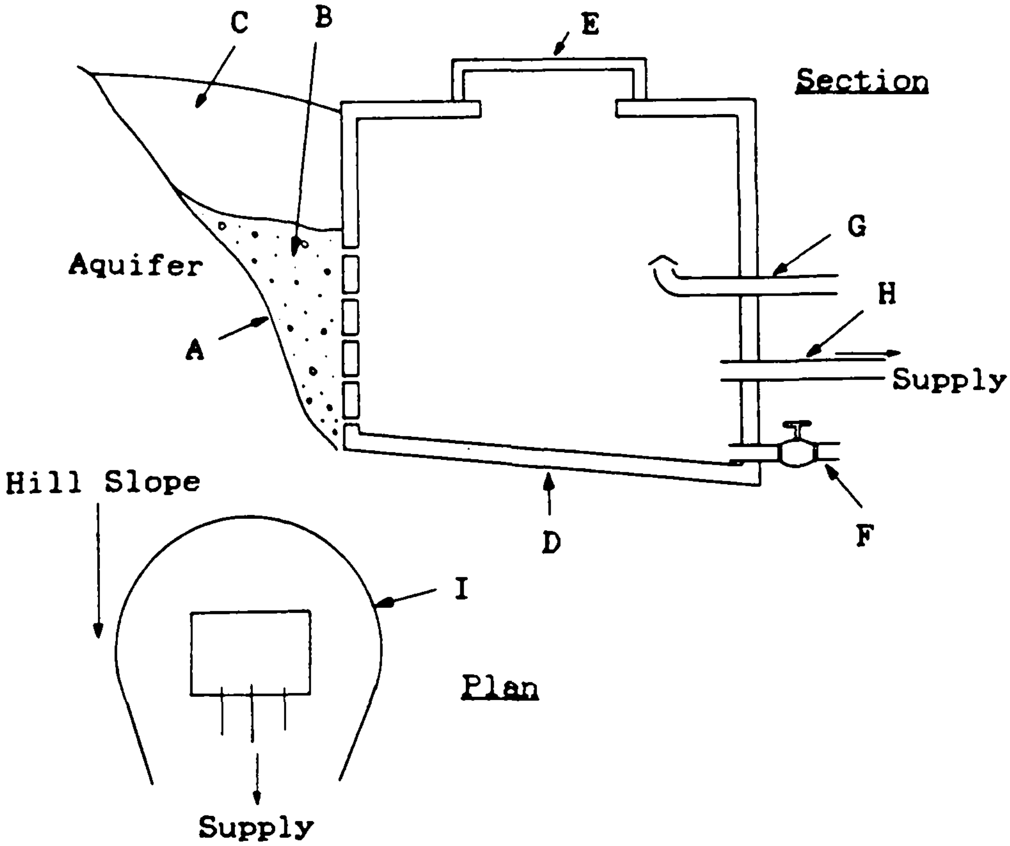

Figure 7. A spring box

A - The edge of the spring, which should have been well cleaned before construction of the spring box.

B - Clean gravel to act as a filter.

C - Clay seal to prevent any surface water leakage.

D - A strongly constructed spring box. It can be made from any materials available locally (eg, stone, brick, concrete) and must be impermeable except for the wall in contact with the spring edge.

E - A manhole through which a person can enter to clean the well and which is normally sealed.

F - A wash out pipe draining from the lowest part of the spring box floor. The pipe needs to be large enough to take more than the free flow of the spring and should be fitted with a valve which can be locked.

G - An overflow pipe capable of accepting the full flow of the spring and fitted with an insect and rodent screen. It should be installed a little below the level of the spring.

H - A supply pipe.

I - A ditch to divert surface water away from the spring box. This is known as the interceptor drain.

a. Annual maintenance

1. Open the washout and removing all accumulated silt. If the box has been in use for some time it may be necessary for someone to enter through the manhole to clean the box thoroughly.

2. If an insect and fly guard has been fitted on the overflow pipe, check that it is intact. Replace the guard if it has been damaged or blocked.

3. Disinfect the box and supply system if a person has entered the box to clean it.

4. After cleaning, check that the washout valve closes fully and that the manhole cover is correctly replaced and sealed.

5. Check the box for leakage. Leakage out of the box may also mean that water is leaking into it.

6. Inspect the clay seal and ensure that it is still impermeable and has not cracked due to drying out.

7. Check that the interceptor drain is clear.

8. Check that the animal-proof fence around the box is in good condition.

9. Maintain the supply system and ensure that it functions correctly. Check that all taps close and open and that the surrounds of the taps are hygienic and not a source of insect breeding.

4. SMALL EARTH DAMS

Routine maintenance of earth dams is of great importance since small leaks in earth dams grow rapidly and may soon cause the collapse of the whole dam.

Maintenance should be carried out annually or after the dam has been subject to stress by abnormally heavy rain.

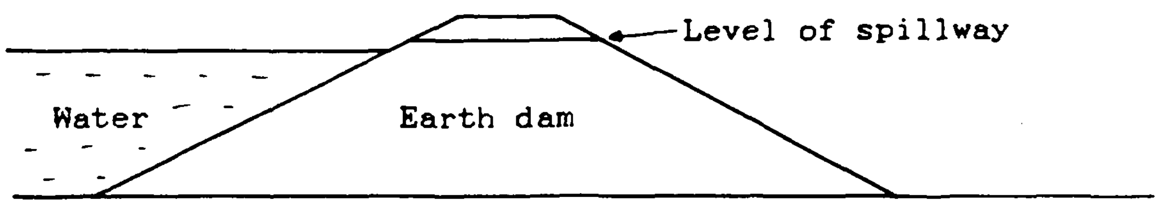

Figure 8. Section of an earth dam

1. Inspect all visable faces of the dam and embankment for any sign of seepage. These can be detected by abnormally damp areas, areas of increased plant growth or different plant growth. If leakage is found it must be repaired immediately by an engineer. The leakage should be sealed on the water side of the dam, if possible. Danger to life could result from a dam collapsing. If the leakage is rapid then you should begin to reduce the level of the water to below the level of the leak by opening the washout pipe at the bottom of the dam. Assistance must be obtained from an engineer.

2. Inspect overflow arrangements and make sure that the overflow is clear of debris and the channel is not blocked by weed growth. Repair any damage to the spillway structure. Check that the spillway approach is clear of floating debris. If there is much floating debris then it might be a good idea to construct a log boom and float it about 20 m from the spillway. It is very important that the spillway is kept clear as water must <u>not</u> be allowed to spill over the top of the dam unless the dam is specifically designed to cope with that. Water spilling over the top will seriously erode an earth dam. For this reason, the spillway should be checked regularly. It is best to check it once a week.

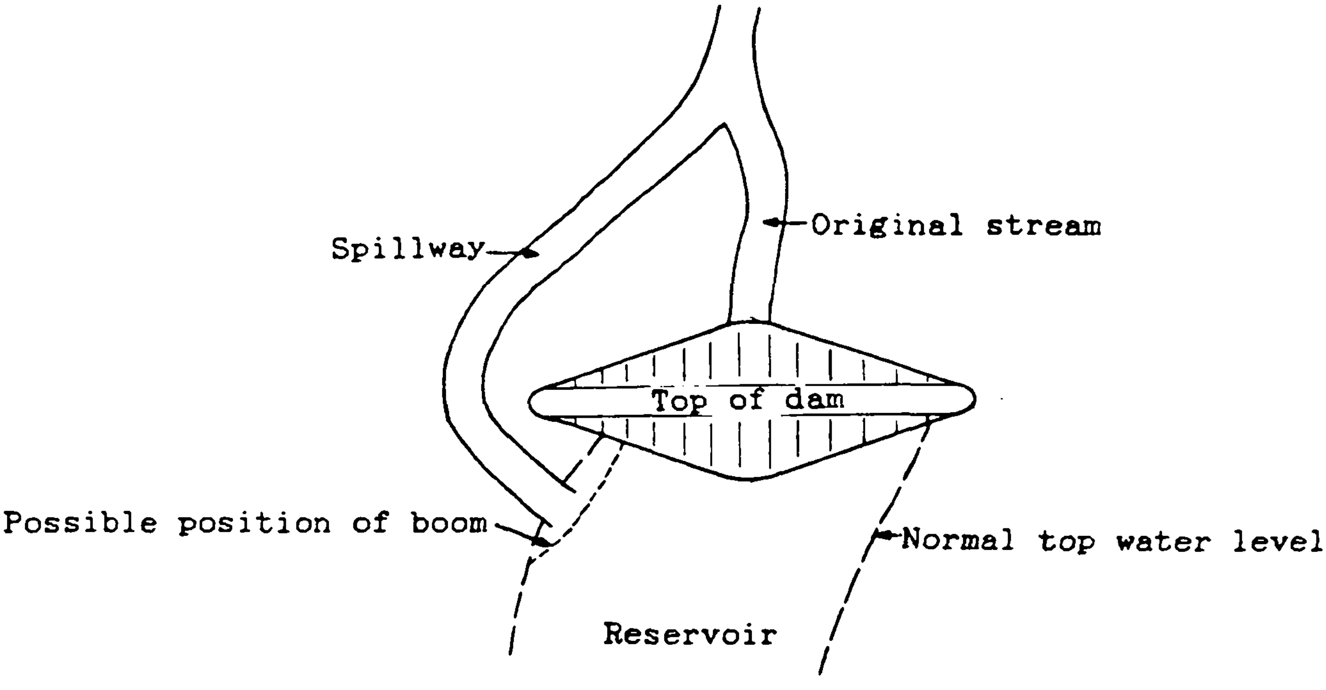

Figure 9. View of an earth dam from above

3. Many earth dams have some leakage all the time which causes no danger. However, leakage should be monitored and if it increases help should be sought from an engineer.

4. Check for any deformities (ie, bumps or bulges) on the crest or sides of the dam. Changes in shape indicate instability.

5. Remove all trees and bushes from the dam faces. If they become too large they may affect the dam stability if they fall, and rotting roots may create leakage paths.

6. Check that the dam is not used by burrowing animals since their burrows can easily become leakage paths.

7. Keep animals such as cows, goats and sheep off the dam. It is especially important to keep them off the water side. Animals can cause damage to the dam and also pollute the water.

8. If a silt trap exists at the reservoir inflow, make sure that it is cleaned out since a full silt trap will not catch any silt and the life of the reservoir will be shortened.

9. Check that the shallow water near the edge of the reservoir is not being used as a breeding area for mosquitoes or snails (which cause malaria and schistosomiasis). If these are discovered, obtain advice from the Health Department.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE 2

SOURCES OF WATER

Instructors Notes

Emphasize the following:

1. The interconnection between ground and surface waters. Utilisation or pollution of one may well pollute or reduce the other.

2. Confined aquifers are polluted mainly from the recharge area what may be far away from the supply point.

3. Unconfined aquifers can be polluted from any point within their recharge area which will be all around at the supply point.

4. The maintenance tasks are simple so ensure that the operators understand WHY the tasks are necessary rather than going into great detail of how, which will vary from installation to installation.

5. In hand dug wells and spray boxes the major task is to keep polluting substances away.

6. In small dams safety is very important as well as pollution.

Demonstration

1. If possible visit a local well, spring box or dam and illustrate on the spot the methods of maintenance. One site visit is worth hours of class room teaching.

2. Demonstrate how to make a suitable disinfecting solution using what chemicals and equipment are available locally.

3. Show how the valves on the spring boxes work using a sample valve and any maintenance that might be needed.

4. Show some geological samples of local soils illustrating local acquifers and confining beds as appropriate.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 3
DELIVERY AND STORAGE OF WATER

Objectives:

To familiarize participants with methods of:

a. detecting leaks in transmission and distribution pipes;

b. repairng and replacing defective pipes;

c. maintaining and repairing valves;

d. maintaining and repairing storage tanks

and

e. maintaining and repairing standposts.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE THREE

DELIVERY AND STORAGE OF WATER

1. LEAK DETECTION AND LOCATION

There are five main methods of leak control in water distribution systems. The method selected for any system depends on local circumstances and the funds available. The methods are listed in order of cost, with the cheapest first.

a) Repair of all self-evident leaks

The easiest method of detecting leaks is by visual inspection. Any damp patches or unexplained areas of vegetation on the path of an underground pipe usually indicate the presence of a leak. This is the only method practised by many people and is quite effective in an area where a burst reveals itself at ground level. Leaks in mains service pipes, standpipes and domestic property must all be repaired if the work is to be effective. There must be some legal means of enforcing owners to carry out repairs quickly on private property. A rapid repair by the Water Undertaking is very important with this method. If immediate repairs are not possible because of some factor, no further leak control method is worth pursuing - all rely on quick repairs.

Illegal connections to a water pipe are a problem, but many factors have to be considered before deciding whether to disconnect them or not. For example, does the illegal removal of water create serious shortages for legal consumers further along the pipeline? If the illegal pipe were disconnected, would that leave some people with no means of obtaining safe water?

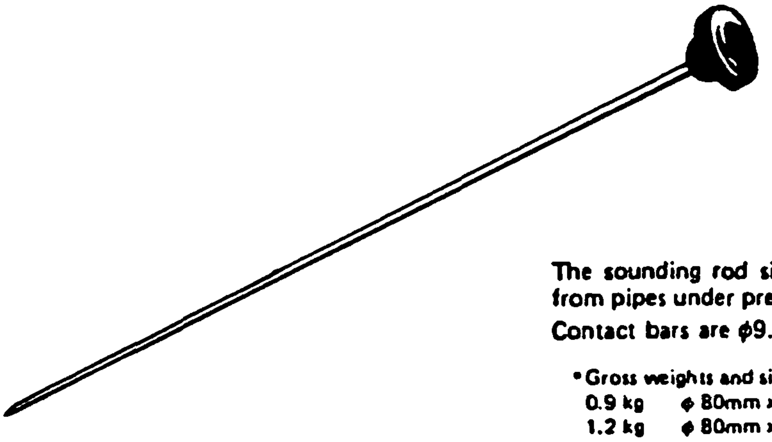
b. Control operating pressures

Most systems contain some areas where the operating pressures are more than that required for a good supply to consumers. If these pressures can be reduced by automatic pressure reducing valves, the leakage rate is immediately reduced. This method is usually practised after visual inspection has been carried out.

c. Regular sounding

This method requires skilled manpower who are able to detect leaks by listening to the sound made by the escape of water through a hole or crack in the pipe. This is done by applying the ear to a listening stick which is placed on the distribution system at all available positions. This means applying the stick to every service pipe on the system and listening very carefully for leak sounds. Valves and hydrants can also be tested, but the most important parts of the system are the service pipes. Stop taps, meters, bore pipes, and any place in direct contact with the pipe must be used as a listening place. Most leaks are detected from stop taps when available. The position of the leak can then be further determined by operating the stop tap. If the noise ceases when the stop tap is closed, then the leak is on the domestic side of the tap. If the noise continues, the leak may be on the nearby main or service connection. Noises on adjacent services often indicate a mains leak.

Sounding on road surfaces is very difficult and often misleading. This can be improved by the use of various electronic devices which magnify the noise. Earphones are used with this apparatus. Surface sounding 'bell' shaped instruments are available which are placed on the road surface and are sometimes effective for location.



The sounding rod simply detects underground water leaks from pipes under pressure.
Contact bars are ϕ9.8mm x 1000mm and ϕ9.8mm x 1500.

• Gross weights and sizes
0.9 kg ϕ 80mm x 1050mm
1.2 kg ϕ 80mm x 1550mm

d. District metering

Districts of up to 5,000 properties are fed by metered mains feeds. Monitoring by districts will indicate the worst districts for leakage, and sounding/listening can be concentrated in that district. This eliminates sounding of 'good' areas.

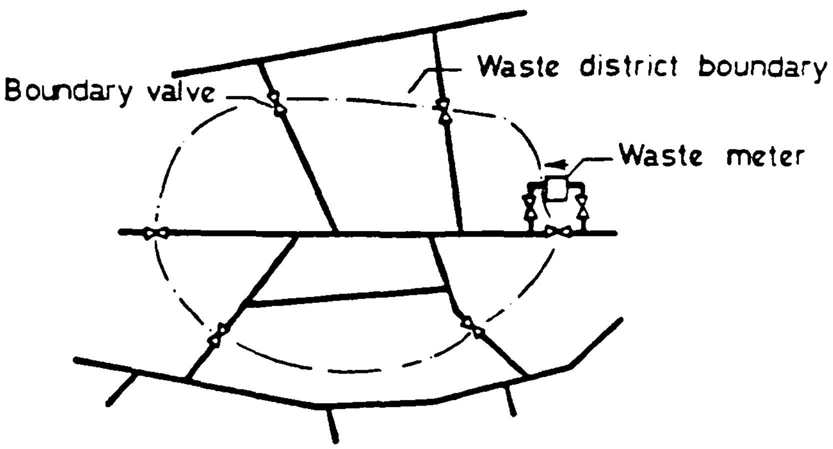
e. Waste metering

The system is divided into waste meter areas of 300 - 1000 properties. Each area is isolated by valves except for one feed main on which the waste meter is situated. The waste meter indicates on a chart the flow rate into the areas at all times. Meters can be permanent and in a chamber, or portable and in a caravan or trailer.

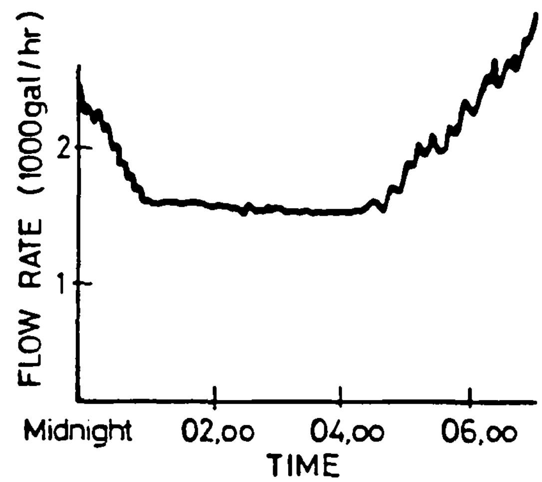
Minimum night flow usually occurs between 0100 hours and 0600 hours. This is known as the 'night line'. Metered premises in the area can be subtracted from this night line and the result is then considered the 'waste' level. This should not be in excess of 8 to 9 litres per property per day. If this level is high, a 'step test' is carried out. Each length of main in the district is progressively isolated and, where a leak is present on this length, a 'step' is registered on the meter. These 'steps' indicating leakage rates are produced on the chart. The leak is then located by sounding on that length of main. The leak is repaired and the area is checked for night line value again.

Setting up a waste meter district

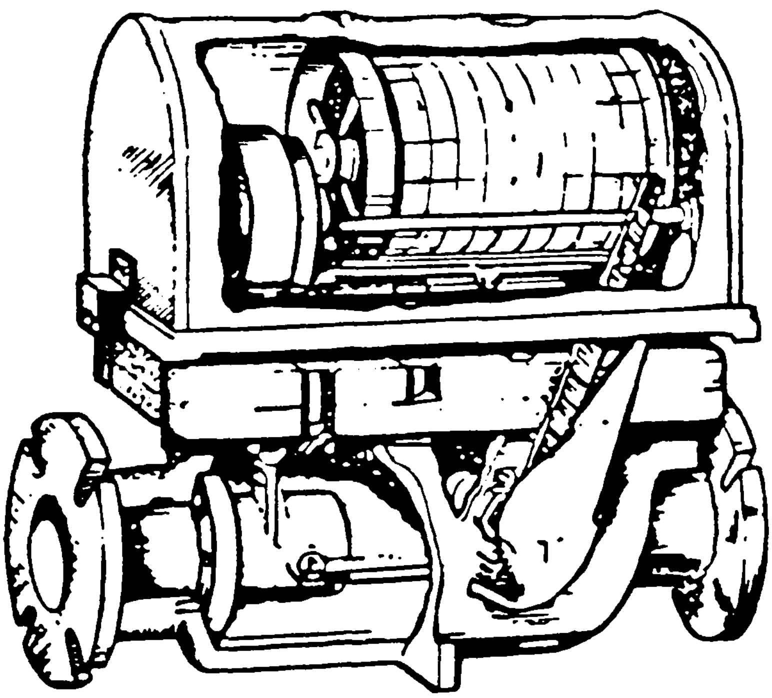
1. Draw plan of mains system showing all valves and large metered supplies.
2. Operate all valves to ensure that they open and close easily.
3. Replace or repair all defective valves.
4. Select the district area and design position of waste meter.
5. Install waste meter or hydrant connections for portable meter.
6. Survey consumers in area and establish number.
7. Close the boundary valves of district and ensure isolation.
8. Record a waste chart for 24 hours.
9. Analyse results - night line reading - leakage rate per property.
10. Run step test of district and establish defective length.
11. Carefully sound defective length and locate leak positions.
12. Carry out excavation for final location and repair.
13. Record a waste chart for 24 hours.



DISTRICT IN WASTE METER RETICULATION



TYPICAL NIGHT LINE CHART



KENT WASTE METER

2. REPAIR AND REPLACEMENT OF DEFECTIVE PIPES

a) Pipes up to 50mm

Excavation must be carried out with care, ensuring that the pipe is not damaged. The excavation must be large enough to allow the mechanical jointing to be done without the trench obstructing the work. This means excavating space under the pipe to a depth of about 200mm, and space 250mm from the sides. The length of excavation depends on the length of pipe that needs replacing and on the type of replacement pipe. If the replacement pipe is flexible (ie, polyethylene), the length removed should be 2-3 metres to allow the pipe to be bent into position. If the replacement pipe is rigid, the length must be at least the length of two couplings placed side by side.

Isolate the section to be repaired by closing valves and drain it before cutting.

Cutting - before cutting, clean the pipe and examine it closely. Cut the pipe where it is in good condition, with no corrosion, pitting, dents or scratches. Cut out the defective length of pipe with a hacksaw, cuts being made at 90° to the axis of the pipe.

Cleaning - Clean the pipe again with a damp cloth, or the joints will not be water-tight. The pipe must have no earth inside, nor any rough edges from cutting.

Jointing - to joint the new length into the pipeline, two couplings of a type to suit the material of the pipeline and the material of the replacement pipe are required. With an iron pipe a "barrel nipple" is often used to change from pipe of one material to another. This requires the ends of the original pipe to be threaded which can be done with a thread cutter. Iron pipes can be welded, but the weld acts as a possible site of corrosion in the future.

Polygrip couplings can be used for jointing different material by changing the insert and split ring. There are many types of joint available for this work and the choice of joint used will depend on many local circumstances. Joints must be tightened in a regular sequence in order that no excessive stress is created in the pipe or joint.

Backfilling - the trench must be refilled with soil after the repair has been carried out. This must be done with great care. Special attention must be paid to the areas under the pipe and immediately next to it. The material used to fill round the pipe must be free from hard pieces which may damage the pipe or joints. The material should be well compacted and there should not be any spaces left around the pipe as this will create stress in the pipe. The best materials for putting round the pipe are dry sand or small sized gravel (pea gravel).

b. Pipes over 50mm

Excavations for repairs must be large enough to allow jointing (especially the use of large spanners and pipegrips) to be carried out without obstruction. It is necessary to have space under the pipe. The length of the excavation must be enough to allow the joints to be cut and made and include space to slide collars clear of the cut face.

Cutting out the defective length may mean more than two cuts in order to safely remove the section. Cutters are either wheels, or hydraulic pressure "squeezers" for cast iron. For other materials, a hacksaw is used. A hacksaw can be used for cast iron, but the teeth will require cleaning and unblocking. Pipes over 450mm require special cutting machines.

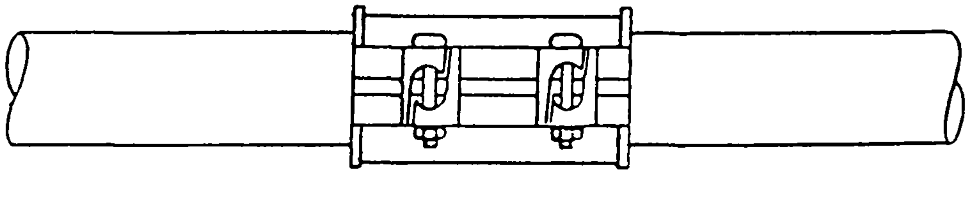
Cleaning of the pipes and joints is essential if satisfactory joints are to be made.

Jointing - there are two different types of jointing for repairs:

1) where a pipe length is replaced;
2) where the failure is circumferential and a clamp is used for repair.

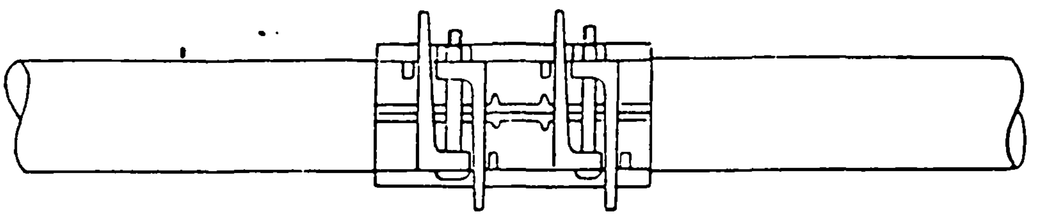
1. The repair couplings vary according to the size and materials being jointed. Different materials, and variations in sizes can be accommodated as shown. "Push in" type joints cannot be used for repairs. The joint rings, usually made from rubber, must be of the correct size and care must be exercised that they are in the correct position before tightening the joint. The bolts should be tightened in sequence, a small amount each time in order that pressure is applied to the joint ring evenly throughout the process.

2. A clamp can be used to repair circumferential failures. There are various types of clamp available. They can be placed round the pipe and must be tightened slowly with pressure being applied evenly along the clamp. The rubber insert must be in its correct location. The illustration shows two types of repair clamp.



VIKING JOHNSON REPAIR CLAMP

(UP TO & INCLUDING 200mm NOMINAL BORE)



STAINLESS-STEEL REPAIR CLAMP

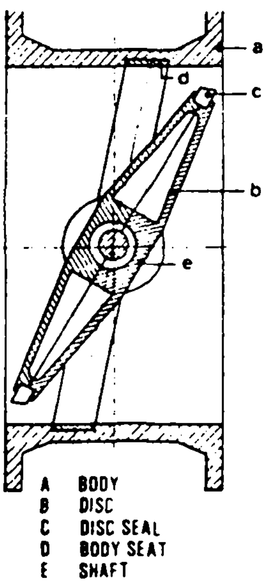
(ABOVE 200mm TO 300mm NOMINAL BORE)

3. MAINTENANCE AND REPAIR OF VALVES

Sluice Valves

Sluice valves in a distribution system are usually maintained by regular operation. This is done at annual intervals, with the valve being opened and closed two or three times. This operation keeps the valve guides clear of debris and the wedge gate faces clean. The gland surrounding the valve-operating spindle needs to be re-packed with metallic asbestos yarn if it becomes worn or hard and a leak results. If the valve gate becomes worn and does not open and close easily, the whole valve is usually replaced. It is sometimes possible to remove the bonnet and spindle/gate assembly, while the main body is left in the pipeline, and to clean these parts if there is no mechanical damage.

Another control valve is the butterfly type, illustrated below. These should be installed in water mains with the spindle in the horizontal position to avoid a bearing situated at the invert of the pipe where there is maximum debris. Maintenance is similar to the sluice valve, but it is not possible to remove the gate in situ.

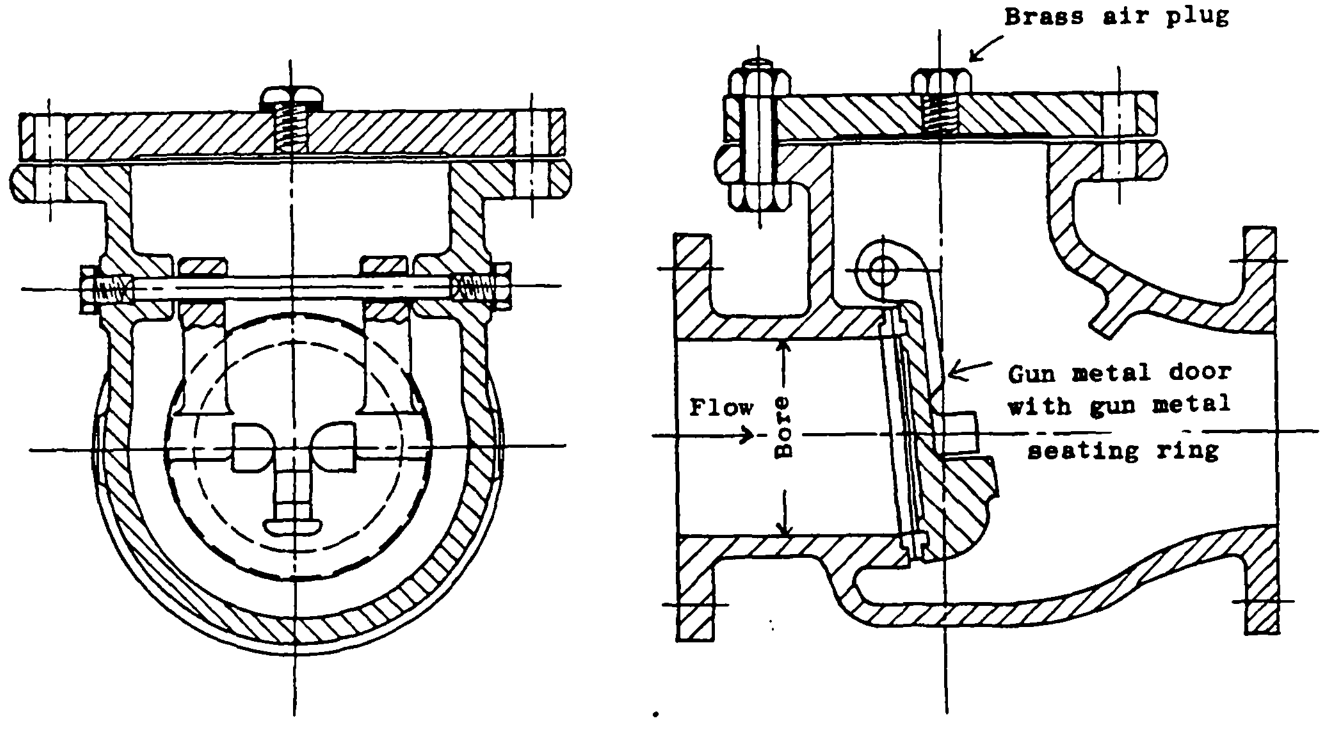


BUTTERFLY VALVE

Air Valves need careful and regular operation and maintenance. The valve floats should be inspected for irregularity of surface and tested by floating to ensure that they are not punctured and full of water. The large and small orifices must be clean and form a perfect watertight seal with the float. Annual inspection is suggested. If the seals become worn or pitted, the valve should be replaced.

Hydrants need annual inspection and testing for correct discharge and tight shut-off. Spindles and stoppers are replaceable in situ, but it is easier to remove the unit to a workshop.

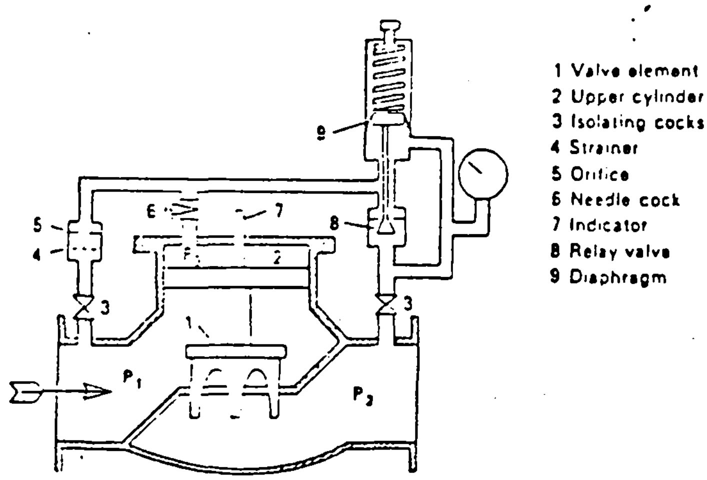
Reflex Valves (or Non-return Valves) - the usual type of non-return valve consists of a flat disc within the pipeline, pivoted so that it is forced open when the flow of water is in one direction, and forced shut against a seating when the flow tries to reverse.



Reflex Valves

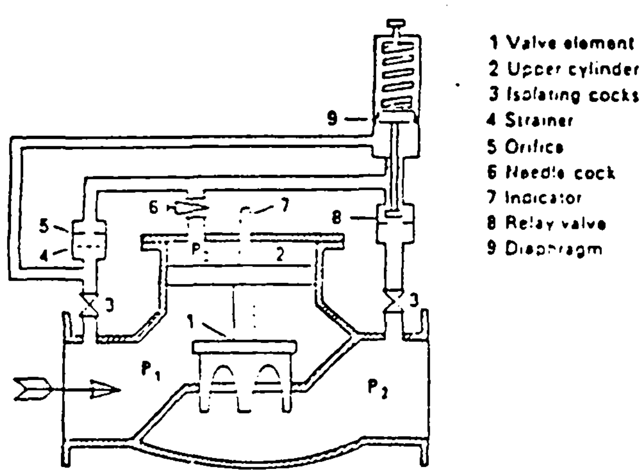
The seating is arranged slightly out of perpendicular when the valve is to be inserted into a horizontal pipe. The metal seatings of door and body must be inspected for wear annually, and any debris removed from the valve as it will obstruct the closing of the valve.

<u>Control Valves</u> The operation of control valves is best illustrated by a <u>standard pressure reducing valve</u> as shown in the illustration. This maintains a pre-set pressure in the water main downstream of the valve, irrespective of the pressure upstream. If the pressure upstream is insufficient, the valve simply opens wide and no more pressure is available downstream than the upstream pressure, less the loss through the valve. Pressure reducing valves of this sort should be sized so that their full open capacity is more than adequate for the desired maximum flow.



Pressure reducing valve.
Operation If the outlet pressure P_2 becomes too high to balance the spring load, the relay valve 8 tends to close allowing pressure P_3 to increase, causing the main valve 1 to tend to close, thus reducing P_2 to the set value. Similarly, if P_2 becomes too low the relay valve opens, P_3 decreases, the main valve opens further and P_2 rises again to the set value.

A <u>pressure sustaining valve</u> operates to keep the pressure upstream of the valve to a given amount. This sort of valve is used, for instance, where a distribution area 'A' feeds a second distribution area 'B'. With a sustaining valve in the feed line, adequate pressure can be maintained in the distribution area 'A', without excessive demand in 'B' pulling the pressure down in 'A'. (In effect, 'A's demand takes precedence over 'B's). When the valve is full open, however, the pressure upstream passes through to the downstream side.



A pressure sustaining valve.
Operation: When the inlet pressure P_1 becomes too high to balance the spring load, the relay valve 8 tends to open, allowing pressure P_3 to diminish so that the main valve 1 tends to open, thus reducing P_1 to the preset value. Similarly, if P_1 becomes too low to balance the spring load, the relay valve closes, P_3 increases, the main valve closes and P_1 rises again to the preset value

Control valves of these types require inspection and cleaning at six monthly intervals. The valve element should be inspected for wear and the component parts of the control system checked for correct operation.

Intermittant Flow in a water distribution system is the cause of several problems. As the system fills and empties, so any debris in the pipes is stirred up and dirty water results. When the pipe is empty, any leaks in the system may be reversed, causing pollution of the pipeline by polluted ground water surrounding the pipe seeping into it. If there are meters on the system, their accuracy in recording the flow will be severely affected. Rotating vanes or propellers will be actuated by air moving along the main during intermittant flow. Intermittent flow should be avoided as much as possible and only adopted as regular practice in extreme emergency (ie, in periods of water shortage).

4. MAINTENANCE AND REPAIR OF STORAGE TANKS

Tanks made from metal plate should be drained, cleaned and inspected annually. The internal parts of the tank should be brushed down and all mud and debris removed. Painting internally and externally should be carried out at five year intervals.

Structural parts should be replaced when badly corroded. Leakage between steel panels can be alleviated by stopping up the seams from the inside of the tank with lead wool, but major leakage may mean re-building the tank with new jointing material. Badly leaking floors can be given extended life by inserting a 150mm concrete floor inside the tank.

Inspection checklist

1. Check vent screens, overflow pipes, and hatch covers.
2. Inspect interior and exterior ladders and safety rails.
3. Inspect balconies and platforms for corrosion.
4. Inspect roof areas for ponded water.
5. Inspect cathodic protection system components.
6. Observe operation gauges and pump limit switches.
7. Examine wall-roof joint for leakage and signs of deterioration.
8. Examine underside of roof for leakage and stalactites.
9. Examine interior and exterior painting for rust stains and corrosion.
10. Inspect walls for cracks and condition of joint material.
11. Examine all internal ties for corrosion.
12. Inspect parapets for trapped moisture and debris.
13. Inspect all steel components for corrosion.
14. Inspect gauges, lights, valves, and other working components.
15. Check floor of reservoir for leakage, sediment and debris.
16. Inspect drainage system.

5. MAINTENANCE AND REPAIR OF STANDPOSTS

Standposts must be checked very regularly as part of the water distribution system.

Inspection checklist:

1. Inspect tap for operation and tight closure.
2. Inspect all exposed pipe joints.
3. Check and read meter.
4. Examine standpipe support for structural failure.
5. Check drainage from surrounding area.
6. Examine impervious collection area for cleanliness, cracks and leakage.
7. Inspect spillage areas for adequate drainage.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE THREE - INSTRUCTOR'S NOTES

DELIVERY AND STORAGE OF WATER

This Module is primarily for participants who have villages with piped water within their area. It places emphasis on leak detection and the reduction of leakage, which are very important in maximizing the benefits of a piped supply.

Either before a course starts or when they first arrive (for example, on the application form or during the registration procedure) participants should be asked whether they have to deal with piped supplies, or whether there are piped rural water supplies in areas where they are likely to work in the future.

If none of the participants have to deal with piped supplies the time allocated to this Module can be greatly reduced. When the Module is presented in full (that is, when several of the participants are either now involved in piped supplies or are likely to be involved in future) efforts should be made to obtain valves and other equipment described in the Study Notes. Ideally these should have split cases so that working parts can be examined. It may be possible to obtain them from a local technical college or from the workshop of a water authority.

The session should start with an explanation of the importanace of reducing unaccounted water. If possible information about losses in local piped water systems should be presented. This can be related to the number of people who could be supplied from existing sources.

Unless some of the participants have had experience of leak detection, the material in the Study Note should be gone through in small steps. After explaining one section (half a page or so in the Notes) the facilitator should check that he or she has been understood. Any demonstration equipment (valves etc) should be carefully examined. If the group is small the participants should gather round the equipment, or it can be passed round the group.

Sections 4 and 5 (storage tanks and standposts) are likely to be more familiar to participants than those dealing with pipelines and valves. A discussion method is then appropriate, participants being asked to tell about any difficulties they have experienced in maintenance.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 4
PUMPS

This module explains the principles of a systematic approach to the operation, maintenance and repair of mechanical equipment; it also stresses the importance of following the specific procedures given in the O&M manual for each piece of equipment.

Guidelines are given on the general operation and maintenace requirements of handpumps, motorised pumps, electric motors and diesel and petrol engines. These include typical preventative maintenance schedules and fault checklists.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE 4

PUMPS

1. INTRODUCTION

This module discusses the operation and maintenance of

- handpumps (section 3)
- motorised pumps (section 4)
- electric motors (section 5)
- diesel and petrol engines (section 6)

Before considering the particular requirements of these types of equipment an overview is given of the various approaches to the maintenance of mechanical equipment (including the repair of equipment after breakdown). These considerations are particularly important for pumps, because the appropriate approach for maintenance of handpumps is quite different to that for motorised pumps.

2. MAINTENANCE MANAGEMENT

a. Objective

Maintenance has the following general objectives:

- to keep equipment operating efficiently and safely;
- to make sure the equipment does not break down too frequently;
- to ensure that equipment is repaired quickly after breakdown and does not stand idle;
- to prolong the life of the equipment;
- to minimise costs of maintenance.

In any particular case, there will be a desirable standard for each of these objectives, and maintenance policy aims to satisfy this standard as closely as possible. It is important to consider here what damage is caused if the equipment breaks down, and whether it is important to repair it quickly. This will indicate appropriate standards for frequency of breakdown and speed of repair, and the justifiable level of maintenance costs. For instance, it may not be a major problem if a handpump breaks down, provided that it can be repaired within a few hours, but breakdown of a sewage pump may cause widespread health hazards very rapidly.

In the most critical cases (eg, in a treatment works) "standby" capacity should be provided, in the form of an extra pump or pumps ready to take over in case an operating pump breaks down. This gives a safety margin, reducing the demands on the maintenance organisation. In other situations where breakdowns would cause serious problems, and where maintenance is difficult or expensive it is also well worth considering the installation of standby capacity.

Another approach is to "overdesign" the facility (ie, to design it for more severe conditions than are expected by giving increased strength), so reducing the frequency of breakdowns. Both "standby capacity" and "overdesign" have the effect of increasing capital cost in order to reduce the frequency and the recurrent costs of maintenance, repair and "out-of-service" periods.

b. <u>Planned and unplanned maintenance</u>

Maintenance can be considered in a number of categories and sub-categories as follows:

i) Planned maintenance

  a) preventative maintenance
    - running maintenance
    - shut-down maintenance

  b) corrective maintenance

ii) Unplanned maintenance

Planned maintenance is carried out in a systematic and organised way on equipment which has not broken down. The purpose of preventative maintenance is to prevent the equipment failing (eg, by re-tightening the bolts on a handpump or refilling an engine with oil). Small simple jobs can be done while the equipment is in use. Others require it to be taken out of service for the maintenance period.

Corrective maintenance is usually done out of service, to repair a problem revealed by an inspection.

Unplanned maintenance is the term given to a maintenance approach where repairs are carried out as required <u>after</u> equipment failure, rather than to an organised schedule.

Unplanned maintenance can have two major disadvantages for rural water supply:

- There may be a considerable delay after breakdown before repairs are carried out, during which time the pump is out of service.
- The labour and material cost of the repair itself may be considerably less than the cost incurred (in time and

transport) by the maintenance team travelling to make the repair.

Because of these problems, there are clear advantages in having a planned maintenance approach for pumps, and an appropriate organisational structure to carry this out.

c. Organisational Structure for Maintenance

Maintenance organisations comprise a number of levels or "tiers":

Tier 1 : a caretaker responsible for one pump (or several pumps)
Tier 2 : a skilled mechanic responsible for a number of pumps
Tier 3 : a maintenance and repair team for an area, which can be called in when required.

Training, resources and responsibilities of each tier vary with the type of pump and local conditions, but for rural water supplies the aim is to organise planned, preventative maintenance procedures which can be carried out successfully at tier 1 as far as possible, and failing that at tier 2. Similarly, after a pump breaks down, repairs should be carried out at tier 2 wherever possible, and the mechanic should have tools, spares and a bicycle or motorbike, to facilitate this. Tier 3 will only be called for in the case of major repairs calling for transport of heavy parts or lifting gear. This team will require four wheel transport.

3. HANDPUMPS

Handpumps are the cheapest, simplest means of raising clean water for domestic use.

However, a major difficulty with handpumps is that they break down frequently and it often takes a long time for them to be repaired.

It has been estimated that at any particular time over 30% of the handpumps installed in the world are out of action. Even the best pumps only last approximately twelve months before breaking down.

One of the reasons for this is the extremely heavy use a pump is subjected to during the course of its life. We imagine that a simple mechanism should work without problems, but a pump may be used by many different people to pump large amounts of water. For instance, a pump which serves 200 people will be operated about 4 million strokes per year.

It is difficult to design a pump for such heavy use, and even more difficult to "overdesign" it to reduce the need for maintenance. The strong, long lasting parts which this requires are also expensive. If the pump does break down, repairs are difficult and expensive (taking into account time and travel costs).

As a result, work by the World Bank has concentrated on the VLOM concept - Village Level Operation and Management of Maintenance. Some pumps come closer to meeting these ideals than others. In all cases, however, the aim should be to give as much responsibility as possible to the village caretaker and to provide him or her with the necessary training and tools.

Table 1 gives a typical basic schedule of maintenance tasks, which need to be assigned to the village caretaker or local mechanic as appropriate. Basic operations are to keep the pump and its surround clean, and to keep the pump properly lubricated with the recommended type and amount of oil and grease. Do not over-lubricate. It is also important to ensure that excess water drains freely from the pump surround, and flows to waste without creating an unhealthy muddy area around the handpump.

The popular India Mark II handpump is shown in Figure 1. This is a positive displacement type of pump for deep wells (water level in the range of 6m to 60m).

TYPICAL SCHEDULE FOR MAINTENANCE OF SIMPLE BOREHOLE PUMPS

Daily Tasks

1. Check that the pump is working satisfactorily.
2. Clean the well-head and drain.

Weekly Tasks

1. Thorough clean-up of pump well-head and surroundings.
2. Oil or grease all hinge pins, bearings and sliding parts, after checking that no rust has developed on them.
3. Record any comments from users about irregularities* in working (tightness of parts, leaks, fall-off in water raised): Correct these where possible.

Monthly Tasks

1. Check that all nuts and bolts are tight, and check that there is no evidence of loose connections on the pump rods.
2. Check for indications* of wear in the plunger and foot valves, noting any comments from users about any falling off in the water raised.
3. Carry out all weekly maintenance tasks.

Annual Tasks

1. Paint all exposed parts to prevent development of rust.
2. Repair any cracked concrete in the well-head and surroundings.
3. Check wear at handle bearings and replace parts as necessary.
4. Check plunger valve and foot valve; replace if found to be leaking.
5. Check the pump rod and replace any defective lengths or connectors.
6. Carry out all monthly maintenance tasks.

* Typical indications of problems are as follows:

A. Noisy working or tightness of parts usually indicates faults with the top-end mechanism. However, stiffness may be due to tight-fitting seals and noise may be caused by a badly fixed pump rod slapping against the side of the riser pipe.

B. If the pump delivers a reduced amount of water, this may be due to worn seals, or less often, to faults with valves or a leaking cylinder.

C. If the pump handle works easily but no water comes, it may be due to any of the factors listed in B, or to the well drying up, or to a blockage at the foot valve. If the pump handle moves with no resistance at all, it may mean the pump rod has broken.

Table 1. Typical schedule for maintenance of simple borehole pumps (adapted from Pacey, 1980)

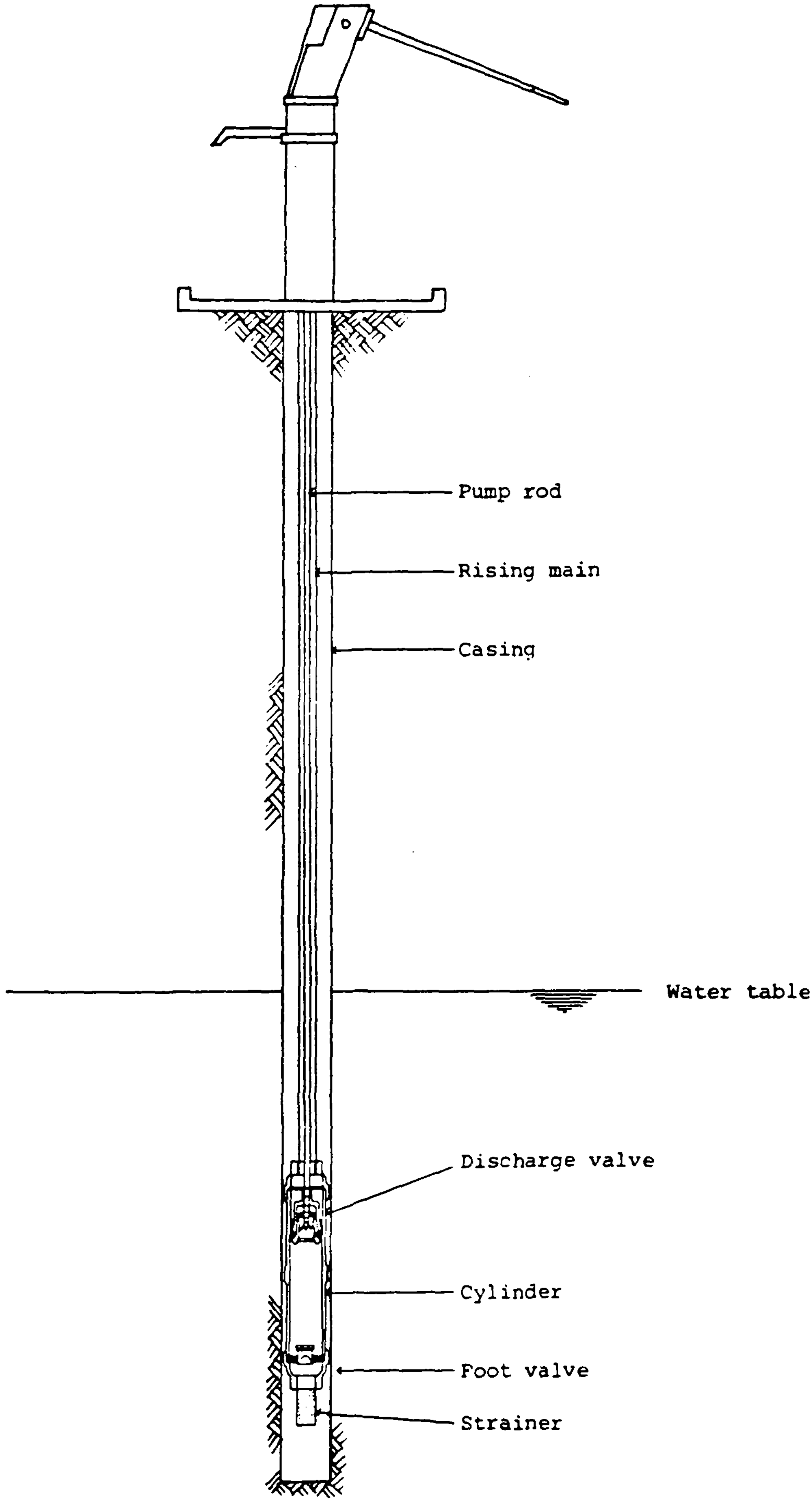

Figure 1. India Mark II handpump

4. MOTORISED PUMPS

a. Operation

The engine, transmission, pump, borehole and pipe form a mechanical system which will have different efficiencies under different conditions of speed, head and discharge. There will be one particular condition which gives the maximum efficiency, and the pump should be operated at, or close to, this condition whenever possible. It is important to keep records of fuel consumption, running speed (diesel engines) and output, and use these to monitor the performance of the pump system.

b. Maintenance Schedule

Manufacturers prepare operation and maintenance manuals for their equipment and it is essential to follow these in detail. A schedule of maintenance tasks for the pump should be prepared according to the manufacturer's instructions, and each task assigned to appropriate staff, who then need to be trained in the tasks.

Table 2 shows a typical preventative maintenance schedule. The next step is to identify the resources of manpower, tools and spares needed to carry out this programme, and arrange for these to be available.

Preventative Maintenance Schedule

Daily Tasks

1. Turn pump on/off as required.
2. Check pump for excess heat in motor or bearing.
3. Check controls for proper operation.
4. Check water level in well.
5. Check piping for leaks.
6. Check condensation in pump house.
7. Check oil level, pressure and fuel level of internal combustion engine.
8. Record water and electric motor readings.
9. Record system pressure.
10. Record unusual observations.
11. Record fuel used and hours run for internal combustion engine.
12. Correct problems identified.
13. Order parts which have a long delivery time.

Monthly tasks

1. Lubricate pump.
2. Check amperage on electric motor.
3. Report on water use for month.

Half-yearly tasks

1. Lubricate pump house door hinges.
2. Close and open gate valves in pump house.

Other tasks

1. Change oil, oil filters, fuel filters in accordance with manufacturer's instructions
2. Do preventative maintenance as specified by manufacturer.

Table 2. Preventative maintenance schedule for motorised pumps (Source: National Development Water Project)

c. Trouble Shooting

The manufacturer's manual will normally provide examples of observable symptoms of problems, together with possible explanations or causes of each. Table 3 gives an example of problem symptoms.

Check Chart for Centrifugal Pump Troubles

Ten Symptoms
Pump does not deliver water.
Insufficient capacity delivered.
Insufficient pressure developed.
Pump loses prime after starting.
Pump requires excessive power.
Stuffing box leaks excessively.
Packing has short life.
Pump vibrates or is noisy.
Bearings have short life.
Pump overheats and seizes up.

Table 3. Check chart for centrifugal pump troubles (Source: National Development Water Project)

A frequent cause of problems is misalignment of shafts during installation, leading to vibration and wear.

5. ELECTRIC MOTORS

Electric motors are easy to operate and need little maintenance if operated from a reliable electricity supply. However, in places with fluctuating supplies, it is important to ensure that the motor is not operated at low voltages, as this can easily cause serious damage. This is best done by fitting undervoltage relays or by the operator monitoring the voltmeter reading. Other points are listed below.

a. Lubrication

Ball and roller bearings must not be over-filled with grease as this causes over-heating and bearing failure. When a bearing is filled with grease take care to fill all the bearing space between the rolling elements, but the outer bearing caps should be only two-thirds full. When the motor is operating, a small amount of additional grease should be added every 2000 running hours.

Every two years completely renew the grease. Ensure that only grease recommended by the manufacturer is used.

For sleeve bearings or oil-filled thrust bearing, check the levels at frequent intervals and top up to the indicated level with the motor stopped.

Every six months completely change the oil. Ensure that only oil recommended by the manufacturer is used. Keep all covers closed and plugs tight.

b. Cleanliness

Except with totally enclosed motors, dust and dirt will be drawn into the motor by the rotor fan. This can lead to overheating and damage to the windings. Clean out any dust regularly, preferably by using a powerful suction cleaner. The use of a high-powered blower can lead to dust accumulating within the internal coils.

c. Temperature

Ensure adequate ventilation. The temperature rise of a normal protected motor is 21°C. If motors are to operate in ambient temperatures above 24°C the final temperature could be excessive unless high temperature windings have been specified, or motors with a lower temperature rise.

d. Single phasing

If a 3-phase motor is running and one phase becomes disconnected (eg, a blown fuse or bad connection), the motor will continue to run as a single phase machine but will take excessive current through the phase windings, leading to rapid burning out. If an attempt is made to start a motor under these conditions it will not rotate or, if it does, will only turn very slowly. The motor will make a loud humming noise and take extremely high currents from the mains, destroying the windings until the other fuses operate.

To reduce the risk of such a break in one phase of the supply, check that the circuit main fuses have a capacity of at least three times the load current of the motor, that the overload trips are correctly set and that protection is fitted to ensure rapid disconnection of the motor should there be reduced or nil voltage in one or more of the phases.

e. Direction of running

A three-phase motor may run in either direction when first connected. To reverse the direction of running, change over any two of the supply lines from the mains to the starter.

f. Safety

Electric current cannot be seen and represents a hidden danger which can easily kill or start fires if proper precautions are not taken, particularly in the presence of water. Particular points to note are:

- all major components (motor, pump and supporting structure) should be properly earthed, with all earth connections electrically bound together.
- protection equipment should be checked by a properly qualified electrician and kept in good condition, including effective trips or fuses on the live wires, suitably armoured cables, earthed and splash proof enclosures.

g. Fault Finding

A checklist is given in Table 4

Fault Finding on Electric Motors

Fault	Possible Cause	Remedy
1) Detection by sight:		
No rotation	Supply failure- either complete or single phase	Disconnect motor immediately (with a single phase fault, serious overloading and burn out could occur rapidly). Ensure that correct supply is restored to motor terminals.
	Insufficient drive power	Check starting power required and compare with motor rating, taking into account type of starter in use.
2) Detection by hearing		
Steady electrical hum	Running single phase	Check that all supply lines are alive with balanced voltages.
	Excessive load	Compare line current with motor rating. Reduce load or change motor.
	Reversed phase	Check connections in turn and correct.
	Uneven air gap between rotor and stator	Check with feelers. If due to worn bearings, fit new ones.
Pulsating electrical hum	Defective rotor	Check speed at full load. If it is low and there is a fluctuating current, the rotor could be defective.
Mechanical noise	Foreign matter in air gap	Check, dismantle and clean.
	Bearings damaged	Check with a listening stick - fit new bearings.
	Coupling out of line	Check coupling gap and realign.

3) Detection by touch

Vibration	Uneven foundations	Check level and alignment-realign.
	Defective rotor	As above for pulsating electrical hum.
	Unbalance	Uncouple from driven machine remove motor pulley or coupling. Run motor between each of these operations to determine whether imbalance is in the driven machine, pulley or rotor. Rebalance.
Frame heating	Excesssive load	Reduce load or change motor.
(NB: frame temperature will be	Foreign matter in air gap	Check, dismantle and clean.
approximately 10°C lower than winding temperature)	Excessive surrounding temperature	Check motor temperature rating.
	Partial short or open circuits in windings	Check with suitable meter.
Bearing heating	Too much/too little grease	Remove surplus/wash bearings and replenish grease.

Table 4. Fault finding on electric motors

6. DIESEL AND PETROL ENGINES

a. General

Both petrol and, more particularly, diesel engines need frequent maintenance using specialist skills. However, the general skills required are used for servicing and repairing motor vehicles, and are quite widely available.

Problems frequently arise with fuel supply for diesel and petrol engines, requiring action to ensure adequate supply of clean fuel (filter it before use) and prevent losses by pilfering or leaking fuel lines. Attention should also be paid to the air filter which is often not renewed as necessary, causing excessive engine wear.

b. <u>Operation</u>

i) Pre-Start-Up Procedure and Checks

Read the Operator's Manual.

Check that:

1) all holding-down bolts are secure;
2) guards on shafts, etc. are fitted;
3) engine is free to turn without obstruction;
4) levels of water, fuel and lubricating oil are correct;
5) fuel and oil systems are primed;
6) the surrounding area is clean and free from obstruction;
7) if fitted, batteries are filled, charged and connected;
8) control and decompressor levels are in the correct position.

ii) Start and Operation

The exact start and stop procedures will be given in the manufacturer's manual, where details will be given for a specific engine depending on the type of starter, size of engine, etc. The way in which an engine is then operated is common to almost all engines, in that the engine must be run on FULL LOAD. It must be made to operate at its rated capacity, and failure to do so will result in glazing of the cylinder bore, excessive oil consumption, and expensive remedial work. Running at light load is one of the most frequently encountered causes of running problems and premature engine failure.

The tightness of bolts, clearances, etc. must be checked after the first few hours, according to the manufacturer's instructions. The exhaust should be observed to be clear of soot when running at full load, and the engine should be carefully checked for oil, fuel and water leaks, undue vibration and unexpected or excessive noise.

c. <u>Maintenance and Trouble-Shooting (Diesel Engine)</u>

The following maintenance schedule is given as an example only, and will vary according to engine size, type of service, and manufacturer. The following schedule should not be considered exhaustive.

i) Routine Maintenance

Daily

1. Check supply of fuel oil.
2. Check level and condition of lubricating oil.
3. Check condition of air cleaner (very dusty conditions).

Every 125 hours

1. Check air cleaner (moderately dusty conditions).
2. Check for fuel and oil leaks - tighten nuts and fittings as necessary.
3. On high-speed engines - drain oil if it is thick and black - refill with correct grade and type.
4. Check safety and relief valves.

Every 250 hours

1. Drain lubricating oil and refill with correct grade and type.
2. Renew the fuel filter element if the fuel used is not perfectly clean.
3. Clean fuel injector nozzles if exhaust is very dirty.
4. Change lubricating oil filter.

Every 500 hours

1. Renew the fuel filter element.

Every 1000 hours

1. Decarbonise if engine shows loss of compression (or blow-by) past the piston. Otherwise do not disturb.
2. Adjust valve clearances.
3. Check oil feed unions.

Every 2000 hours

1. Decarbonise.
2. Clean the inlet manifold and exhaust system.
3. Examine the fan blades and clean.
4. Check for free working of the governor linkage and its adjustment.
5. Drain and clean fuel tank.
6. Check fuel pump timing.
7. Clean or replace the fuel injector nozzles and adjust pressure settings.
8. Clean cylinder and head.
9. Check lubricating oil pressure, and examine the pump and valves if necessary.
10. Renew the air cleaner element.

Every 6000 hours

1. Major overhaul.

ii) Trouble Shooting

Fault	Probable Cause	Rectification
Engine difficult to turn (manual)	Lubricating oil too heavy.	Drain sump, refill with correct grade.
	Incorrect decompressor clearance.	Adjust.
	Load not disconnected from engine.	Investigate.
Engine difficult to start	Lack of fuel.	Fill tank and bleed system.
	Air in fuel system.	Check and tighten all joints and bleed system.
	Defective fuel pump.	Overhaul or replace.
	Faulty injector.	Test or replace.
	Stop control incorrectly positioned.	Set in start position.
	Air cleaner or exhaust blocked.	Clean.
	Valve sticking.	Remove and clean.
Running below normal speed.	Engine overloaded.	Reduce load.
	Fuel system not primed.	Bleed and prime.
	Injection retarded.	Retime fuel pump.
Loss of power	Incorrect fuel.	Drain and refill.
	Choked air cleaner.	Change element.
	Choked fuel filter.	Change.
	Fuel injector not functioning correctly.	Test, replace if necessary.
	Fuel pump not operating correctly.	Replace.
	Incorrect tappet clearance.	Adjust.
	Choked exhaust.	Remove restriction.
Erratic, uneven running	Air in fuel system.	Check all fuel lines and connections - bleed system.
	Incorrect fuel pump timing.	Retime.
	Faulty injector.	Test and/or replace.

Table 5. Fault finding on diesel and petrol engines

7. BOREHOLES

A pump depends on good borehole conditions for it to work efficiently, and therefore poor pump performance, may in some cases, be due to problems with the borehole. Examples are as follows:

- reduced discharge or pumping of air, caused by low water level in the borehole

- sand in the water, caused by screen failure (this can lead to excessive pump wear if the pump continues to be used)

These examples reinforce the point made in Section 4, that attention must be paid to the whole system: engine, transmission, pump, borehole and pipe. The human element must also be stressed, particularly the importance of appropriate management of maintenance, in order to prevent pump failure.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE 4

PUMPS - INSTRUCTOR'S NOTES

1. INTRODUCTION

Both the instructor and the trainees should have a lot of experience to bring to this topic and it is important to draw on this and direct the module at the particular local situation and pump types.

2. MAIN TEACHING POINTS

The main messages are:

- each pump or related piece of equipment has its own requirements for operation and maintenance;
- O & M manuals provide detailed instructions on these requirements, and these must be followed closely;
- management arrangements for O & M are very important, and may determine how often a pump breaks down and how long it is out of service.

3. REFERENCES AND FURTHER READING

Arlosoroff, S et al, "Community Water Supply - the handpump option", IBRD/World Bank, 1987.

Austin, Vincent, "Rural Project Management" Batsford, 1984.

Fraental Peter, "Water-pumping devices", IT Publications, 1986.

National Demonstration Water Project, "Water for the World - Operating and Maintaining Mechanical Pumps", Technical Note No RWS 4.0.2, USAID, nd.

Pacey, Arnold, "Handpump Maintenance In The Context Of Community Well Projects", Revised edition, I T Publications, 1980.

4. VISUAL RESOURCES

Diagrams of pumps in use locally should be obtained and copied onto flipcharts or overhead projector transparencies. It would also be useful to borrow as many pump spare parts as possible to illustrate particular features.

5. DISCUSSION QUESTIONS FOR USE WITH PARTICIPANTS

Some examples of possible questions follow, but the instructor will be able to develop these for the trainees' own work situations.

What types of pumps does your organisation deal with?

Which pumps are covered by planned maintenance arrangements in the organisation, and which by unplanned maintenance?

For each type of pump, which personnel are involved in operation and maintenance? What are their respective jobs? Have they been adequately trained, ? and do they have the necessary facilities? How could improvements be made?

For each type of pump, what happens when the pump breaks down?

Where are the operation and maintenance manuals kept for the motorised pumps and engines?

What records of operation and maintenance are kept for each pump and engine? Can improvements be made?

6. FURTHER EXERCISES

The trainees should go through the o & m manuals for the main pumps, engines and motors and identify the most important checklists for each one.

A quiz could be held: "If this problem occurs, what are the possible causes?"

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 5
SIMPLE WATER TREATMENT

Objectives:

To familiarize participants with:

a. the reasons for treating water and in particular the advantages of selecting water sources that need no treatment;

b. the undesirable substances in water which should be removed to make it wholesome and palatable;

c. the processes by which water is treated for rural water supplies, and the measures required for satisfactory maintenance and operation, dealing in turn with -

- storage and sedimentation
- aeration
- filtration

and

- slow sand filtration

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE FIVE

SIMPLE WATER TREATMENT

1. WHY TREAT WATER?

Whenever water is provided for rural areas in developing countries there should be the minimum possible treatment. The best source is one which needs no treatment at all.

The trouble with treatment is that it requires looking after. If the treatment process, however simple it may be, does not receive adequate attention it will not function properly. Providing a piped water supply without adequate attention to operation and maintenance of the treatment plant may, in fact, lead to an increased danger to public health. If the raw water is contaminated with disease-causing organisms which are not properly removed, a large number of people can be infected at the same time. There is plenty of evidence of outbreaks of typhoid fever, cholera and hepatitis due to the breakdown of water treatment. Even in the USA 20% of water-borne disease cases have been attributed to deficiencies in the operation of treatment plants.

A survey carried out in one developing country showed that 80% of the water treatment plants studied were not receiving proper attention. This survey covered municipal plants and it is reasonable to assume that a higher proportion of small rural plants are not maintained efficiently.

Another disadvantage of providing treatment is the cost. Even if reliable staff are available for treatment plants, their salaries have to be paid. For some forms of treatment chemicals have to be provided and paid for. It is therefore important to consider all possible sources of water when a water scheme is devised. Providing a long pipeline from a distant source of good quality water may well be cheaper in the long run than using a nearby source whose waters require treatment.

In addition, many treatment processes require large amounts of imported equipment, and some need imported chemicals. A reliable supply of chemicals (whether imported or locally produced) presents considerable difficulties in many rural areas.

Rainwater, highland stream water and some groundwater is generally suitable for drinking, and little or no treatment is required. Water from village ponds, lowland streams and some underground sources may contain a variety of impurities which must be removed to make the water acceptable.

2. WHAT IS WATER TREATMENT?

Treatment largely consists of preparing good water by the removal of undesirable substances by a variety of processes.

Water intended for human consumption should be free from organisms and from concentrations of chemical substances that may be a hazard to health. In addition, supplies of drinking water should be as pleasant to drink as circumstances permit.(World Health Organization)

Drinking water should be wholesome and palatable.

+ To be wholesome water must be free from disease organisms, poisonous substances and excessive amounts of mineral and organic matter.

+ To be palatable it must be significantly free from colour, turbidity, taste and odour and well aerated.

The undesirable substances include the following -

+ Disease-causing organisms (pathogens). Most of these are derived from human excreta, although guinea-worm disease is transmitted when eggs are discharged into water from someone suffering from the disease. Evidence of faecal pollution of water is obtained by looking for the presence of E coli.

+ Toxic substances. Chemical or poisonous substances are often the result of industrial pollution, and so are unlikely to affect rural water supplies. Maximum levels of arsenic, lead, mercury and other toxic substances are given in the WHO Guidelines for Drinking Water Quality.

+ Mineral matter. Drinking water should not contain any settleable suspended solids and should be clear, although clear water is not necessarily fit for human consumption. Clear water is said to have low turbidity.

+ Salinity. The main effect of salinity is on taste which is discussed below. Excessive salinity, especially if present as magnesium sulphate, can have a laxative effect. Local people can become accustomed to water with more than 4000 mg/l total solids, but the effects are often distressing for visitors.

+ Hardness. Carbonates and bicarbonates of calcium and magnesium cause hardness. Hard water requires more soap to form a lather than soft water. Hardness also causes scale formation in pipes and fittings.

+ Organic matter. If organic matter is of vegatable origin it may be quite harmless. [For example, tea may contain 2000 mg/l of organic matter; wine and soup may have higher concentrations.]

+ Taste and odour. Objection to taste and odour is to some extent subjective. For example, the concentration of iron which makes water unacceptable varies from 0.04 mg/l to over 200 mg/l. Odours are stronger at higher temperatures. Even if tastes and odours are harmless in themselves, consumers often interpret them as evidence of pollution and consequently use other sources which are inferior from a health point of view.

+ Colour. Iron and manganese are the main causes of colour, although organic material discolours some water. Strong colour makes water unsatisfactory for washing clothes and is especially objectionable when textile-processing is carried out.

The most common processes by which water is treated for rural supplies are -
+ storage and sedimentation
+ aeration
+ filtration
+ disinfection (dealt with in Module 6)

3. STORAGE AND SEDIMENTATION

Tanks, reservoirs or ponds through which water passes slowly are often provided for the settlement (or sedimentation) of suspended matter and the reduction of turbidity. Occasionally, concrete sedimentation tanks of conventional design are constructed. The rate of settlement of solids depends on the size of the particles and may only amount to a few millimetres an hour for fine clays and colloids unless coagulation is aided by chemicals such as alum.

Large reservoirs or storage basins reduce turbidity by sedimentation, but their primary purpose is usually to enable water to be drawn throughout the year when the rate of flow of water in the stream is variable. They also balance the quality by mixing highly turbid floodwaters with clear settled water. Another benefit of storage is due to the environmental conditions created, which are unfavourable to micro-organisms arising from pollution, including pathogens. Colouring matter in the upper part of reservoirs is bleached by sunlight, and sunlight also has a germicidal action in the top three metres or so of waters with low turbidity.

Routine maintenance of reservoirs should include the removal of plants growing on sloping banks by cutting them down or applying herbicides under careful control.

Algae and slime growths on vertical walls of open basins may be minimized by coating the part of the walls extending from above the normal water level to a depth of 0.6 metres below the water level with a mixture of lime and copper sulphate. The mixture may be made by adding 100 grams of copper sulphate to 10 litres of water in a suitable container and then adding 100 grams of hydrated lime. As copper sulphate corrodes galvanized iron, the mixture should be prepared in a wooden or plastic bucket or an earthenware container. It can be applied to the walls with a large whitewash brush.

Unless mechanical equipment is provided for sludge removal, the depth of sludge should be measured regularly. When the depth exceeds that for which the storage basin is designed, sludge should be removed.

Storage basins usually have waste drains with valves. Opening the valves discharges water with sufficient force to remove sludge from near the drain. Other sludge can be washed towards the drain using a hose-pipe. Alternatively, dried sludge can be dug out and removed by wheelbarrows or headpans once the water has drained from the basin.

Engineers who design basins should pass on clear instructions regarding the maximum depth of sludge which should be permitted. If sludge becomes deeper than the design depth the efficiency of the sedimentation process is reduced.

In some plants <u>coagulation</u> (addition of chemicals such as alum) and <u>flocculation</u> (gentle agitation) are used to cause fine material to coalesce so that they precipitate in the sedimentation tanks. Special care is needed in the storage and handling of chemicals. Instructions provided by equipment manufacturers should be followed strictly.

4. AERATION

Water that has no dissolved air (hence no dissolved oxygen) has a flat taste. Aeration gives it a fresh taste, and also releases some substances that give the water taste or odour, for example hydrogen sulphide and some volatile products of decomposition.

Aeration also makes water less corrosive by removing carbon dioxide. Where natural water has a high iron or manganese content the greatest benefit of aeration may be oxidation. In the presence of oxygen, soluble ferrous salts in alkaline water are reduced to insoluble ferric oxide, which can be settled out in sedimentation basins.

The methods of aeration which are commonly used for rural treatment plants are:

spray aeration
cascades
inclined aprons
tray aerators.

1. Spray aeration
When water is under a pressure head of 7 metres or more, as when it is discharged from boreholes, it can be sprayed into basins through nozzles of special design.

2. Cascades
Water is allowed to fall down one or more steps, usually made of concrete. A variation has a series of concentric platforms which form steps.

3. Inclined aprons
Water passes down an inclined channel fitted with studs or plates so that the flow is turbulent with a zigzag movement.

4. Tray aerators
Water falls through small holes (5-12mm diameter) in a series of trays. The trays may be filled with coke or gravel of about 50mm size.

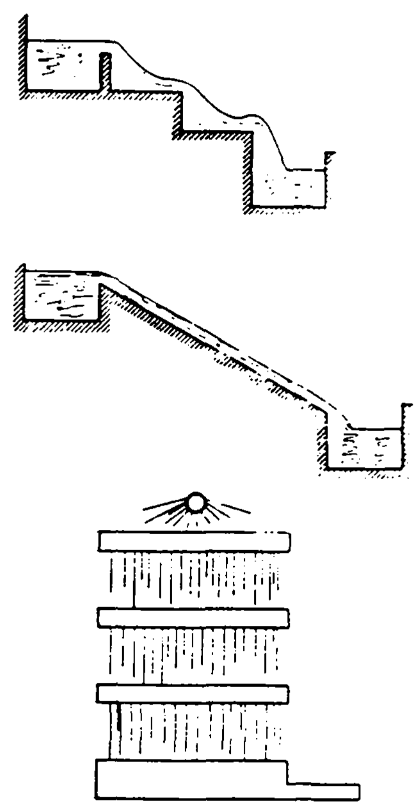

Figure 1. Aerators

A hand-operated unit for the removal of iron and manganese has been developed in India. The unit consists of four cylinders placed on top of each other, as shown here. Water collects in the bottom cylinder and is withdrawn as required through the tap.

The gravel in the top two cylinders becomes coated with oxides of iron which help in the further oxidation of iron and manganese.

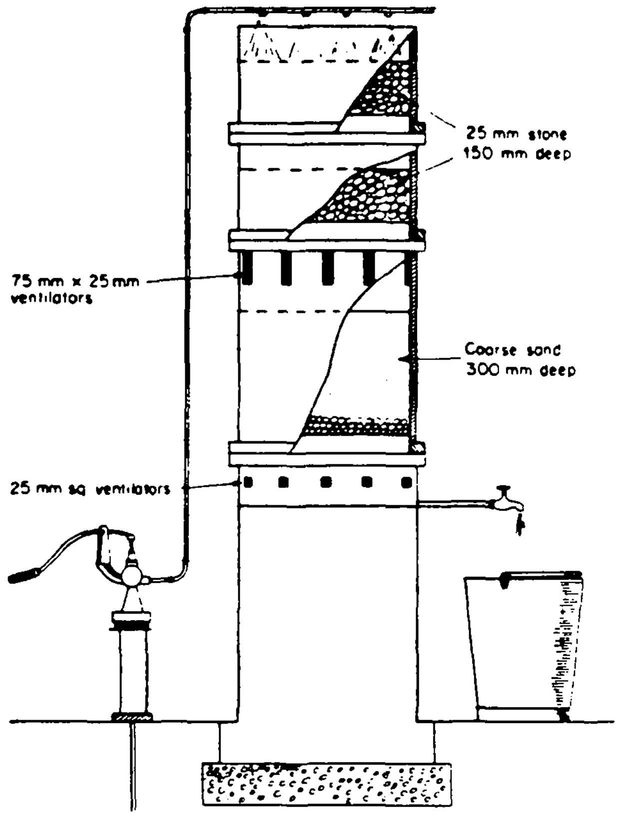

Figure 2.

The main tasks when operating aerators are keeping the equipment clean and controlling the flow of water to give maximum water surface and maximum agitation of the water.

When the rate of flow is below the design level of spray aerators some of the nozzles should be isolated so that the reduced flow passes through fewer nozzles and the pressure remains enough to produce a fine spray through those still in use. No change of operating procedure is required with the other types of aerator. Lower flow rates result in a greater ratio of surface area to volume and the aeration efficiency is improved.

Operators may be able to improve the performance of badly-designed aerators. The following are examples of how this can be done.

+ The position of nozzles may be changed to ensure that the spray from spray aerators covers the whole of the basin and that sprays from individual nozzles do not interfere with the spray from other nozzles.

+ A shallow layer of gravel may be placed on the steps of cascades.

+ The position of obstructions on inclined aprons may be altered, or additional obstructions may be provided.

\+ Gravel or coke (if not already provided) may be placed on tray aerators. *This increases the surface area of water* in contact with air and the time during which there is contact.

Slime and algal growths on the surfaces of aerators should be removed periodically, using copper sulphate or a mixture of lime and copper sulphate (like that used for clearing slime on the walls of open basins, as described above).

5. FILTRATION

Filtration is the most important treatment process. There are several methods in common use, including the following.

a. Candle filters, such as the Berkefeld shown here, have candles that are often made of diatomaceous earth. The pores of the material forming the candles are small enough to retain bacteria. The candles should be thoroughly cleaned and boiled every few days. The surface of some candles is coated with a silver catalyst which kills bacteria. Such filters only need cleaning when they become clogged.

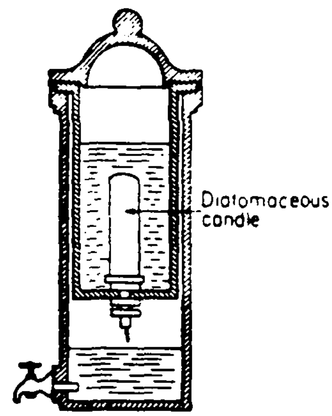

Figure 3.

b. Rapid filters are commonly used for the treatment of urban water supplies. Water is passed through a bed of coarse sand which retains suspended solids. Flow may be by gravity through an open bed or under pressure in a closed vessel. The solids are removed from the bed by backwashing which may be assisted by blowing air through the bed. Backwashing has to be done carefully and is usually necessary every day. The process is therefore unsuitable for rural supplies.

The upper part of Figure 4 shows a rapid sand filter under normal operating conditions. The lower part of the drawing shows the filter being backwashed.

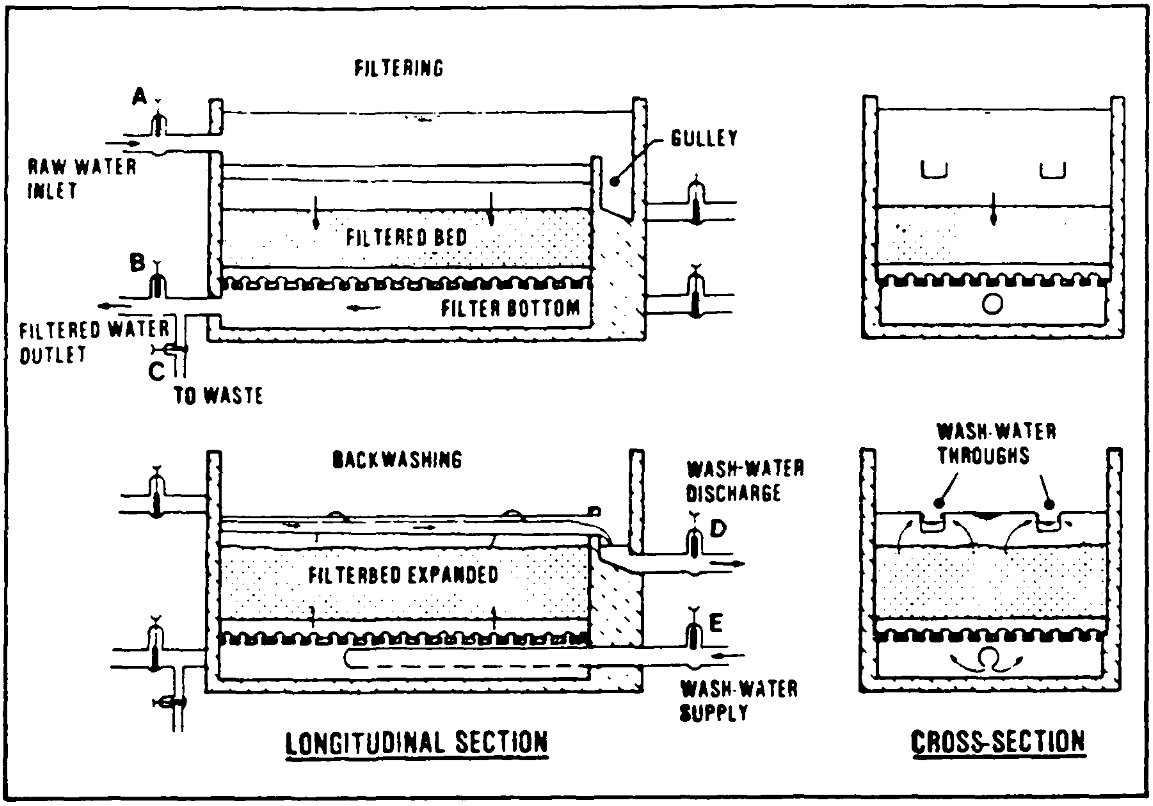

Figure 4. Rapid sand filter

c. Slow sand filtration is generally the most appropriate process for village supplies, and therefore justifies special attention.

6. SLOW SAND FILTRATION

Water flows by gravity through a bed of fine sand. In the upper layers of the sand several physical and biological processes occur, resulting in the removal of suspended matter, including bacteria and most viruses. The filtered water is therefore of very good quality and is fit to drink.

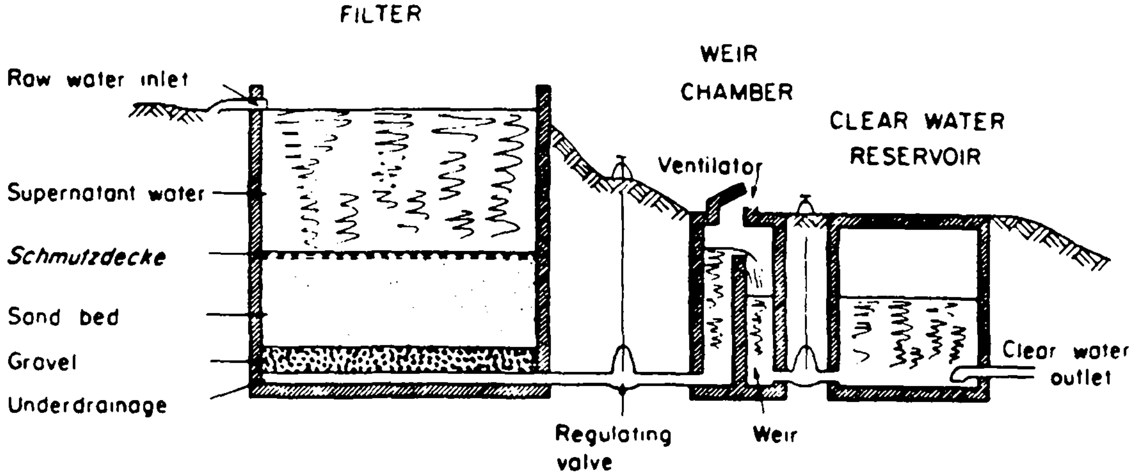

Figure 5. Slow sand filter

Above the bed is a reservoir in which the water is stored for up to twelve hours, undergoing the type of treatment which occurs in a storage basin. Heavy solids settle and light solids coalesce. Bacteria are reduced. Algae grow during daylight, increasing the oxygen content of the water. Some chemical oxidation of organic matter also takes place.

At the top of the sand bed a mat called a schmutzdecke forms. This consists of algae, plankton, bacteria and other forms of life and is very active. It breaks down organic matter in the water and a great deal of inorganic matter is retained by straining. As the schmutzdecke develops there is more resistance to the flow of water through the filter.

Therefore, during operation the flow must be controlled to make sure that there is a constant output of water. This may be done by valves in the inlet or outlet pipes. With a new filter, or after the filter has been cleaned, the valve is partly closed and then it is gradually opened as resistance to flow increases.

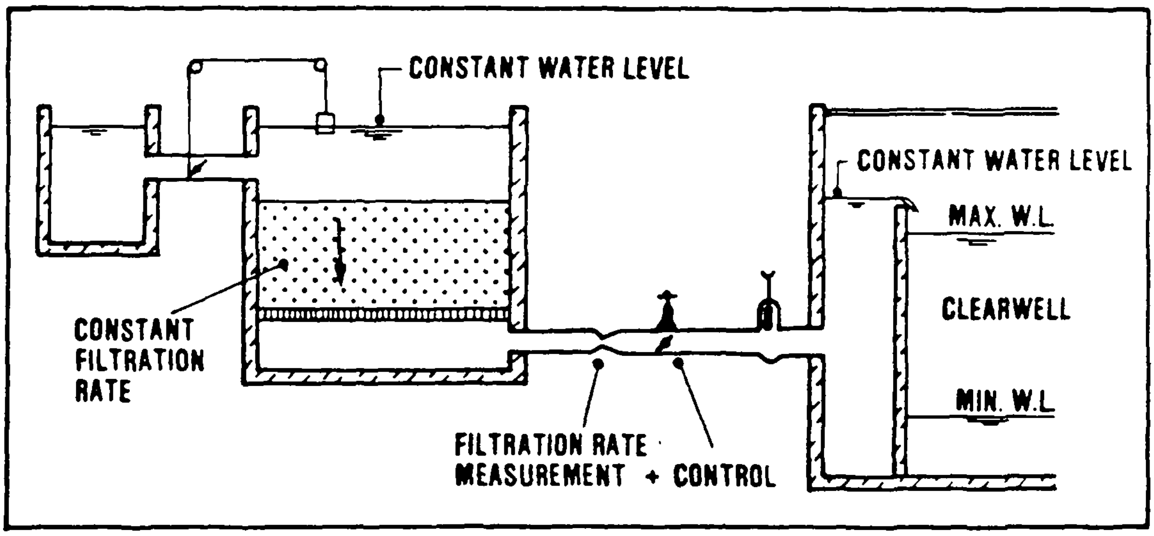

Figure 6.

Another regular activity should be the removal of any floating matter such as leaves from the surface of the water. Some filters have a channel built to take the scum away, although more often the material is removed with rakes.

Maintenance of slow sand filters is simple, and is only required after several months of operation. When the schmutzdecke is so developed that the required flow cannot pass through, even with the valves fully open, a thin layer is removed using flat shovels. The water level has to be lowered. The procedure described below applies to the type of filter shown in Figure 7 and is slightly varied for different arrangements of the inlet and outlet pipes and valves.

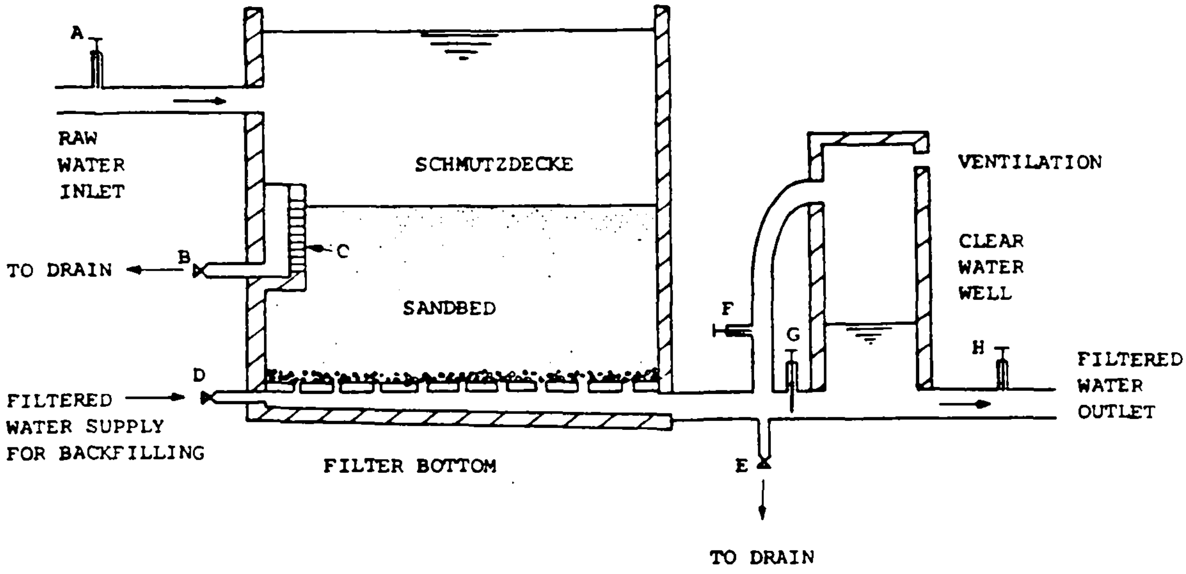

Figure 7.

Under normal operating conditions valves A or F control the rate of flow; valves B, E and G are closed. The stop logs which form a weir at C are removed as necessary so that the top of the weir is at the level of the top of the sand.

When the filter is cleaned the supply of water to the filter is stopped by closing valve A. This is often done in the evening and water continues to pass through the filter, going out through valves F and H during the night. Some hours later (for example next morning) valves F and H are closed and the water level is further lowered to the top of the sand by opening valve B. Valve E is opened for a short time to allow water to drain out of the top 20mm or so of the sand. Then 15mm to 20mm of the schmutzdecke is carefully removed using flat shovels. When cleaning is completed valve B is closed and filtered water is slowly admitted through valve D until the level of the water is about 100mm above the top of the sand. Then valves A and E are partially opened to allow flow through the filter at about a quarter of the normal rate. During the next twelve hours or so the rate of flow is gradually increased to normal. After another twelve hours or more valve E is closed and valve H is opened.

Sand removed in the schmutzdecke is often discarded or used for filling low-lying land. In some places the sand is washed so that it can be used again. Washing can be done by hosing a heap of sand on a concrete platform. Equipment for cleaning sand is also available, but is generally not used in rural areas.

If the filter bed is out of use for a long time the clear water well should be drained through valve G during the filter cleaning operation. This has to be done when new sand is added to the bed.

When a bed has been cleaned so many times that the depth of the bed has reached its lowest allowable level, clean sand has to be added. For example, the initial depth may be 1.2 metres and the minimum depth may be 0.7 metres, allowing 500mm to be removed. Thus 15mm - 20mm of schmutzdecke can be taken off about thirty times before new sand has to be added.

The clean sand is placed under sand already in the filter so as to preserve the active organisms on which the filter depends for treatment. The method usually employed is to remove the sand in a trench about 300mm deep across one end of the bed and put it beside the filter. New sand is put in the trench. A second trench is then dug alongside the first one. Sand taken from the second trench is placed on top of the new sand in the first trench. This process continues to the other end of the bed. The sand which was taken from the first trench is then put above the new sand in the last trench.

Pretreatment by HRF filters

Slow sand filters can easily deal with raw water that has a low concentration of suspended solids (low turbidity). If the raw water has high turbidity the filter runs are very short and some form of pre-treatment has to be provided. Plain sedimentation or prolonged storage reduce suspended solids, but the reduction is usually not sufficient for satisfactory slow sand filter performance. Chemical flocculation and rapid sand filtration, although commonly used for urban water treatment, are generally not suitable for rural conditions.

However, a horizontal flow roughing (HRF) filter is both simple to operate and is effective in reducing turbidity. The filter normally has three or more compartments filled with gravel. Coarse gravel (15mm - 20 mm) is placed in the first compartment, fine gravel (5mm) in the last compartment and medium gravel in intermediate compartments. Before roughing filters are used they should be completely filled with gravel, which is then washed, the wash water passing out through drains in the bottom of the filter.

Most HRF filters discharge over a fixed weir. When the filter is clean the water level near the inlet end is only a few millimetres above the level of the water surface over the weir. As the filter becomes clogged with suspended solids the water level near the inlet rises. It should be checked regularly, and should never be allowed to rise above the top of the gravel. When the water level approaches the top of the gravel the filter should be cleaned hydraulically. The filter should also be cleaned hydraulically just before the rainy season, as raw water is likely to have a heavy load of solid matter as stream levels rise at the start of the rains.

Hydraulic cleaning is carried out by passing water at a high rate from the inlet and out through the drains. The drains should be used in turn, starting with the one nearest the inlet. When drainage water becomes clean at the first drain the process is repeated with the other drains, moving to the drain nearest to the outlet (that is, the drain under the compartment containing fine gravel).

Manual cleaning of gravel is necessary if an HRF filter has no drains or if hydraulic cleaning fails to remove solids around the gravel. Failure of hydraulic cleaning may be due to accumulation of jelly-like organic matter. Manual cleaning is normally too time-consuming for the caretaker to undertake alone; the whole community may assist, or the work given to a contractor. Gravel has to be removed (care being taken not to mix grades) and then washed, seived and returned.

When refilling a HRD filter after cleaning the rate of flow should be about half the normal through-flow until water has filled the filter to about a third of the normal level. The rate can then increase to the normal through-flow rate and for the final one-third of the depth may be at a rate in excess of the through-flow rate (for example one and a half times that rate).

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE FIVE - INSTRUCTOR'S NOTES

SIMPLE WATER TREATMENT

1. INTRODUCTION

This module will be taught as a lecture with demonstrations. It should be followed by visits to water treatment works in order to consolidate what has been taught.

2. INSTRUCTIONAL AIDS

The following should be provided to help demonstrate some of the treatment processes and equipment.

a. A glass or transparent plastic receptacle containing water with finely-divided suspended solids. This should be shaken so that the solids are evenly dispersed throughout the water and then left so that students can see how solids settle.

b. The candle of a Berkefeld or similar household filter.

c. Large-scale drawings of filters (as in Annex A to these Notes, which are reproduced to a smaller scale on pages 7 and 8 of the Student's Notes). These can be reproduced as wall charts or overhead transparencies.

d. Samples of fine and coarse sand to show what is suitable for slow sand filters.

3. TOPICS FOR DISCUSSION

At the beginning of the class, the instructor should find out the answers to the following points through discussion with the students.

1. With which types of water treatment are the students familiar?

2. What experience have they had of good and bad operation in water treatment plants?

3. What experience have they had of good and bad maintenance?

4. To what extent was poor operation and maintenance due to inappropriate selection of treatment processes?

5. To what extent was poor operation and maintenance due to operators' lack of understanding of the treatment processes?

6. Check the student's understanding of the treatment processes by asking pertinent questions and use their misunderstanding as an introduction to an explanation of the processes. If the students already have a good understanding of the various treatment processes, the class can be used to discuss management problems in water treatment works and their solutions.

3. VISITS TO TREATMENT WORKS

The training programme should always include a visit to a water treatment works. If possible, several plants should be visited, preferably going first to the best designed, operated and maintained works. Then less satisfactory works should be examined.

At the good works the programme instructor or members of the works staff should explain all processes and point out what has to be done to operate and maintain the works.

For the visits to unsatisfactory works the students might go round the works in groups of two or three for a limited time (say half an hour). Each group should make notes of deficiencies in operation and maintenance.

This might be run as a competition. When the groups gather together at the end of the set time their notes could be passed to another group for checking. Deficiences that have been noted should be read out, each group in turn. Points can be scored for the total number of deficiencies noted, the instructor being the judge as to whether a deficiency is worthy of a point. An alternative method of marking is to award points for a deficiency noted by one group but not by any other group.

Although the instructor should be the final judge regarding award of points, there should be plenty of discussion before he gives his verdict. Discussion about the operation and maintenance of the plant (or questions by the instructor with answers by nominated students) is important. Students should be required to decide for themselves whether what they see is satisfactory.

Noting deficiencies is not enough. It must be followed by recommendations (based on full discussion) about how the operation and maintenance can be improved, noting any constraints (such as inaccessibility, quality of raw water, unreliable electricity supply and difficulties in obtaining chemicals and other supplies.

4. FURTHER READING

COX C. R. - Operation and control of water treatment processes. (World Health Organization, Geneva, Switzerland, 1969)

HOFKES E. H. - Small community water supplies - technology of small water supply systems in developing countries. (International Reference Centre for Community Water Supply and Sanitation (IRC), The Hague, Netherlands, and John Wiley & Sons, Chichester, England, 1983.

PICKFORD J. - Water treatment in developing countries. In 'Water, wastes and health in hot climates', edited by Feachem, McGarry and Mara. (John Wiley & Sons, London, 1977)

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 6
SIMPLE DISINFECTION

This module demonstrates the importance of effective disinfection of potable water and the need for disinfection as one stage in the water treatment process. Factors that may influence the disinfection methods are mentioned briefly. Various methods are available for the disinfection of water and this method concentrates on the use of Chlorine and Chlorine compounds, which are used extensively. Practical advice is also provided on the selection of Chlorine compounds for disinfection of water; and recomendations are made as to how these compounds may be used to add suitable doses of Chlorine to water supplies in order to make waters safe to drink.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE SIX

SIMPLE DISINFECTION

1. INTRODUCTION

Various water treatment processes other than disinfection contribute to improving the quality of water and to making water safer to drink. Disinfection is nevertheless a very important stage in the final treatment of potable water. The purpose of disinfection is to reduce to a safe level the number of organisms present in water that is to be used for domestic purposes. Disinfection may be needed for three reasons:

(i) the water source may be polluted;
(ii) the water may become polluted during storage; and
(iii) the water may become polluted during distribution.

Several forms of disinfection techniques have been developed for use in a variety of different situations. Some of these may be effective at just one point, making the water safe at the point of disinfection, but providing no safety against possible subsequent pollution. Other disinfection methods may be effective beyond the point at which the disinfection is applied; this gives some protection against later contamination.

For disinfecting community water supplies, the most common substances used are:

a. Chlorine and Chlorine compounds, and
b. Ozone.

Other forms may be used to suit special circumstances, such as emergency situations, to provide additional precautions, or for very small community water supplies. Some of these methods are:

a. Boiling of water (in emergencies, or for extra precaution),
b. Radiation (for small supplies),
c. Addition of Silver (for individual household use),
d. Addition of Iodine (in emergencies),
e. Addition of Potassium Permanganate (for extra precaution).

2. FACTORS THAT MAY AFFECT THE DISINFECTION PROCESS

The rate at which disinfection takes place depends upon a number of factors. Some of these are mentioned briefly below.

a. Time - Disinfection will cause the numbers of bacteria to decrease rapidly at first, but then more and more slowly as time passes. The disinfection rate itself depends on other factors (such as temperature, disinfecting dose applied, etc.)

b. Temperature - Disinfection, which kills micro-organisms by causing chemical damage to them, will become more rapid as temperatures are raised.

c. Disinfection dose - The higher the dose of the disinfecting agent, the more rapid (or more complete) the disinfection will be.

d. Age of micro-organisms - Older organisms have thicker cell walls than younger organisms and are more resistant to disinfecting techniques.

e. pH - Any changes of pH from normal (making conditions more acid or alkaline) will make the environment more hostile to micro-organisms and are likely to benefit the disinfection process.

f. Chemicals - The presence of certain chemicals may cause reactions that reduce the effectiveness of the disinfectant.

3. THE VALUE OF CHLORINE AS A DISINFECTANT

The most commonly used disinfectant worldwide is chlorine, either as a gas or in the form of chlorine-based compounds. Chlorine is a very strong oxidant (ie. it readily causes substances to combine chemically with oxygen), and while disinfecting water it will indiscriminately oxidise any organic matter present in it. Because it is such a powerful oxidant, great care must be taken in handling any chlorine-based products. As a liquid, chlorine can cause severe burns to the skin; as a gas it can cause burning to the throat and lungs if inhaled, probably with fatal results. It readily absorbs moisture from the atmosphere, and then becomes highly corrosive.

In most situations, chlorine is the disinfecting agent that most closely satisfies the requirements of chemical disinfectants, namely:

(i) Quick and effective at killing micro-organisms.

(ii) Readily soluble at the concentrations needed for disinfection.

(iii) Tasteless and odourless at the concentrations required.

(iv) Non-toxic to human life at the concentrations required.

(v) Easy to handle, transport and apply.

(vi) Easy to detect, and concentrations easy to measure.

(vii) Capable of providing protection against later contamination.

(viii) Readily available.

(ix) Cheap.

4. DOSAGE OF CHLORINE

The amount of chlorine needed to disinfect water will vary from source to source. Waters should be clear, and free from organic matter and suspended solids.

When chlorine is added to water, some is used immediately to oxidise any organic matter and to kill bacteria in the water. Any that is not used straight away remains in solution in the water as 'residual chlorine' and protects against any possible future contamination of the water. There is no purpose in adding too little chlorine to a water, because the chlorine will be used up in oxidation of organic material, and there may be insufficient chlorine to kill any bacteria present. Disinfection is performed by any chlorine that remains after organic matter has been oxidised, and is therefore carried out by the last, not the first, few parts per million of chlorine in the water. A sufficient quantity of chlorine should be added to leave an adequate chlorine residual in the water. The residual chlorine level should not, however, be so great as to cause consumers to complain about the taste of chlorine in the water.

Applied chlorine dosage rates are usually in the range 0.5 to 2.0 mg/l, depending upon the initial quality of the water. A suitable contact time following addition of chlorine should be provided to allow the water to be fully disinfected before it reaches any consumers. Contact times are between 10 and 30 minutes, with a time of 30 minutes being recommended. After this contact time the water should have a chlorine residual of 0.2 to 0.5 mg/l or more.

Higher chlorine doses may be necessary for disinfecting new water mains, new wells or reservoirs, or other items that may have been contaminated. Samples of water should be taken immediately after disinfection to confirm that no coliforms are present.

New water mains need to be disinfected prior to commissioning, and older mains should be disinfected following repairs or after any major cleaning programme if they are found to have been contaminated. First of all the pipelines should be flushed out with clean water and a foam swab passed through the pipe to remove slime, dirt and deposits. Pipelines may then be disinfected by filling them with water containing chlorine at a concentration of at least 20 mg/l (50 mg/l is frequently used) and leaving this in the pipeline for not less than 24 hours before draining the chlorine solution away.

Wells, reservoirs and storage tanks should also be disinfected before being put into service following construction, repairs, cleaning or maintenance. The walls should be brushed down as thoroughly as possible using a strong chlorine solution containing between 50 and 100 mg/l of chlorine. Prior to this, reservoirs and storage tanks may be hosed down using high pressure water jets. Following cleaning, the well, reservoir or tank should be filled with water containing at least 20 mg/l of chlorine and left to stand for not less than 24 hours before the contents are drained away to waste. The tank should then be refilled with fresh water to remove any chlorine that may create undesirable tastes in the water.

5. CHLORINATION PRACTICE

Some basic definitions that refer to chlorination practice are given below. Assuming that a sufficient dosage of chlorine is added to water, the chlorine may be used in a variety of different ways. Some chlorine will react immediately to oxidise any organic matter in the water. The organic matter may include some bacteria and living micro-organisms, which will be killed. Any remaining chlorine will remain in solution in the water, either as dissolved chlorine gas (Free Available chlorine) or in the form of chlorine-based compounds (Combined Available chlorine) created by the reaction of the chlorine with other chemicals (notably ammonia) present in the water. See Figure 1.

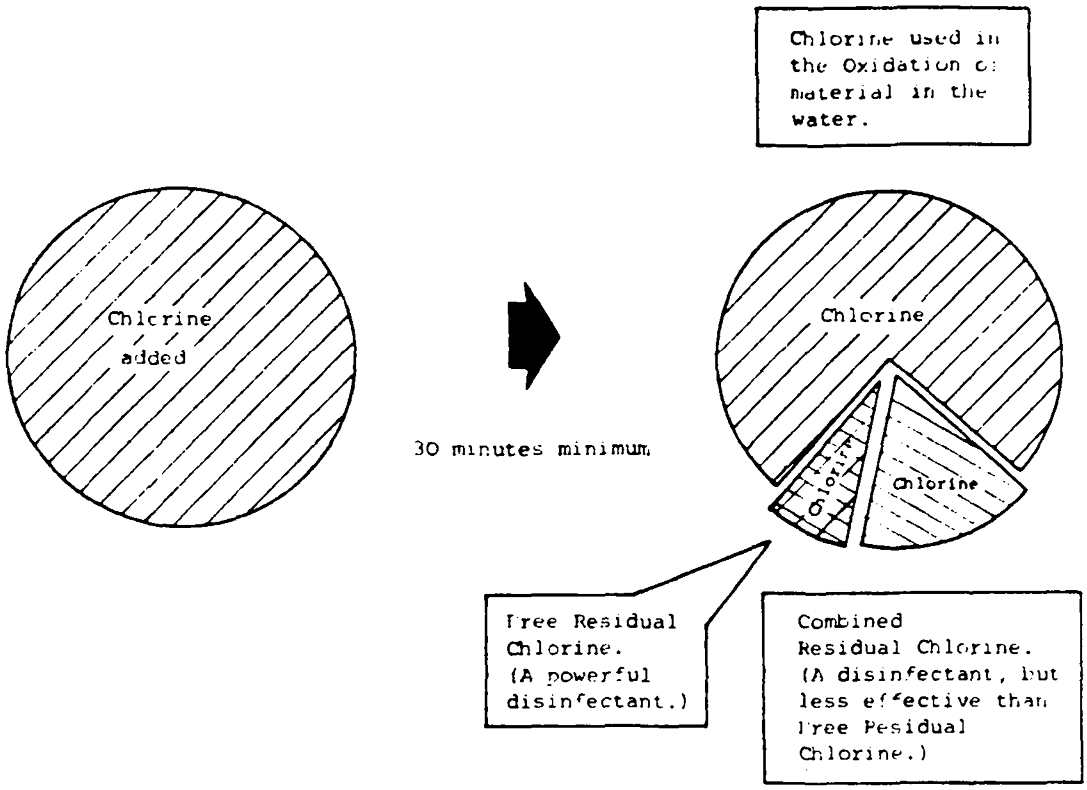


Figure 1.

Chlorine requirement. The chlorine requirement of a water is the quantity of chlorine that is needed to disinfect the water, oxidise material in the water and maintain the desired chlorine residual after a specified contact period.

Residual Chlorine. Chlorine present in water following an initial contact period is able to provide a residual (or long-term) disinfecting action on the water. The residual chlorine may be described in three ways; free available chlorine, combined available chlorine and total residual chlorine. Free available chlorine has good disinfecting properties; combined available chlorine has poorer disinfecting properties but a longer residual disinfecting period. Total residual chlorine is the measure of the total quantity of chlorine present in both forms of free and combined available chlorine.

6. MEASUREMENT OF RESIDUAL CHLORINE LEVELS IN WATER

The importance of chlorine as a disinfecting agent for water, and the need to monitor residual chlorine levels in potable water, has led to the development of several techniques to enable residual chlorine levels (free, combined and total) to be measured. Colorimetric methods are widely used, for which the water containing the chlorine is mixed with other chemicals to produce coloured solutions. The intensity of the colour depends upon the concentration of residual chlorine present, and the colour intensity may be measured in a variety of ways. The colour is often campared visually with reference colours, or the amount of light absorbed by the coloured sample may be measured with a spectrophotometer.

Several alternative forms of colorimetric methods may be used. The best known are the DPD (Diethyl-para-Phenylenediamine) method, and the Orthotolidine method. The latter method is seldom used because Orthotolidine has been found to cause cancer. Addition of Orthotolidine to water containing chlorine results in a straw yellow colour, and addition of DPD to water containing chlorine produces a pink colour. The DPD method is the only colorimetric test method able to distinguish between the different forms of residual chlorine present.

7. CHLORINE GAS

Chlorine gas is a yellowish green gas that is denser than air. It may be purchased in cylinders containing liquified gas at high pressure (containing about 30 kg of liquid chlorine) or drums (containing about 860 kg of liquid chlorine). Chlorine gas may also be produced on site by passing an electric current through a solution of salt in water.

Chlorine should never be injected into water directly from cylinders or drums. Direct injection is a dangerous practice and it is not possible either to control or know with any accuracy how much chlorine is being applied. In all usual situations it is necessary to use chlorinating equipment that controls and measures the doses of chlorine applied.

The chlorine dose is usually applied to the water to be disinfected by being sucked into the water at a narrowing of a pipe, known as a Venturi constriction, shown in Figure 3. The narrowing of the pipe causes the speed of the water to increase and its pressure to be reduced, so allowing chlorine to be sucked in. Following the addition of the chlorine, thorough mixing is necessary to ensure that the chlorine is uniformly distributed through the water. Figures 2 and 3 illustrate typical items of equipment for use when disinfecting water with chlorine gas.

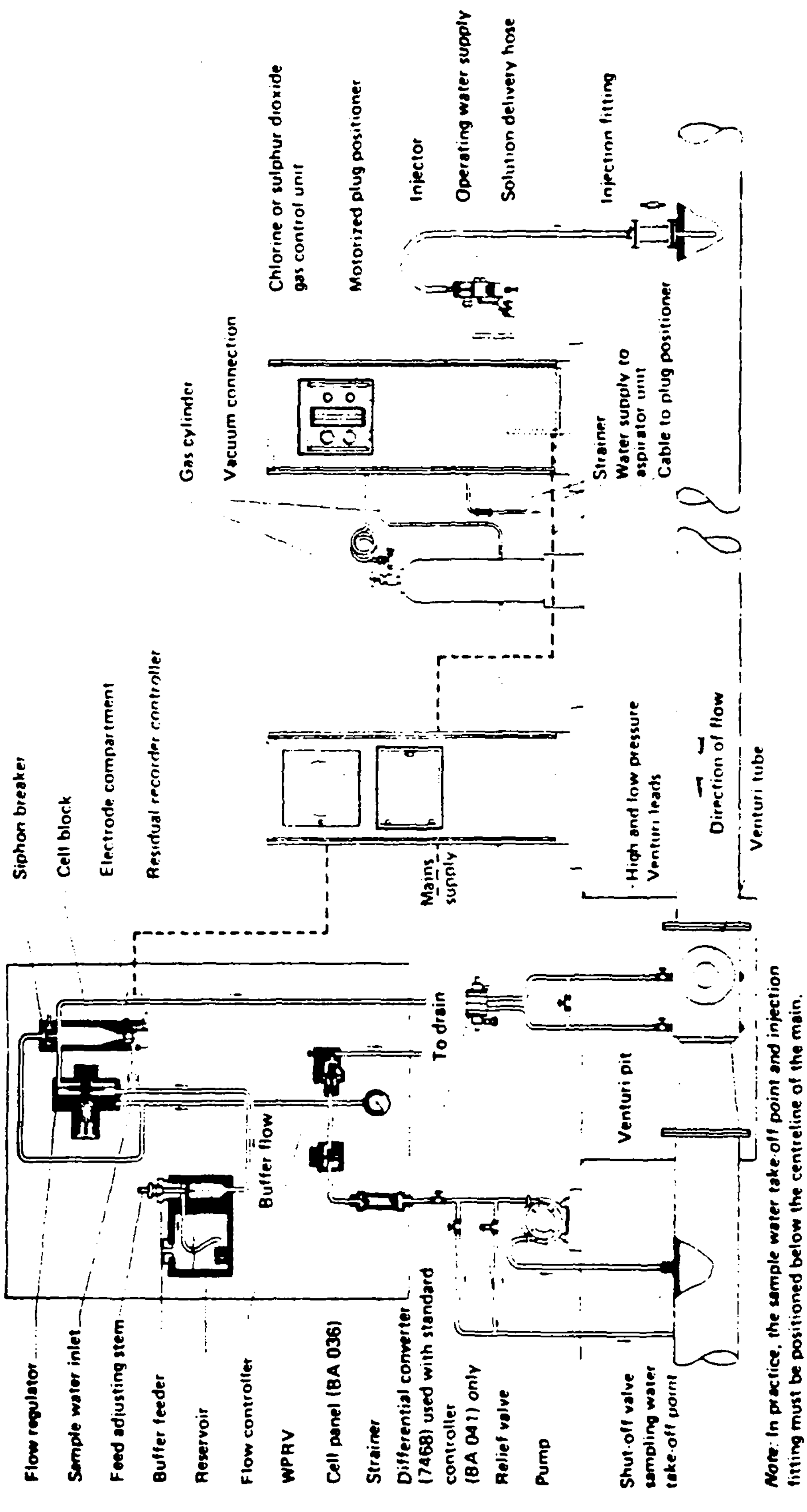


Figure 2. Flow diagram for chlorination control (Wallace & Tiernan Ltd.)

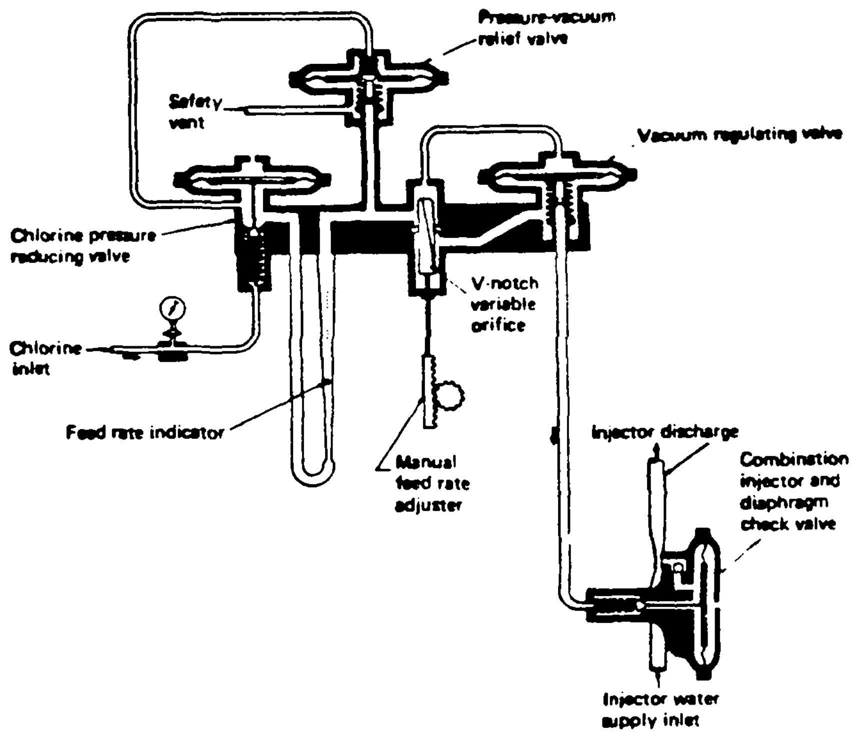


Figure 3. The control of gas flow through a chlorinator.

Chlorine gas is added to water by passing through a 'V' shaped opening. Any changes in the settings of the chlorination equipment should be made in accordance with the manufacturer's instructions. The supply of chlorine added to the flow of water should be adjusted to maintain the desired level of chlorine residual after the specified contact period.

Chlorine gas is not widely used in some countries, and this module does not therefore provide detailed advice relating to some important aspects of its use. For further information about such topics as safe working practices, storage of gas cylinders, requirements for chlorine dosing rooms and first aid, reference should be made to appropriate technical publications. Medical treatment, involving examination by a qualified doctor, should be provided urgently to anybody who comes into contact with chlorine gas.

8. CHLORINE COMPOUNDS

For small supplies, salts of Hypochlorous Acid may be used to provide chlorination for swift disinfection of water. Sodium Hypochlorite solution, also known as 'Javel Water', contains about 5 - 16% available chlorine by weight; Bleaching Powder (or Chloride of Lime) contains 20 - 35% available chlorine, and High Test Hypochlorite (HTH) contains 60 - 70%. The chlorine content of these various compounds, and solutions made from them, can be expressed in various ways:

by the percentage (by weight) of chlorine,
in chlorometric degrees, or
in parts per million (ppm) or milligrams of chlorine per litre. (Usually only for very dilute solutions.)

In order to convert from one unit to another, a 1% solution contains 10 grams of chlorine per litre (10000 parts per million); and 1 chlorometric degree is approximately equal to 0.3% chlorine by weight.

Javel Water, Bleaching Powder and High Test Hypochlorite are the most commonly used chlorine compounds, the choice of chemical being influenced by the relative costs and availabilities, and by the ease with which they can be transported.

In composition, bleaching powder contains a mixture of calcium hypochlorite, calcium chloride and calcium hydroxide. The costs of transport and storage are high because bleaching powder contains excess lime that serves no purpose in disinfection. Lime is also insoluble in water, and solutions made from bleaching powder should be allowed to stand after mixing and the solids allowed to sink. The solution on top should then be decanted into a storage tank. Any lumps of cemented bleaching powder should be broken up prior to mixing, and the bleaching powder should be added to water - NOT water added to bleaching powder. The sediment (lime residue) resulting from the preparation of chlorine solution from bleaching powder is of no value to the disinfection process and should be thrown away, using a safe disposal system. Failure to remove insoluble material would result in the blocking of valves and pipes.

High Test Hypochlorite consists of Calcium Hypochlorite, and allows chlorine to be released steadily and slowly. It has certain advantages over bleaching powder, being more stable, less likely to deteriorate during storage, even in tropical climates, and having good solubility so that relatively clear solutions may be prepared. Storage and handling conditions should be as for bleaching powder. The stability of High Test Hypochlorite should not be overestimated. There have been instances reported of cans bursting as a result of storage in direct sunlight. The high percentage of available chlorine and the good solubility in water result in lower transport and storage costs than for bleaching powder. High Test Hypochlorite may be supplied in powder, tablet or granular form, and chlorine solutions should be prepared using the same methods as for bleaching powder.

Javel Water (Sodium Hypochlorite solution) is convenient because it is supplied as a clear solution which is unlikely to cause blockage of dosing equipment. On the other hand, because the solution contains a large proportion (by weight) of water, the handling and transport costs are expensive.

Storage of Chlorine Compounds

Bleaching powder can be handled easily, but it is bulky and unstable, losing some of the available chlorine during storage. Loss of chlorine results from exposure to the atmosphere, moisture, light or heat. The powder, and solutions prepared from it, should therefore be stored in corrosion-resistant containers in cool, dry, dark locations. Sealed drums of bleaching powder should be used within two years of production, and once opened should be used within three weeks.

High Test Hypochlorite is more stable than Bleaching Powder, but the same storage requirements apply to both compounds. Javel Water should also be stored in sealed containers and in dark conditions. Once containers of Javel Water are opened, their contents should be used within a week.

The rate at which chlorine is lost from chlorine compounds during storage cannot be estimated reliably. Before use a concentrated solution should be made, and the strength of this solution measured. A solution should then be prepared of the strength and volume required for dosing purposes.

For a sample of bleaching powder containing 30% available chlorine, 33.3 grams of the bleaching powder in 1 litre of water will produce a 1% chlorine solution (10 grams of chlorine per litre), which could be used to dose 10 000 litres (10 cubic metres) of water at a dosage of 1 mg/l. For High Test Hypochlorite containing 65% available chlorine, only 15.3 grams of the sample would be needed to produce an equivalent solution. Unfortunately, in practice it is not usually possible to know what is the percentage of available chlorine in a sample of bleaching powder or High Test Hypochlorite prior to making a chlorine solution.

The following tables indicate the quantities of various Chlorine compounds that should be used to produce Chlorine solutions and to disinfect water supplies.

TABLE 1. Weights (grams) of Chlorine Compounds needed to produce 1% Chlorine solutions for dosing purposes.

Chlorine content in the compound.	5%	10%	15%	20%	30%	50%	60%	70%
To make 1 litre.	200	100	67	50	33	20	17	14
To make 5 Litres.	1000	500	333	250	167	100	83	71
To make 10 litres.	2000	1000	667	500	333	200	167	143
To make 20 litres	4000	2000	1333	1000	667	400	333	286
To make 50 litres.	10000	5000	3333	2500	1667	1000	833	714

To make X ltres of Chlorine solution of Y% strength from a compound containing Z% Chlorine by weight, the amount of compound to be used is:

$$\frac{X \times Y \times 10 \times 100}{Z}$$ grams of Chlorine Compound.

TABLE 2. Volumes (litres) of 1% Chlorine solution required for disinfection of water supplies.

Chlorine dosage (mg/l)	0.5	1.0	1.5	2.0
Volume of water to be Chlorinated. (cubic metres)				
5	0.25	0.5	0.75	1.0
10	0.50	1.0	1.5	2.0
25	1.25	2.5	3.75	5.0
50	2.5	5.0	7.5	10.0
100	5.0	10.0	15.0	20.0
250	12.5	25.0	37.5	50.0
500	25.0	50.0	75.0	100.0

The volume of A% Chlorine solution needed to Chlorinate B cubic metres of water at a dosage rate of C mg/l is:

$$\frac{B \times C}{10 \times A}$$ litres.

Simple Constant Rate Systems for Dosing of Chlorine Solutions

A variety of constant-rate chlorine dosing systems have been designed, and the designs can often be copied or adapted to make use of locally available materials. Two of the more reliable devices are the 'constant head siphon' and the 'floating bowl solution feeder'. Despite this reliability, the outlets of these devices may become partially obstructed by sediment and scale, especially at low flow rates. Chlorine solutions should be added to a flow of water, ensuring that the chlorine solution is thoroughly mixed with the water. The required dosage may be estimated from tests on the water, and the precise rate at which the chlorine solution is added can be adjusted so that the required level of residual chlorine is maintained after the necessary contact time.

For the constant head siphon, which is shown in Figure 4, flow rates remain constant because the head causing flow remains steady. The driving head is the difference in level between the base of the air inlet tube (where pressure is atmospheric) and the siphon outlet. The siphon device is very reliable, giving constant feed rates irrespective of the level of water in the reservoir. Construction, operation and maintenance is simple, although care should be taken to ensure that the reservoir is well sealed and that air cannot enter the siphon tube from the air inlet pipe.

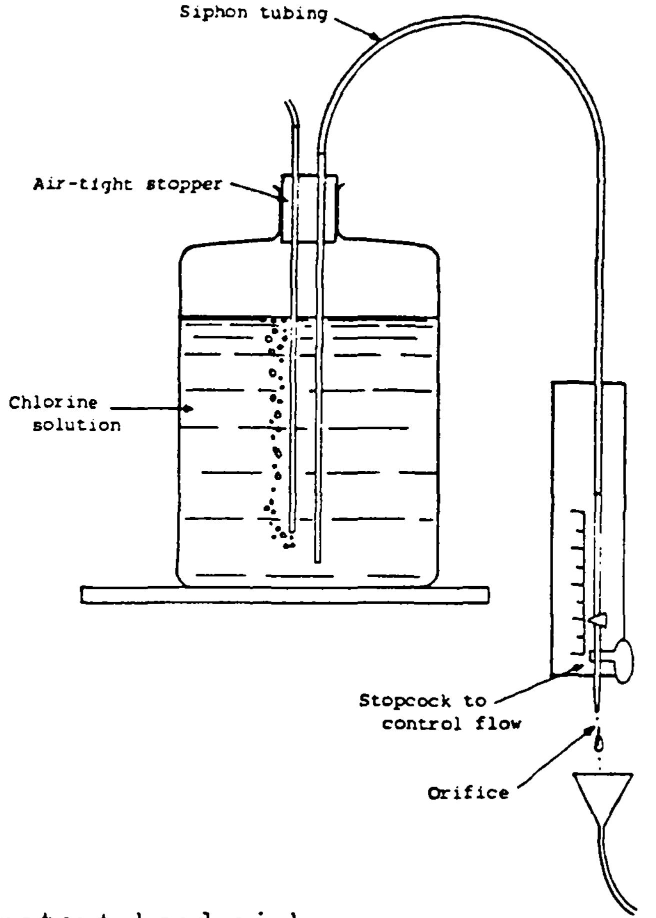


Figure 4. Constant head siphon

Flow control can be achieved by moving the air inlet tube, changing the height of the siphon with respect to the air inlet tube, or by use of a tap on the siphon outlet. The air inlet tube should not be obstructed, and flow control by use of a tap on the air inlet is unsatisfactory.

The floating bowl solution feeder may be of two possible designs; either with the inlet above the outlet (Figure 5), or with the inlet below the outlet (Figure 6). Either design may be used, but the bowl may require some ballast (such as gravel) and a vertical guide wire should be provided to prevent the bowl from tilting over and to keep it floating in a controlled manner as the bowl descends during dosing (See Figure 7). Flow control may be achieved by altering the sizes of the tubes or by adjusting the levels of the tubes in the bowl.

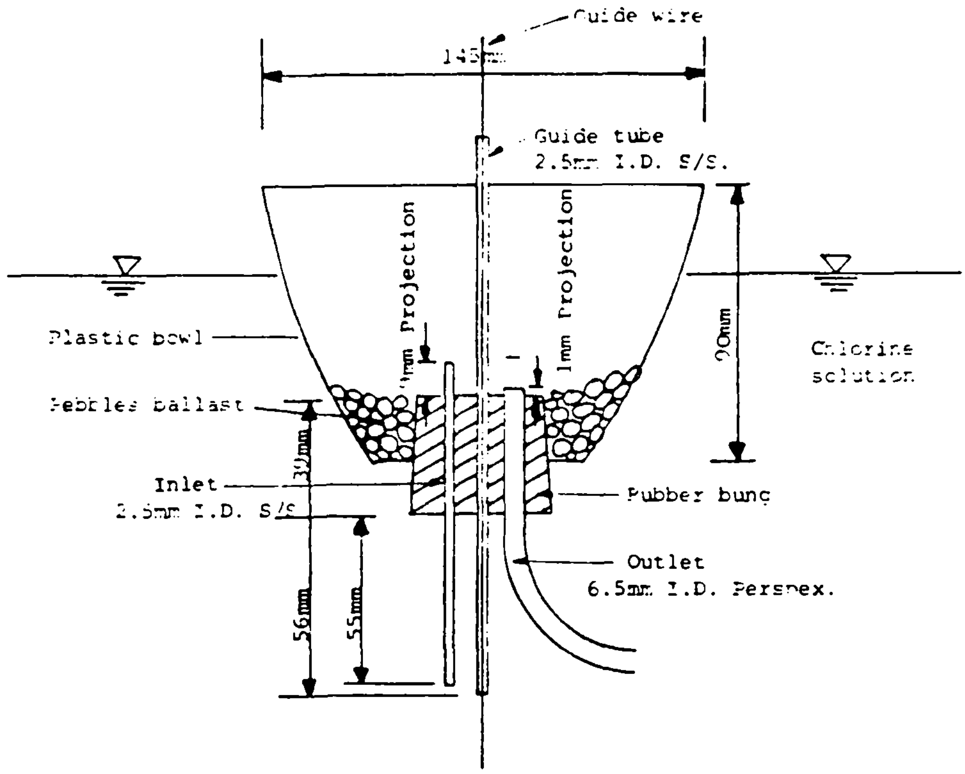


Figure 5. Inlet above outlet bowl chlorinator

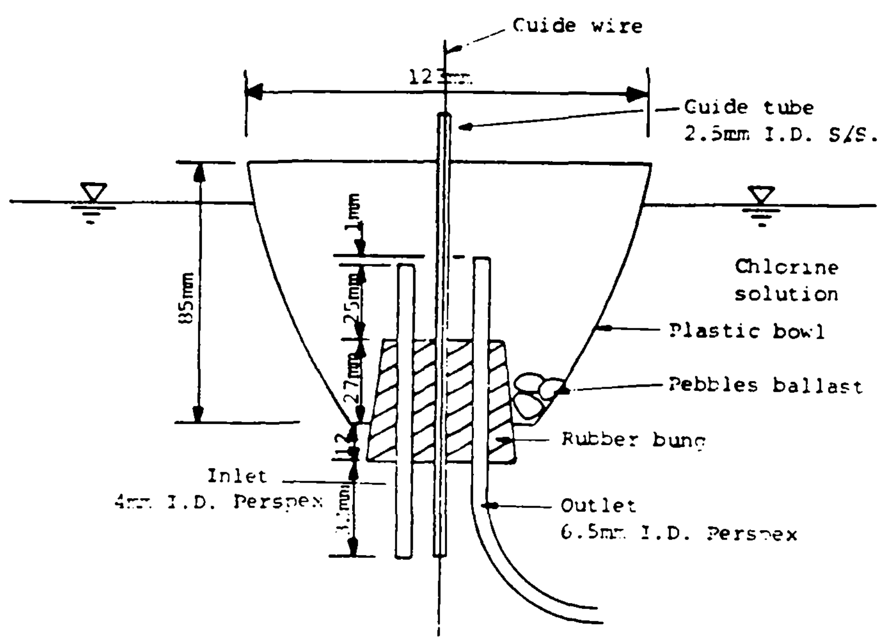
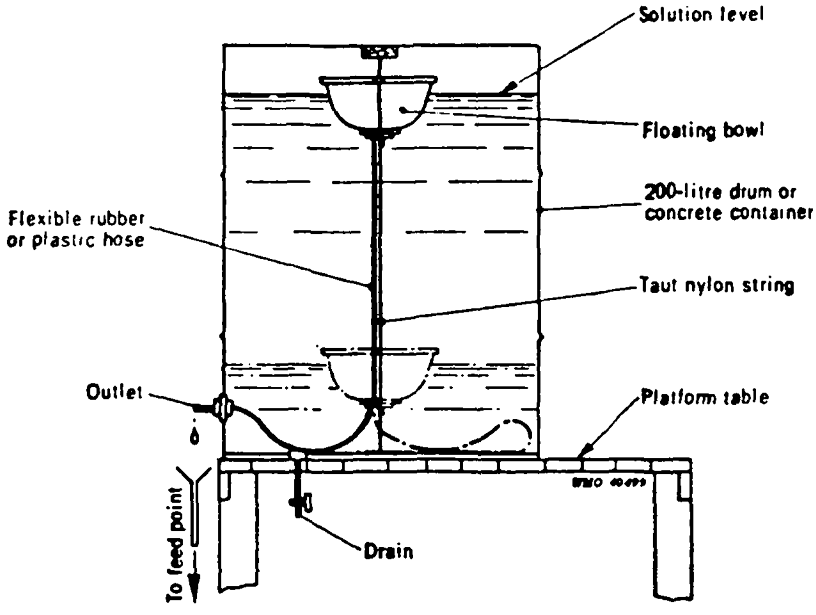


Figure 6. Inlet below outlet bowl chlorinator



Reproduced from International Program in Sanitary Engineering Design (1966).

Figure 7. Floating bowl solution feeder

Chlorination of Wells

Water obtained from wells and boreholes is very difficult to disinfect with any reliability, and underdosing or overdosing is almost inevitable. The volume of water contained in a well or borehole is seldom known accurately and rates of extraction will vary from day to day and during each day.

Simple disinfection may be used to provide residual chlorine in waters of high initial quality, but the most reliable form of ensuring accurate dosing is to store the water obtained from a well or borehole in a reservoir, and to disinfect the water, whose volume and chlorine requirement can be measured, in the storage reservoir.

The practice of adding chlorine solution directly to a well or borehole is not recommended, as the only factor that can be controlled is the residual relative to the original dose. The chlorine solution may not mix thoroughly with the water in the well, and any metal linings or fittings may become corroded.

It has been reported that water in wells may be disinfected by the use of chlorination pots, containing a mixture of sand and either bleaching powder or HTH. The problems associated with this technique are not so widely reported. One design for such a chlorination pot is shown in Figure 8.

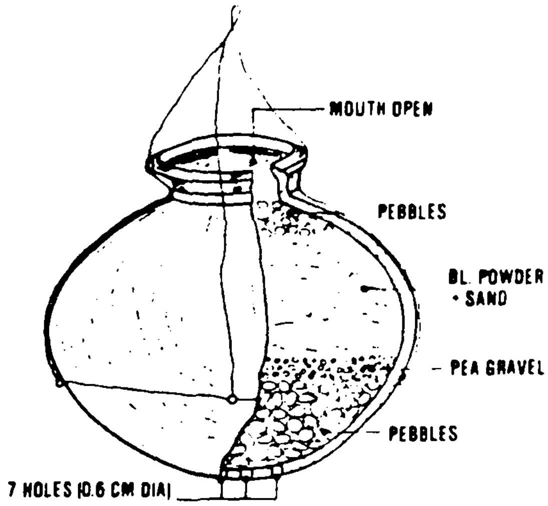


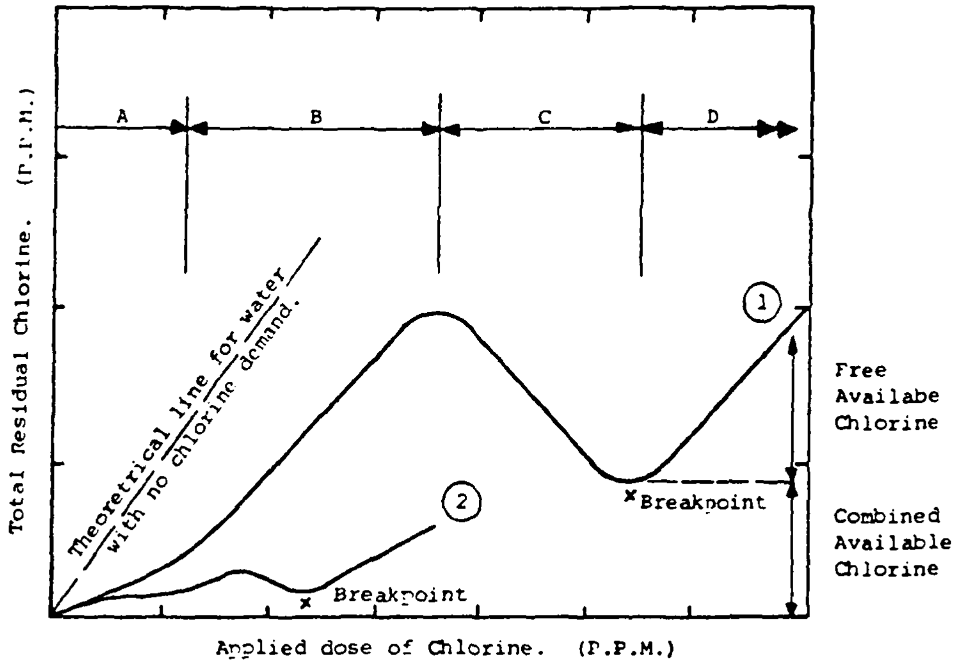
Figure 8. Chlorination pot with holes at the bottom

Chlorination pots are not widely used, although certain publications would lead one to believe otherwise. The operating principle for these chlorination pots assumes that water soaks into the chlorine compound used, forms a chlorine solution which then mixes with the remainder of the water in the well. In reality, the outer layer of the chlorine compound adsorbs water and then sets hard, like cement, forming a hard shell that effectively prevents water from reaching the interior of the mixture. Tests have shown that by adding a small quantity (about 5% by weight) of Sodium Hexametaphosphate to the bleaching powder or HTH, the mixture remains soft, but the difficulty of controlling the dosing rate remains.

A practical problem associated with chlorination pots is related to patterns of water use. During the night, when little or no water is taken, the water in contact with the pot may develop such a high chlorine content that it becomes unacceptable for drinking purposes. Through the day, as water is extracted and stocks of water are replenished, the chlorine level decreases, reaching a minimum level by evening.

9. CHLORINATION TECHNIQUES

Various chlorination techniques may be used, and the various reactions that may take place when chlorine is added to water are shown in Figure 8. The type of chlorination technique used in a particular situation will depend upon the quality of the water to be disinfected, but for most situations chlorine is added following other water treatment processes (post-chlorination).



1 Water with appreciable Free Ammonia.

2 Water containing little or no Free Ammonia.

A Absorption of Chlorine by Organic Matter, etc.

B Formation of Chloramines, Chlorine present as combined available Chlorine.

C Oxidation of Chloramines by Chlorine.

D Chlorine present as Free Residual Chlorine increasing in proportion to dose.

(A–D: For graph ①)

Figure 9. Reactions of chlorine in water (Institution of Water Engineers, 1969)

10. CONCLUSION

Various disinfection methods and products may be used in order to ensure that water is of a good bacteriological quality. Chlorine and chlorine-based chemicals are the most commonly used products, and over many years and in a variety of different conditions these have proved to be simple and reliable in use. Disinfection should not be considered to be a complete water treatment process in itself, but should be used in conjunction with other treatment operations to produce waters that are consistently safe and of good quality and appearance.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

SIMPLE DISINFECTION

1. INTRODUCTION

This module will be taught as a lecture with demonstrations and slides (optional).

2. TEACHING HINTS

Explain the difference between Sterilization (the removal of all life from a substance or object) and Disinfection (the killing or removal of all organisms capable of causing infection). Sterilization may not be necessary and may not be practically possible.

The disadvantages of small scale disinfection techniques other than Chlorination could be explained. The major disadvantages are:

- their high costs for community water supplies, and
- their lack of residual disinfection potential.

Work through some examples showing how to calculate the weight of Chlorine compounds needed to disinfect water supplies, using information about the percentage of available Chlorine in the samples.

If at all possible, samples of bleaching powder and HTH should be shown to the students, and a colorimetric test using the DPD method demonstrated.

Relevant slides or photographs should be shown to the students. The following slides are included with this module. Additional slides can be shown if desired.

Captions for slides

1. Samples of Calcium hypochlorite: 60% (left) and 35% (right) available Chlorine.

2. DPD colorimetric test equipment.

3. DPD colorimetric test on a water sample. The tube on the left shows Total Available Chlorine, the tube in the centre is for Free Residual Chlorine, and the tube on the right is a blank reference sample.

4. A simple item of colorimetric equipment being used for a DPD test in a refugee camp in Honduras.

5. A laboratory spectrophotometer for accurate measurement of available Chlorine using the DPD method.

6. Apparatus for a constant-head siphon Chlorine doser.

7. Models illustrating the two types of floating bowl Chlorinator.

8. A floating bowl Chlorinator installation.

9. An experimental pot Chlorinator, intended for use in wells.

Overhead projector transparencies should be prepared to illustrate or emphasise important points. Samples of such transparencies are attached. Do not project the full transparency straight away. Only show the part you want to talk about first and cover the parts you want to talk about later with a piece, or pieces, of paper. Uncover these sections only as you come to talk about them. Example 6 attached, showing what happens when Chlorine is added to water, consists of four separate sheets: a) Chlorine added, 30 minutes minimum, b) Chlorine used in the Oxidation of material in the water, c) Combined Residual Chlorine, d) Free Residual Chlorine. Sheet a) is shown first, then sheet b) is laid on top, followed by sheets c) and d). In this way the picture of what happens during Chlorination is gradually built up.

3. TOPICS FOR DISCUSSION

After the material in the Student's Notes has been taught, the students can be set the following questions in either oral or written form in order to check their understanding of the topic.

a) Explain what is meant by 'contact time' with reference to Chlorination.

b) Why should a bottle of Ammonia be kept in a room that is used for disinfection of water using Chlorine Gas ?

c) What ventilation should be provided for rooms used to store Chlorine or Chlorine compounds ?
Should gas-masks be kept in such rooms ?

d) The addition of a disinfectant to a water supply does not always mean that the water has been disinfected.
What supervision is necessary to ensure that disinfection is effective?

e) 'The only form of disinfection that need be considered by an Engineer is Chlorination.' Explain whether you agree, or disagree, with this statement, giving reasons for your answer.

f) Describe the usual method used to test for Chlorine in water. What does the presence of Chlorine indicate ?

4. FURTHER READING

Cairncross S. and Feachem R. G. - Environmental Health Engineering in the Tropics: an Introductory Text. (John Wiley and Sons, Chichester, England. 1983)

Hofkes E. H. (Editor) - Small Community Water Supplies - technology of small water supply systems in developing countries. IRC Technical Paper 18. (International Reference Centre for Community Water Supply and Sanitation, The Hague, the Netherlands, and John Wiley & Sons, Chichester, England. 1986)

Rajagopalan S. and Shiffman M. A. - Guide to Simple Sanitary Measures for the Control of Enteric Diseases. (W.H.O., Geneva. 1974)

Twort A. C., Law F. M. and Crowley F. W. - Water Supply, Third Edition. (Edward Arnold, London. 1985)

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 7
LOW COST SANITATION - CRITEREA AND GENERAL PRINCIPLES

Objectives:

To familiarize participants with:

a. a definition of sanitation as the removal, treatment and/or disposal of human excreta and its relation to other aspects of environmental sanitation;

b. the reasons for sanitation - health, convenience and reuse of resources (for the latter the use of decomposed excreta as a fertilizer is briefly considered in terms of handling, composting and biogas)

c. the requirements for satisfactory sanitation - restriction of the spread of disease - additional requirements in developing countries - convenience of users;

d. decomposition of excreta in pits and calculation of pit capacity;
and
e. groundwater pollution resulting from the disposal of excreta in pits.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE SEVEN

LOW-COST SANITATION - CRITERIA AND GENERAL PRINCIPLES

1. INTRODUCTION

!!! "Sanitation", as used in this course, is the removal,
!!! treatment and/or disposal of human faeces and urine.

This is the sense in which the word is used by the World Bank and other international organizations and in the International Drinking Water Supply and Sanitation Decade (1981-1990).

Sometimes *environmental sanitation* is taken to also include:

a. removal, treatment and/or disposal of solid waste, including vegetable peelings, ash, dust, paper, plastics, tins and glass;

b. removal, treatment and/or disposal of sullage, which is dirty water that has been used for bathing and for washing clothes, food, dishes and for other domestic purposes, but does not include waste from water closets;

c. removal, treatment and/or disposal of stormwater, which is rainfall that runs off the surface of roofs, roads, etc;

d. personal and environmental hygiene - that is, keeping bodies, clothes, houses and their surroundings clean and tidy.

Solid waste is covered in Module 11, sullage and stormwater in Module 12 and personal and environmental hygiene in Module 1.

2. REASONS FOR THE PROVISION OF SANITATION FACILITIES

There are two main reasons for improving sanitation: they are health and convenience. In some places reuse of resources is also important.

a. Health

Many diseases are spread by the "faecal-oral route". That is, pathogens (the "germs" or microorganisms by which diseases are transmitted) pass from the faeces of someone who is suffering from the disease to the mouth of another person.

Good latrines can be a barrier to all these routes, providing they are kept clean and are properly used by people whose personal hygiene is also good.

A "latrine" is any room or separate building used for defecation and urination, but not one in which there is a water closet from which the excreta is flushed down a drainpipe to a sewer or septic tank.

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b. Convenience

Where there are no wc's or latrines, people defecate in their own yards, on open land, on roadsides or in streams or stream beds.

Most adults, and especially women, seek privacy when relieving themselves. In many places deforestation and the destruction of vegetation by over- population and drought make it difficult to find bushes or trees behind which to defecate. A good latrine provides privacy.

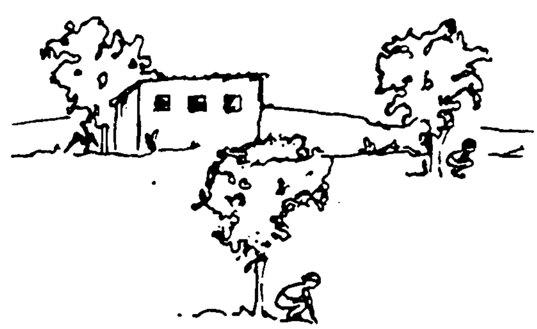

Figure 1. Open defecation

A toilet inside or close to a house is especially advantageous for -

+ old people, who may have difficulty in reaching a distant defecation place;

+ children, who can remain under the eyes of their parents and guardians;

+ people suffering from diarrhoea; and

+ menstruating women.

Convenience is greatest where a latrine is provided for each household. Communal latrines, such as those on the outskirts of villages, are rarely satisfactory. The cleaning and maintenance of communal latrines can be a problem. This issue is discussed in Module 8.

c. Reuse of resources

Some communities have a tradition of applying excreta to land as a fertilizer. Other people put excreta into ponds where they provide nutrients for microscopic plants on which fish or ducks feed.

Because of the health risks to workers, the handling of excreta to place it on land or in ponds is not recommended. Some pathogens are very persistent. This means that they can infect another person with disease a long time after they have been excreted. The most troublesome pathogens from this point of view are the eggs of roundworm (sometimes called ascaris ova). These eggs may remain effective for up to a year or so under normal conditions. Consequently, faeces should only be considered as completely safe to handle a year or more after they have been excreted.

Handling

The solids which accumulate as sludge and scum in double pit latrines (which are described in Module 8) can be safely handled if no fresh excreta has been added for a year or more. They can then be applied to land.

Sludge removed from single pits or from septic tanks or aqua-privies (described in Module 10) contain freshly-deposited faeces. They should therefore be handled with great care. Removal of sludge in buckets exposes workers to health risks. However, sludge and scum can be withdrawn by pumps or vacuum tankers, as shown in Figure 2.

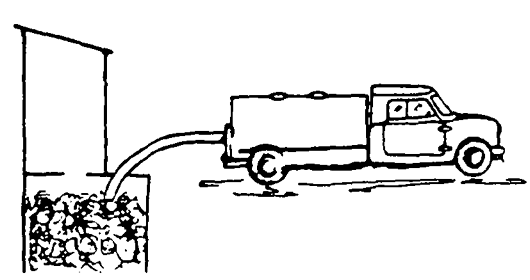

Figure 2. Vacuum tanker withdrawing sludge

Composting

Sludge and scum removed from latrines or septic tanks may then be composted with vegetable waste. The material should be kept "aerobic" - that is, with enough air for micro-organisms which need oxygen to break down organic matter. The temperature may rise enough to kill off all pathogens, including roundworm eggs. Aerobic conditions can be maintained by turning over heaps of mixed vegetable waste and sludge every few days. The compost can then be used to fertilize and condition land.

Composting can be carried out in the chambers of compost latrines, which are dealt with in Module 9.

Another way in which excreta may be a useful resource is by the production of biogas, which is also considered in Module 9.

3. REQUIREMENTS FOR SATISFACTORY SANITATION

A sanitation system serves its main purposes if it improves the health of the people by reducing the incidence of excreta-derived disease and if it is convenient for the users. Any benefit derived from reuse of excreta may be considered as a bonus.

In order to restrict the spread of excreta-related diseases, the system should satisfy the following conditions to the greatest possible extent:

- No pollution of soil;
- No pollution of surface water;
- No pollution of groundwater (see Section 5 below);
- No access to fresh excreta by flies and other insects and animals;
- No handling of fresh excreta.

For sanitation in rural areas of developing countries there may be additional requirements.

- The cost should be low so that it is affordable by all sections of the the community.
- Construction, operation and maintenance should be simple.
- Where water is scarce, little water should be used.

Convenience of users can best be satisfied by providing -

- an individual latrine for every household;
- public latrines at markets, bus stations and similar places;
- latrines at schools, hospitals, and other institutions;
- latrines at offices, factories and other places of work.

All latrines should provide privacy. They should suit the customs and wishes of the community. They should be built in such a way that they can be cleaned and maintained easily.

Unfortunately, no sanitation system can satisfy all these conditions. Even the sewers and sewage treatment provided in cities in industrialized countries usually result in some pollution of surface water. Their cost is high and construction, operation and maintenance often require a high level of technology. A large amount of water is needed to move excreta along the sewers.

4. DECOMPOSITION OF EXCRETA

As soon as faeces are excreted they begin to decompose. This is caused by bacteria and other micro-organisms, many of which are already in the excreta. Faeces gradually break down, forming gases and water. A solid residue remains. Similar processes take place whether faeces are excreted onto the ground, are contained in pits under latrines, or are treated in a septic tank or sewage treatment works.

Most low-cost sanitation involves the decomposition of faeces in a pit. Gases escape to the atmosphere. Water soaks into the soil around the pit. Some solids are carried into the soil, either dissolved or suspended in the water. The remaining solids consolidate at the bottom of the pit where they are pressed down by the weight of new excreta which is added on top.

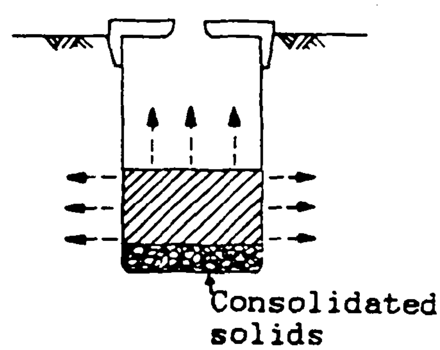

Figure 3. Decomposition of excreta

The rate at which solids accumulate depends on whether the decomposition occurs under wet or dry conditions. In a dry pit activity by the micro-organisms is slower. Less solids are carried into the surrounding soil.

Some pits are wet. This may be because a lot of water is put in during anal cleaning, when flushing the pan or washing the latrine floor, or if bath water and other sullage is discharged into the pit. A pit may also be wet because the groundwater rises above the bottom of the pit either seasonally or throughout the year.

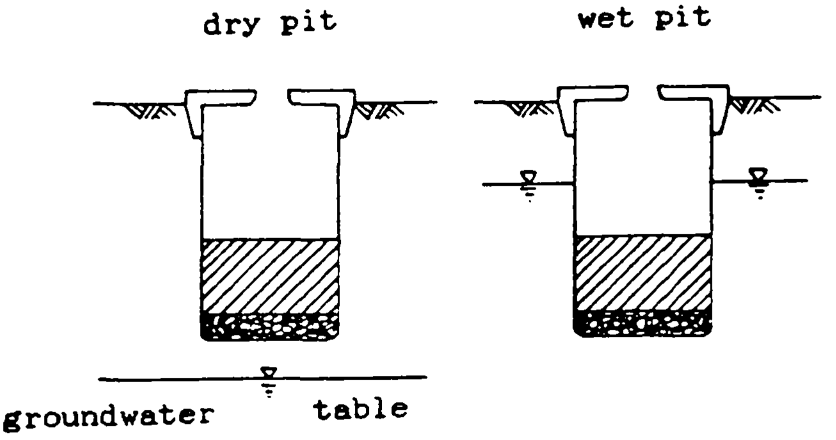

Figure 4. Dry and wet pits

In some places solid materials such as hard paper, stones, sticks and corn-cobs are used for anal cleaning and the cleaning material is put in the pit.

The rate of solids accumulation varies with local conditions such as the type of food people eat. In the absence of local information the following table may be used to calculate the amount of solids per person per year.

	water used for anal cleaning	solids put in pit
DRY PIT	60 litres	90 litres
WET PIT	40 litres	60 litres

Table 1. The amount of solids produced per person per year depending on methods of anal cleaning.

To calculate the size of a pit, the appropriate figure from Table 1 is multiplied by the estimated number of people who are likely to use the latrine. This gives the total amount of solids produced each year. This must then be multiplied by the number of years that the pit is designed to last (which should always be at least two). This gives the total volume for solids accumulation. In addition, at least 500mm must be allowed between the top of the solids and the bottom of the cover slab.

5. GROUNDWATER POLLUTION

Many methods of sanitation involve disposal of liquid to the ground. For example, when septic tanks are used in connection with water-flushed sewerage from buildings with a good piped water supply the effluent from the tanks is normally passed to soakage pits or drainage trenches. Septic tanks are not efficient in removing bacteria or viruses and the effluent contains large numbers of faecal microorganisms, which may include pathogens.

Low-cost sanitation usually consists of a pit from which liquid soaks into the surrounding soil. This liquid, like the effluent from septic tanks, contains faecal microorganims.

The movement of liquid through the soil is complex and is not fully understood. Field studies of the movement of effluent through soil are continuing in several countries.

Liquid flow through soil is principally influenced by three factors:

- the nature of the soil;
- the position of the groundwater relative to the pit or trench; and
- clogging of pores in the soil by solids in the liquid.

Liquids pass most easily along cracks or fissures in broken rock. Effluent may travel several hundred metres in a short time.

Permeability

Liquid travel in other soils depends on the particle size. It is most rapid in gravels and course sand. Some clays are resistant to flow, especially if they expand when they become wet. The ability of soils to allow liquid travel is known as their 'permeability'. The permeability can be estimated by digging a hole in the ground and filling it with water. Next day more water is put in the hole and the rate at which the level drops is measured. If the permeability is less than 10 mm per day the soil is not suitable for a soakaway (a pit from which water soaks into the soil). A pit dug in such soil would quickly become watertight.

In soil above the groundwater most movement of liquid is downwards and there may be very little horizontal spread. In the 'saturated zone' (see Figure 3), where water occupies the spaces between the soil particles, the flow of any liquid entering from a pit or trench follows the movement of the groundwater.

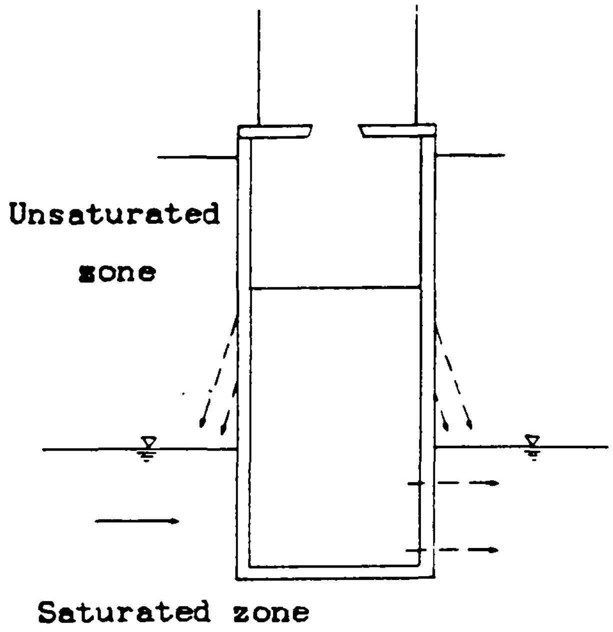

Figure 5. Movement of liquid

Microorganisms and organic matter in the effluent from latrine pits and septic tank soakpits and trenches clog the pores in the soil. The time taken for the pores to become so clogged that liquid flow is prevented depends on the type of soil and the movement of the liquid, but it has been found in the field that after a microorganic mat has formed the permeability of effluent is about one tenth of that of clean water.

Pollution of groundwater is of concern if the groundwater is used for domestic purposes. Consequently some textbooks and byelaws lay down that wells or boreholes should be at a certain minimum distance from latrines or soakage pits. Fifteen metres or fifty feet is often given. Rules of this kind ignore the variation of soil types and groundwater level. The following guidelines may be more suitable.

+ If there is fissured rock, try to get expert advise, for example from a hydrogeologist.

+ In other soils there is little danger of pollution from bacteria or viruses if the groundwater at its highest level is more than <u>three metres below</u> the bottom of a pit or trench.

+ If the pit or trench penetrates the groundwater (either all through the year or seasonally), pollution by bacteria or viruses is unlikely to extend beyond the distance travelled by the groundwater in ten days.
For example, if the groundwater travels 1.5 metres in one day, then it will travel 15 metres in ten days. Therefore, a pit latrine should be dug more than 15 metres from any well or hand pump. It is very difficult to estimate groundwater flow accurately and the assistance of a hydrogeologist should be obtained if possible.

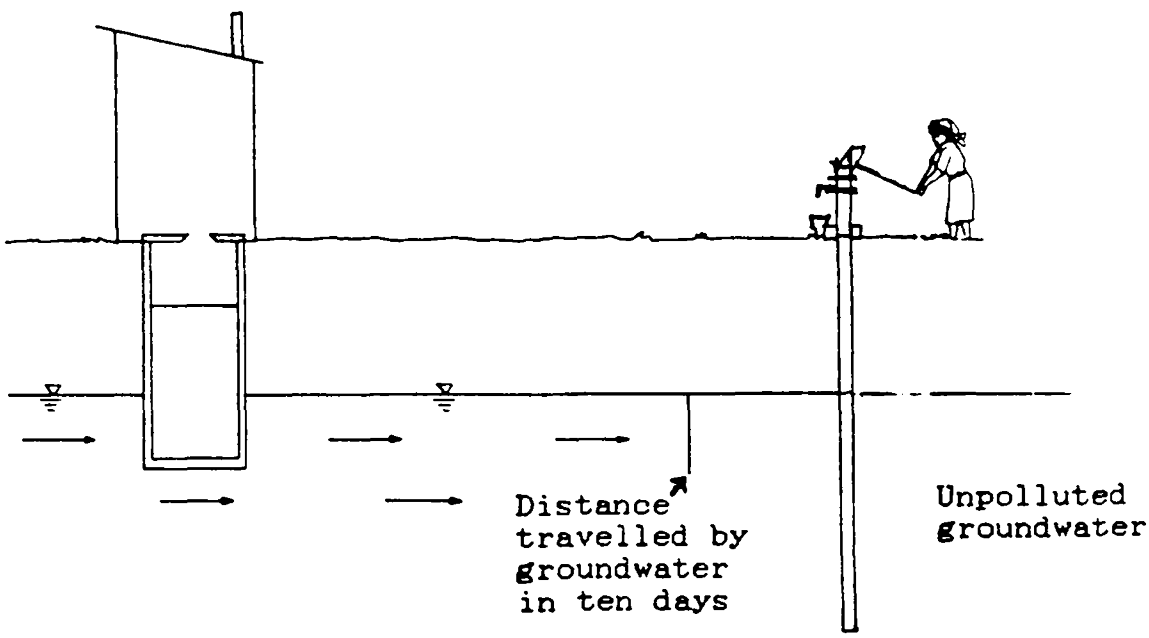

Figure 6. Pollution of groundwater

Pollution of groundwater by bacteria and viruses presents a health hazard because they are the main carriers of faecal-originating diseases. Larger pathogens (such as worm eggs) are likely to be filtered from effluent soon after entering the soil.

Chemicals in effluent (such as nitrates and chlorides) may travel much further. High concentrations of nitrates may build up, giving a slight risk of disease.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE SEVEN - INSTRUCTOR'S NOTES

LOW-COST SANITATION - CRITERIA AND GENERAL PRINCIPLES

SUGGESTED METHOD OF INSTRUCTION

1. Introduction
Outline the five components of sanitation; explain that this module only deals with excreta.

2. Reasons for the provision of sanitation facilities
By question and answer ensure that the students are familiar with the faecal-oral route of disease transmission. Ask what examples of such diseases are prevalent where they work.

Discuss the convenience associated with household latrines. Are there circumstances (other than those mentioned in the notes) for which a nearby latrine is especially advantageous?

Are there any local examples of reuse of excreta?

3. Requirements for satisfactory sanitation
Deal with this section using a chart or overhead transparency as follows:

SATISFACTORY SANITATION
- no pollution of soil
- no pollution of surface water
- no pollution of groundwater
- no access to fresh excreta by flies etc
- no handling of fresh excreta

Rural areas
- cost affordable by all sections of community
- simple construction, operation and maintenance

Convenience of users
- an individual latrine for every household
- public latrines at markets etc
- latrines at schools, hospitals etc
- latrines at places of work
- PRIVACY

4. <u>Decomposition of excreta</u>
   Go through the student notes.
   Explain that Table 1 gives the maximum volume required.
   In many situations it has been found that the rate of accumulation of solids is much less than those given.
   Calculate the volume required for various conditions.

5. <u>Groundwater pollution</u>
   Go through the student notes.
   Discuss and try to overcome students' worries.
   Many people are unduly concerned about the dangers of groundwater pollution. Microbiological pollution must be avoided but disease arising from chemical pollution is much less harmful than disease due to having no latrines at all.

PUBLICATIONS FOR FURTHER INFORMATION

FRANCEYS Richard, PICKFORD John and REED Bob. *On-site sanitation.* World Health Organization, Geneva, 1988.

KALBERMATTEN John M, JULIUS DeAnne S, MARA D Duncan and GUNNERSON Charles G. *Appropriate technology for water supply and sanitation: a planner's guide.* World Bank, Washington DC, 1980.

WAGNER E G and LANOIX L N. *Excreta disposal for rural areas and small communities.* Wld Hlth Org Mono Ser No 39. World Health Organization, Geneva, 1958.

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

ADDITIONAL NOTES - 8

ORGANIZATION OF TRAINING PROGRAMMES

OBJECTIVES

The reasons for training should be clearly understood by the staff and participants before a programme starts and should be constantly in mind during preparation and throughout the course. The ultimate aim is the improvement of the level of maintenance and operation of rural water supply and sanitation systems in the Eastern Mediterranean Region.

The immediate objective of this course is:

to enable participants to conduct effective courses for subordinate staff, including assistant sanitarians, junior technicians, community health workers, UNHCR sanitation and health education workers, and other health education staff.

For courses for subordinate staff, the objectives should be clearly defined at a very early stage in preparation. They will include *imparting knowledge and motivation to enable participants to carry out their duties (including additional duties to which they may be assigned following training) in an efficient and effective manner.*

FACILITATORS

The staff for the course should be carefully selected. They should have considerable experience and knowledge of rural water supplies and sanitation, including the technology and management of maintenance and operation. Specialists may be employed to look after particular parts; for example, a mechanical engineering expert may deal with pumps, a health education expert and a chemist may deal with "health, water and sanitation" and so on. Alternatively, the whole programme may be taught by two or three people with good general experience and knowledge over the whole field.

It is essential that facilitators should be good instructors and should have the ability and experience to assist (that is, to "facilitate") self-learning by participants. Courses are most successful if participants are actively involved in the learning process. Facilitators should therefore have the kind of personality which encourages participants. They should have the ability to criticize participants' efforts in such a way that improvements follow.

PARTICIPANTS

For courses for training facilitators the qualities required participants are the same as those of the course facilitators. Selection should therefore be based on

a. *motivation*: it is absolutely essential that applicants are keen to be involved in training junior staff; no one should be considered without this interest;

b. *experience*: applicants should have practical knowledge of operation and maintenance of systems gained through field work and supervision of junior staff; they should also have been involved in training, either in a full-time or a part-time basis;

c. *education*: applicants should have attained a standard which enables them to understand what is being taught, to learn from publications, to adapt as necessary course material to suit the needs and ability of those attending and to communicate in writing and orally;

d. *sympathy*: applications should understand the point of view of those they will instruct and should be ready to help those who have difficulty in understanding the course material.

Participants on courses for subordinate staff should already be involved in maintenance and operation of rural water supplies and/or sanitation, or be undergoing formal or informal training which will enable them to be employed on maintenance and operation duties. Their education and experience shuld be related to the level of the course.

PRELIMINARY ARRANGEMENTS

In the early stages of planning for a training course the following points are amongst those to be considered.

a. What are the objectives?

b. For whom is the course planned - who will be the participants? What level (of post held, of experience, of education) should they have?

c. Is the course to be restricted (for example, to those employed by a particular department or organization), or is it to be open to all suitable applicants?

d. What is to be the maximum number of participants?

e. Will there be a minimum number, resulting in the cancellation or postponment of the course if enough applications are not received?

f. What geographical area will be covered - local, district, national, multi-national?

g. What subjects will the course cover - all the topics included in this course, water supply only, sanitation only, or some other selection of modules?

h. Who will be the course organizer?

A suitable venue must then be selected. It should be conveniently reached by participants from all parts of the geographical area which is to be covered. The accommodation at the venue should be appropriate for instruction. There needs to be suitable residential accommmodation close by, and facilities should be available for meals. University or college premises often provide for all the needs of a course, especially if the dates are during a vacation.

The date and duration of the course need to be settled at an early stage. The date should be far enough ahead to ensure that all necessary arrangements can be made in good time. There should be ample time -

- for news of the course to reach potential participants or their employers early enough for careful consideration of who should attend;
- for names and other details of applicants to be submitted to the course organizer; and
- for joining instructions sent by the organizer to reach participants early enough for them to prepare for the course.

If the course is to be open to several departments or organizations an anouncement should be sent to all. Usually a form is included so that names and other details of applicants can be sent to the organizer. Where possible the backing of appropriate agencies should be obtained by making contact by personal letter, telephone, telex or by visits to officers responsible for training.

THE COURSE PROGRAMME AND INSTRUCTIONAL METHODOLOGY

A programme for a course for training facilitators is given as an appendix to this Note. For other courses, such as those for junior staff, the topics should be limited. The participants will normally be unable to learn so quickly and it is better for them to gain a thorough grasp of a few topics.

Methods of instruction should vary according to the level of the participants and the objectives of the course. For example, a short course for junior engineers might be specifically designed to familiarize participants with non-technical matters such as health or community participation. If the participants have recently graduated from a university or college course they are familiar with learning from lectures. Older staff may have difficulty in returning to a classroom atmosphere. For many courses for technicians and artisans the programme might largely consist of practical work under supervision.

For most courses there needs to be a combination of methods. Direct instruction, such as is given in a lecture, should be alternated with sessions in which participants are actively involved. Variety should be provided, not only between the various components of the programme but also within a session itself. For example, within an instructional period some time may be taken up by the facilitator lecturing, some by discussion and some by the participants solving problems. Variety can be introduced into a lecture by using a variety of teaching aids - a chalkboard, slides, tape-slides, films.

Except for courses that are entirely of a practical nature (for example, a course devoted to the maintenance of motors) the programme should include outside visits which reinforce what is taught by emphasizing its practical relevance.

FACILITIES

Although some courses may have to be held in unsuitable premises so that they are conveniently located (for example, centrally in a rural area) every effort should be made to obtain accommodation which has good facilities for instruction. For most course the following are desirable -

- a room with a comfortable temperature;
- sufficient space and appropriate furniture so that participants can write notes during instruction;
- curtains or blinds so that the room can be darkened for showing slides and films during daylight hours;
- electrical power points for projectors;
- a chalkboard or whiteboard; and
- projectors for showing slides, transparencies amd films.

ADMINISTRATION

Enrolment

On arrival at the course participants should be enrolled and should be welcomed. First impressions are important, so it is essential that enrolment is efficiently carried out.

Handouts

Whenever possible participants should be provided with duplicated or printed sheets giving at least the most important points covered in a session. Handouts reduce the need for participants taking notes so they can concentrate on understanding and remembering what they are taught. On return to they work the handouts are a valuable means of revision and reference.

Assessment

If participants are given certificates showing that they have completed a course satisfactorily, there needs to be an assessment of the extent to which they have benefitted from the course. Exceptionally the assessment may be based on a written examination; sometimes there may be a practical or written test; often facilitators' evaluation of participants is the best measure of performance. A major advantage of facilitators' direct involvement in assessment is that they can judge *improvement* rather than simply the ability of participants at the end of the course.

Certificates

As a rule all participants who attend courses should receive documents certifying their attendance. If possible the certificate should show satisfactory progress, assessed in ways indicated in the last paragraph. Certificates should be attractively printed or duplicated so that recipients are proud to display them. They should be signed by at least one authorized person (normally the course organizer) and may well have several signatures. There is no harm in providing elaborate and impressive certificates for elementary courses, providing they are not to be compared with other certificates for which more effort is required. For example, if an assistant is expected to attend several courses over a number of years, the subsequent certificates should be more impressive than earlier ones.

***Meals and refreshments

If meals or drinks are to be provided during a course it is worth making certain that they are served at the correct time. There are few things more annoying than to expect a drink of tea or coffee at the end of a difficult session and then to find it is not ready.

Payment and cost-recovery

Generally training courses are of two types: those which are entirely funded by the participants' organization or by an external agency such as WHO, and those which are intended to be self-funding, the costs involved being recovered by charging fees. It is often difficult to determine the appropriate level for the fee, especially for courses intended for senior participants. A higher level of fee may result in less applications and so result in a lower total income. On the other hand, too low a fee may be interpreted as an indication that the course is not very good. Only experience - a trial and error process - can show what fees should be charged.

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

ADDITIONAL NOTES - 9

COURSE EVALUATION

If possible every course should be evaluated by someone who was not directly involved in the course itself. The evaluation should be based on the following information.

a. reports by the course organizer and facilitators compiled immediately after the end of the course;

b. questionnaires completed by participants at the end of the course*;

c. comments by employers indicating whether the performance of participants has improved as a result of attending the course (such comments may sometimes be obtained by telephone); and

d. (for courses for training facilitators) reports and comments by independent persons relating to participants subsequent activity as facilitors.

* A questionnaire suitable for participants' comments is given as Appendix A.

Participants should be assessed by facilitators in order to ascertain the extent to which they have benefitted from the course and (for courses for training facilitators) whether individual participants should be employed as facilitators, either straight away or after further training.

Appendix A

QUESTIONNAIRE FOR PARTICIPANTS' EVALUATION

Please complete this form, giving your frank and honest opinion. There is a space at the end of the form for your name, but you need not fill this in if you do not wish your identity to be known.

PLEASE WRITE CLEARLY, or put an X in the appropriate box.

Return the form to the Course Organizer at the end of the course

Title of course: ....

Location of course: ....

Dates: start of course: .... end of course: ....

Who informed you that you had been selected for the course?

....

Were you aked whether you wished to attend the course before you were informed that you had been selected? Yes [] No []

How long before the start of the course were you informed that you had been selected?

- More than four weeks []
- Two to four weeks []
- One to two weeks []
- Less than one week []

Were you given adequate information about where the course was to be held and what to bring? Yes [] No []

Briefly describe what you understood to be the objectives of the course *before you started the course*

....

....

....

When you were told the objectives on the first day of the course, were you -

- surprised []
- pleased []
- disappointed []

Having attended the course, which one of the following best describes your confidence in acting as a facilitator?

- You will be able to organize a course by yourself []
- You will be able to facilitate in all subjects []
- You will be able to facilitate in a few subjects []
- You need more training before doing anything []
- You do not want to be a facilitator at all []

Which of the following have you found most useful in training you to be a facilitator?

- Learning the subject matter of the modules [ ]
- Learning about methods of instruction [ ]
- Practicing instruction yourself [ ]
- Nothing helped you [ ]

Which one of the following best describes your opinion of the course content?

- Too many subjects were included [ ]
- The course content was about right [ ]
- More subjects should have been included [ ]

What additional subjects should have been added to the course?

....

Was the length of the course

- too long [ ]
- too short [ ]
- about right [ ]

INDIVIDUAL MODULES

Which of the following comments apply to the modules listed? Base your answer on your experience of local conditions.

a. the whole module is essential; material is relevant
b. the whole module is essential but some of the material should be amended to make it more relevant
c. most is essential, but some could be omitted
d. the material should be drastically reduced
e. more information should be included
f. the subject is important, but the way it is covered is not suitable for local conditions
g. the whole module is unnecessary and should be taken out of the course

Unless your answer is 'a' or 'g' describe what should be changed

	a	b	c	d	e	f	g
1. Health, water & sanitation	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
2. Sources of water	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
3. Delivery & storage of water	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
4. Pumps	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
5. Simple water treatment	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

	a	b	c	d	e	f	g
6. Simple disinfection	[]	[]	[]	[]	[]	[]	[]
7. Sanitation - criteria &c	[]	[]	[]	[]	[]	[]	[]
8. Pit latrines	[]	[]	[]	[]	[]	[]	[]
9. Bio-gas & compost latrines	[]	[]	[]	[]	[]	[]	[]
10. Septic tanks & aqua-privies	[]	[]	[]	[]	[]	[]	[]
11. Solid waste management	[]	[]	[]	[]	[]	[]	[]
12. Vector and rodent control	[]	[]	[]	[]	[]	[]	[]
13. Production of concrete	[]	[]	[]	[]	[]	[]	[]
14. Management	[]	[]	[]	[]	[]	[]	[]
15. Management and finance	[]	[]	[]	[]	[]	[]	[]
16. Community participation	[]	[]	[]	[]	[]	[]	[]
17. National/internat' agencies	[]	[]	[]	[]	[]	[]	[]

Your name ....* Date of birth ....

The position you hold ....

Your employer ....

** If you wish to remain anonymous do not give your name.*

Appendix B

FACILITATORS' EVALUATION OF PARTICIPANTS

Details of participant

Name: ....

Date of birth: .... Age in years: ......

Employer: ....

Position held: ....

Nominated for course by: ....

Education and qualifications (highest reached): ....

....

Experience of operation and maintenance
of rural water supply and sanitation: ....

....

....

Experience of facilitating training: ....

....

Motivation

The participant appeared to -

- be keen to acquire new knowledge and skills []
- be keen to pass on knowledge to others []
- be more interested in own career than in in helping others to improve []
- have little interest in learning []
- have no interest in learning []

Facilitating

Assessment of performance during practice sessions

	very good	good	fair	poor
evidence of thorough preparation	[]	[]	[]	[]
examples from his/her own experience	[]	[]	[]	[]
introduced his/her own ideas	[]	[]	[]	[]
use of visual/audio aids	[]	[]	[]	[]
clarity and audibility of voice	[]	[]	[]	[]
liveliness and variation of voice	[]	[]	[]	[]
rapport with class	[]	[]	[]	[]
manner of dealing with questions	[]	[]	[]	[]
manner of dealing with discussion	[]	[]	[]	[]
time-keeping	[]	[]	[]	[]

Knowledge
Assessment of participant's understanding of modules

	very good	good	fair	poor	not known
1. health, water & sanitation	[]	[]	[]	[]	[]
2. sources of water	[]	[]	[]	[]	[]
3. delivery & storage of water	[]	[]	[]	[]	[]
4. pumps	[]	[]	[]	[]	[]
5. simple water treatment	[]	[]	[]	[]	[]
6. simple disinfection	[]	[]	[]	[]	[]
7. sanitation - criteria &c	[]	[]	[]	[]	[]
8. pit latrines	[]	[]	[]	[]	[]
9. bio-gas & compost latrines	[]	[]	[]	[]	[]
10. septic tanks & aqua-privies	[]	[]	[]	[]	[]
11. solid waste management	[]	[]	[]	[]	[]
12. vector and rodent control	[]	[]	[]	[]	[]
13. production of concrete	[]	[]	[]	[]	[]
14. management	[]	[]	[]	[]	[]
15. management and finance	[]	[]	[]	[]	[]
16. community participation	[]	[]	[]	[]	[]
17. national & internat agencies	[]	[]	[]	[]	[]

OVERALL ASSESSMENT

The participant demonstrated the ability to
- *organize and facilitate training programmes alone* []
- *assist in organizing and facilitating programmes* []
- *facilitate a limited range of modules* []
- *facilitate after further training in instruction* []
- *facilitate after further practical experience* []

- be involved in training at all levels []
- be involved in courses for junior staff only []

The participant is considered to be unsuitable for consideration as a facilitator []

Signed

....
Facilitators Date ....

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 9

BIOGAS AND COMPOSTING TOILETS

This module is intended to be an introduction to two different methods of extracting a resource from human and /or animal wastes. It is intended for participants who have no previous knowledge of the topics.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE NINE

BIOGAS PLANTS AND COMPOSTING TOILETS

INTRODUCTION

The module is divided into two parts. Part I concentrates on bio-gas plants and Part II on composting toilets.

PART I

1. BIOGAS PLANTS

Introduction to biogas

If any organic material is kept in conditions where air cannot get to it, microscopic organisms (such as bacteria) which use the material as a food source will begin to grow. As the bacteria grow, the organic material breaks down, producing other simpler organic materials. Under certain conditions one of the new materials formed will be a flammable gas known as bio-gas.

Operation and maintenance is very important in bio-gas plants. No matter how well the plant is designed and built, if it is not properly operated and maintained it does not produce bio-gas. For this reason it is most important that the plant operator is fully committed to the production of biogas and is properly trained in its operation.

Bio-gas plants can be made in many different sizes - some serve individual farms; others serve large cities.

This module is about plants suitable for individual farms or small communities.

2. BIOGAS PLANT DESIGNS

There are a number of different designs of biogas plant which have developed in various parts of the world to suit the particular environment. The two most common, however, are the fixed dome type and the floating dome type.

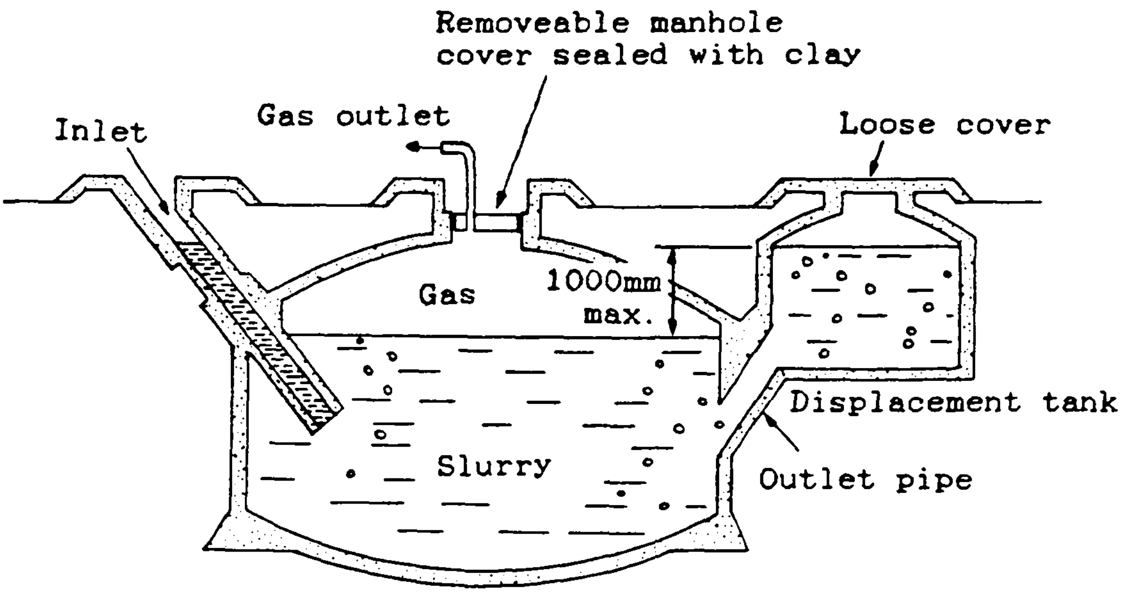

Figure 1. Fixed dome biogas plant

This design of plant originated in China where over seven million are known to be in operation. Fresh organic waste in the form of a slurry (a mixture of organic material and water) is fed in through the inlet. Bacteria and other micro-organisms in the chamber break down the slurry releasing gas which collects under the dome at the top of the chamber. Slurry displaced by the gas and the incoming slurry is discharged into the outlet tank from where it can be removed. A gas pipe fitted in the top of the dome is connected to the user points.

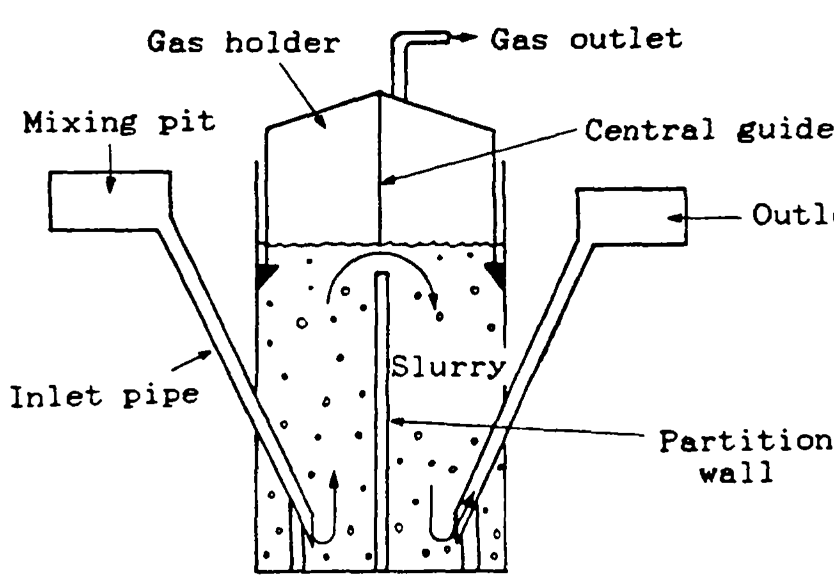

Figure 2. Floating dome biogas plant

Developed in India, the floating dome type works in the same way as the fixed dome type except that as gas is produced the floating gas holder rises to accommodate it rather than the slurry surface level being depressed. This means that the gas pressure remains constant rather than increasing as the slurry level falls.

The chamber is also usually fitted with a central partition wall to ensure that the slurry is well mixed and that it does not pass through the chamber too quickly.

3. OPERATING PARAMETER

a. Type Of Waste

Almost any organic waste can be used to generate biogas but the most common are the wastes from domestic animals such as cattle and chickens. Human wastes can also be used but on their own they do not produce much gas. Other materials used are grasses and crop residues such as rice and wheat straw although these must be chopped up to prevent blocking the plant.

b. Slurry

A concentration of 1 to 9 per cent dry matter in water is generally found to work best. Most animal manure is about 18 to 25 per cent dry matter. Additional water needs to be added to produce the right consistency. Water should be added until a consistency similar to a very thick, creamy soup is achieved.

When mixing the slurry, the following materials should not be put in: earth, sand, large pieces of grass or straw, sawdust, peat moss, oil, soap or detergents. All of these will block the chamber or kill the bacteria that produce the gas.

c. Temperature

The activity of the bacteria and the amount of gas produced is strongly related to the temperature of the slurry. Maximum gas production takes place at 35°C and 55°C but a reasonable production rate can be expected at lower temperatures.

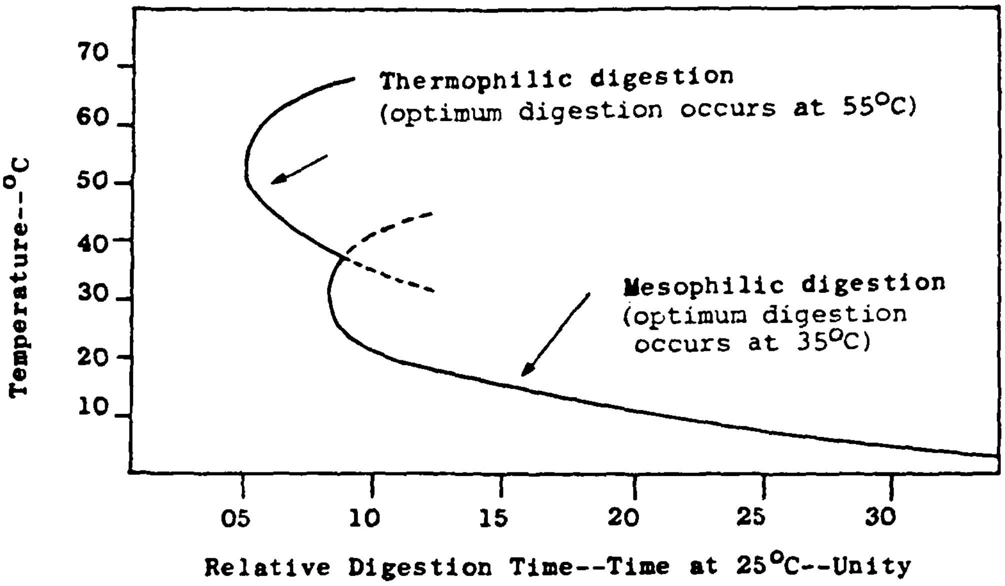

Figure 3. Relative digestion time

The most important thing to avoid is a sudden temperature change. A rapid change in the temperature of the slurry of as little as 0.5°C may stop gas production completely. For this reason biogas plants are usually built underground as the ground acts as an insulator.

d. pH (Acidity)

The pH of the slurry should be kept neutral (pH 7.0). If the plant is operating properly, self regulation keeps the acidity at the correct level so any changes in the pH is an early indication of problems.

e. Carbon/Nitrogen ratio

The carbon to nitrogen ratio governs the amount of bacterial activity in the slurry (and hence the amount of gas production). It is very difficult to measure the carbon/nitrogen level and the ability to judge it comes with experience. For best results the carbon/nitrogen level should be between 20:1 and 30:1. This may mean that extra ingredients must be added to the slurry to keep the correct ratio.

Proportions of different materials to be put into the digester

Material	Proportions
Fresh human waste/dry straw (wheat stalks)	1.75:1
Fresh pig waste/dry straw (wheat stalks)	4.55:1
Fresh human waste/dry rice stalks	1. 4:1
Fresh pig waste/dry rice stalks	3.65:1
Fresh human waste/corn stalks	1.13:1
Fresh pig waste/corn stalks	2.95:1
Fresh human waste/fallen leaves	0.85:1
Fresh pig waste/fallen leaves	2.22:1
Fresh human waste/soya bean stalks	0.45:1
Fresh pig waste/soya bean stalks	1.1 :1
Fresh human waste/wild green grass, including water weeds	1 :10
Fresh pig waste/wild green grass, including water weeds	1 :25
Fresh human waste/fresh pig waste/ dry rice stalks	1: 1:1
Fresh human waste/fresh pig waste/ dry wheat stalks	1: 2:1
Fresh human waste/fresh pig waste/ dry corn stalks	3: 4:4
Fresh human waste/fresh pig waste/ green grass, including weeds	1:10:180

Source: Information made available by the Chinese authorities to the members of the Interregional Biogas Study Tour in China from 1 to 21 September 1979, organized by the United Nations.

Note: The C/N ratios of sheep, cow and horse dung fall in the optimum range (20 to 25:1), hence they may be digested alone or with any of the above material mix.

Table 1. Proportions of materials

f. Retention time

The longer slurry stays in the chamber the more it is degraded and the more gas is produced. However, the amount of gas given off tends to decline with time and the bigger the tank, the higher the cost of building it. It is therefore necessary to consider whether enough gas will be produced to justify the cost of building a large tank.

Generally, slurry is left in the chamber for between 30 and 60 days depending on the plant design and temperature.

4. OPERATION

Many well designed and constructed biogas plants do not work because of poor operation and maintenance. The most important factors to be considered are given below:

a. Slurry input

Slurry should be put into the digester regularly (usually daily). The amount added and its thickness must be constant since the bacteria digesting the slurry quickly stops working if the loading is not constant. For this reason, the plant should be designed to suit the lowest amount of organic material produced at any time throughout the year so that the amount added can be the same all the time.

The amount of slurry used should not exceed the plant's design since this also affects bacterial activity. The capacity of the chamber can be calculated by dividing the volume of the chamber by the retention time.

The carbon to nitrogen ratio must be carefully controlled. If the material to be digested changes even slightly, then the C/N ratio should be checked and, if necessary, adjusted. As mentioned before, experience in operating biogas plants is most important. For example, if the gas production rate is reducing, experience tells the operator what materials to add.

b. Stirring the slurry

Stirring (or mixing) the slurry in the chamber increases the gas production. It also helps to prevent the build up of a surface scum layer or sludge on the bottom. The method and amount of mixing depend on the digester design.

5. MAINTENANCE

a. Gas holder painting

With the floating dome type the gas holder is commonly made of steel. This normally needs painting every year. Only the outside needs painting as the inside does not rust (there is no oxygen).

b. Scum removal

A build-up of scum on the surface of the slurry prevents the the gas from escaping. The frequency of removal depends on the contents of the slurry and the care of the operator. The method of removal depends on the type of plant but it should be done just before winter.

c. Condensate removal

Water in the gas often collects in the gas pipe leaving the digester. The gas pipe should be raised every one to seven days so that the water can run back into the digester.

d. Routine maintenance

Other maintenance activities include:

1. repairing masonry;
2. lubricating gas taps and valves;
3. removing dried slurry; and
4. checking flexible gas pipes for leaks.

6. OUTPUTS

a. Gas

Biogas is primarily used for domestic heaters and lighting where, providing the appliances have been properly designed to run on biogas, the results will be very satisfactory.

In addition the gas can be used for powering petrol and diesel engines, running refrigerators and generating electricity, although these uses are more likely at larger plants.

b. Slurry effluent

The value of the effluent (the slurry that comes out of the biogas plant) is usually of more value as a fertilizer than the influent (the slurry that goes in). This is because the bacteria convert the nutrients in the slurry into a form that is more readily accepted by the soil and plant roots but is less easily washed away by rain. This is particularly true for the nitrogen in the slurry.

Alternatively, the slurry can be used for other things such as algae production, animal food or fish food.

c. Health aspects of effluent

The effluent from a biogas plant has far fewer dangerous organisms in it than the influent. This does not mean that it is completely safe, however, and any handling should be done with care.

PART II

1. COMPOST TOILETS

If human excreta is mixed with other organic material, bacteria develop that break down the organic mass into a form suitable for use as a fertilizer. This process is usually called composting. The material should be kept 'aerobic' - that is, with enough air to enable micro-organisms which need oxygen to break down organic matter. The temperature may rise enough to kill off all pathogens, including roundworm eggs. Aerobic conditions can be maintained by turning over heaps of mixed vegetable waste and sludge every few days.

Two groups of bacteria can be utilized for breaking down the organic mass and the toilet design decides which group is used.

2. COMPOST TOILET DESIGNS

The two most common types of compost toilet are the double vault latrine and the continuous composting toilet.

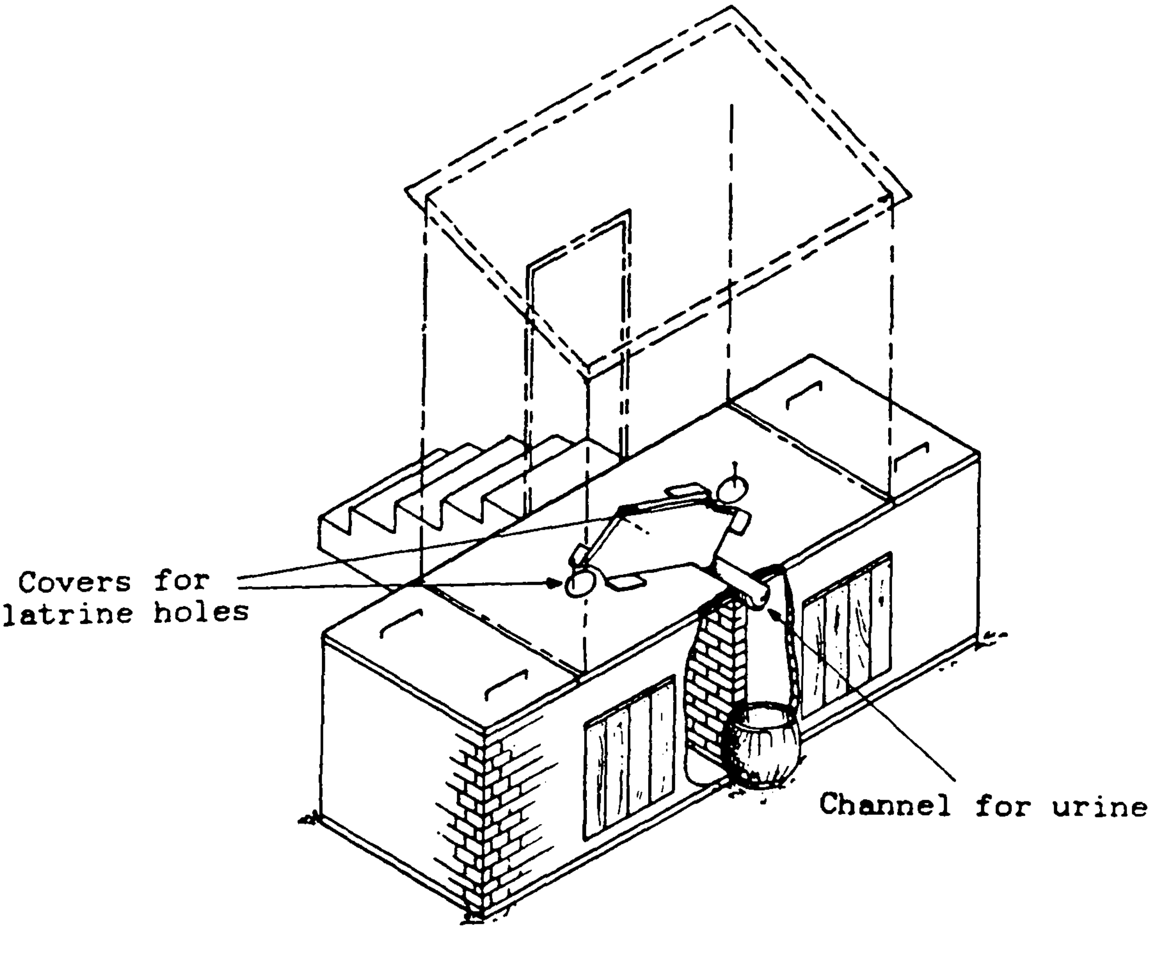

Figure 4. Double vault latrine

A watertight box is divided by a central wall and covered with a slab containing two toilet openings (one for each chamber). The toilet opening to one of the chambers is closed. The other chamber is lined with a dry absorbent material such as straw.

The lined chamber is then used as a latrine. The moisture content of the chamber must be carefully controlled, so after each use the excreta is covered with ash or sawdust.

Other organic material such as grass cuttings, kitchen vegetable waste and yard sweeping must be added regularly. This controls the carbon to nitrogen ratio and ensures that the bacteria have sufficient nutrients to grow.

Since the box is sealed (except for the latrine hole) any air in the mass is quickly used up and bacteria develop that thrive in an oxygen free enviroment (anaerobic bacteria).

When the first chamber is full the latrine hole is closed and sealed and the second chamber used in the same way as the first one.

When the second chamber is full (at least two years should be allowed to pass) the contents of the first chamber will have been fully composted and can be safely dug out for use as fertilizer. The chamber can then be re-used.

3. OPERATION AND MAINTENANCE

a. Moisture Content

The moisture content of the compost is critical to the operation of the latrine. If it is too wet the contents smell and are difficult to remove. If it is too dry the bacteria die and composting ceases. In general, the problem is too much moisture rather than too little.

It is most important that water entering the latrine should be kept to a minimum. If possible, urine should be collected separately. After each use the fresh faeces should be covered with ash or sawdust to absorb excess moisture and deodorize the mass. The people who use the latrine need to be responsible and committed to operating the compost latrine properly.

b. Regular upkeep

Other organic material such as floor and yard sweepings and kitchen leftovers should be put into the chamber every day. Several times a week grass, weeds, straw or leaves should also be put in the chamber to ensure the correct organic balance of the compost. Material that does not easily decompose such as glass, plastic, corncobs, wooden sticks, etc, should not be put in the chamber.

c. Cleaning the latrine

When the floor of the latrine is cleaned it should be washed with the minimum amount of water and no disinfectant should be used as it kills the composting bacteria.

d. Emptying the pit

When the second chamber is nearly full the first chamber may be emptied. This will be an easy and safe matter provided the moisture content has been properly controlled.

The access door in the side or top of the chamber is opened and the contents dug out with a spade or shovel.

CONTINUOUS COMPOSTING TOILET

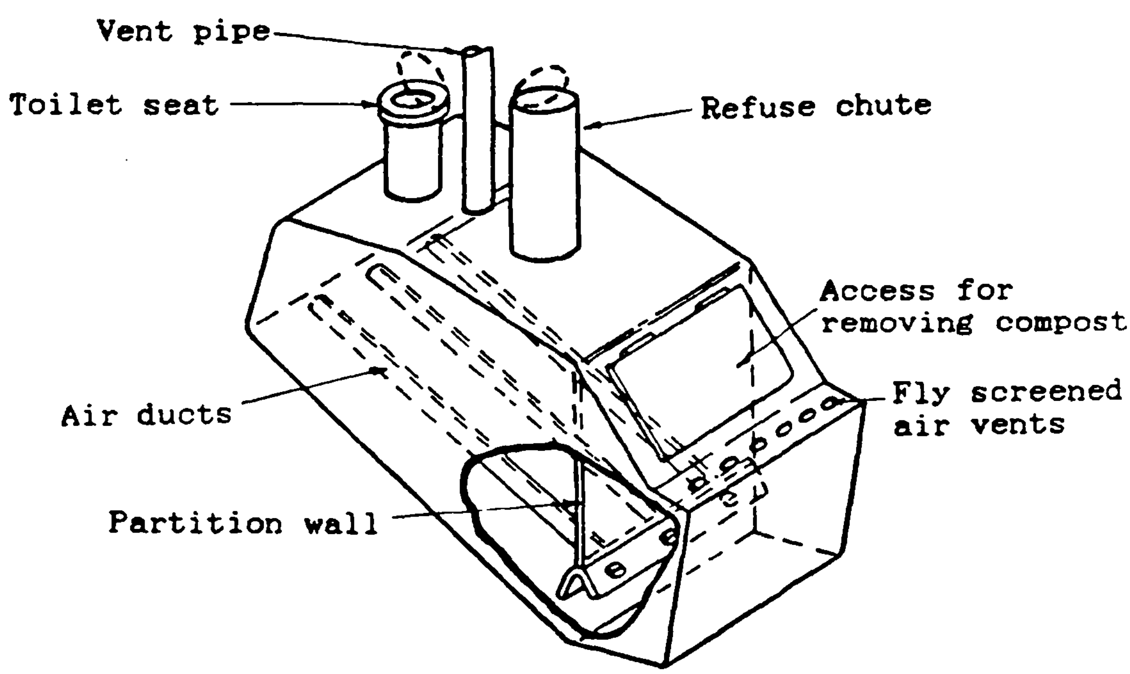

Figure 5. Continuous composting toilet

A large tank with a sloping floor is divided into two chambers. The first, and largest chamber is fitted with a number of air ducts and a ventilation pipe. The toilet is situated on the top of the large chamber as far as possible from the chamber dividing wall.

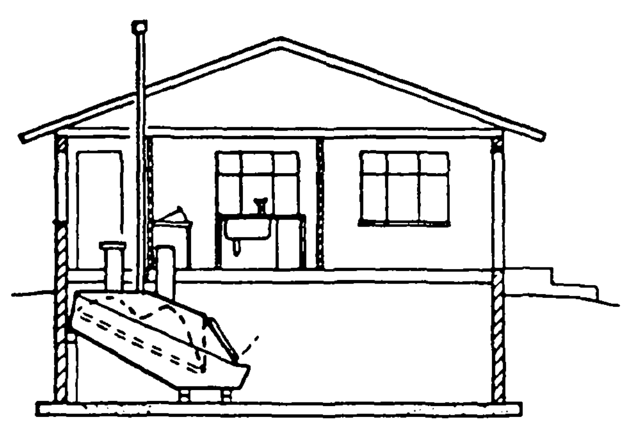

Figure 6. Toilet installed in the cellar of a house

The operation is similar to the double vault latrine but the ventilation pipe and air ducts ensure that there is a continuous flow of fresh air through the compost. This encourages the breeding of bacteria that require oxygen to survive. The method is called 'aerobic composting'.

As the latrine is being used, the composting material gets covered by fresher material and slowly moves towards the bottom of the chamber. The slope on the chamber floor causes the composting material to slide along the floor and collect in the second chamber. The size of the first chamber governs the time taken for the composting material to reach the second chamber. It should take at least two years.

Periodically the contents of the second chamber can be dug out and used as a fertilizer.

4. OPERATION

The operating procedure is generally the same as with the double vault latrine. Slightly more moisture can be allowed to enter a continuous composter than a double vault because the air flow through the compost tends to cause any excess moisture to evaporate.

5. OUTPUT FROM COMPOSTING TOILETS

If used properly all composting toilets produce a useful soil conditioning agent. The material which is finally removed from double pit or compost toilets is known as compost. It is a valuable land conditioner and can be used on farms and gardens. It contains some nitrate, phosphorus and potassium which are nutrients essential for plant growth. Trace quantities of other minerals in compost may help growth and increase resistance to plant disease. The nutrients in compost are readily available for plants at the rate required for growth. Compost also controls the rate of release of nutrients from artificial (chemical) fertilizers when both are applied together.

One of the greatest benefits of mature compost is its action as a soil conditioner. It improves the soil structure and the ability of the soil to retain moisture. This makes the soil less liable to erosion by wind and water.

6. PROBLEMS WITH COMPOSTING TOILETS

Composting toilets have been tried in many parts of the world and there have been many failures. The failures have been mainly due to overuse (more people using the latrine than it was designed for), high moisture content, smell and flies.

Regular routine operation is critical to their proper operation and this can only be achieved if the users are completely committed to using composting toilets.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE 9

BIOGAS PLANTS AND COMPOSTING TOILETS

INSTRUCTION NOTES

1. INTRODUCTION

This module is intended to be an introduction to two different methods of extracting a resource from human and/or animal wastes. It is intended for students who have no previous knowledge of the topics.

The two topics covered are very different and it is therefore more appropriate to deal with each of them separately.

PART ONE - BIOGAS PLANTS

2. MAIN TEACHING POINTS

Micro-organisms living in an oxygen free environment can break down organic material and produce a flamable gas.

There are two basic designs of plant ie fixed dome and floating dome. The lecturer should explain the difference.

The major factors affecting gas production, particularly the types of waste, moisture content and carbon to nitrogen ratio.

The importance of operation and maintenance to the production of gas.

The value and health hazards of the effluent.

3. REFERENCES

Gunnerson C G & Stuckey D C 1986 "Integrated Resource Recovery - Anaerobic Digestion - Principles and practices for Bio Gas Systems". World Bank Technical Paper No 49. Washington D C, USA.

4. VISUAL RESOURCES

Overhead projector copies of the drawings in the text.

PART TWO

COMPOSTING TOILETS

5. MAIN TEACHING POINTS

Explain how organic wastes are converted to fertilizer.

Explain the principles of operation of the Double Vault and Continuous Composting toilets.

Highlight the importance of controlling the moisture content and the Carbon to Nitrogen ratio.

Highlight the problems associated with composting toilets.

7. REFERENCES

Winblad U, Kilama W, Torstensson K, 1978. "Sanitation Without Water"

8. VISUAL REFERENCES

Overhead projector copies of the diagrams shown in the text.

DISCUSSION QUESTIONS

These questions relate to both parts of the text.

Is this type of technology appropriate in your community?
If the answer is 'no' then why not?
If the answer is 'yes' then how should it be amended to suit your particular environment and who should pay for the construction costs.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 10
SEPTIC TANKS AND AQUA PRIVIES

The objectives of this module are to explain the requirements of operation and maintenance of septic tanks and their associated effluent disposal systems. In order to understand these requirements fully, the wastewater treatment processes which occur in a septic tank are explained. Constructional details which are pertinent to satisfactory operation of a septic tank are illustrated. The rates of sludge and scum accumulation and their measurement are discussed in order to introduce the concept of regular desludging. A section on the disposal of tank effluent is included to emphasise the imporatnce of the provision and maintenance of means of effluent disposal.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE TEN

SEPTIC TANKS AND AQUA PRIVIES

1. INTRODUCTION

Septic tanks are a common form of wastewater treatment for individual households in low density residential areas. Large tanks can be constructed to serve insitutions such as schools and hospitals, or small housing estates. The wastewater passed into a septic tank may contain either toilet waste only, or a mixture or toilet waste and sullage (used water from bathing, washing clothes, and kitchens). A septic tank provides primary treatment of wastewater, principally by allowing settlement to occur.

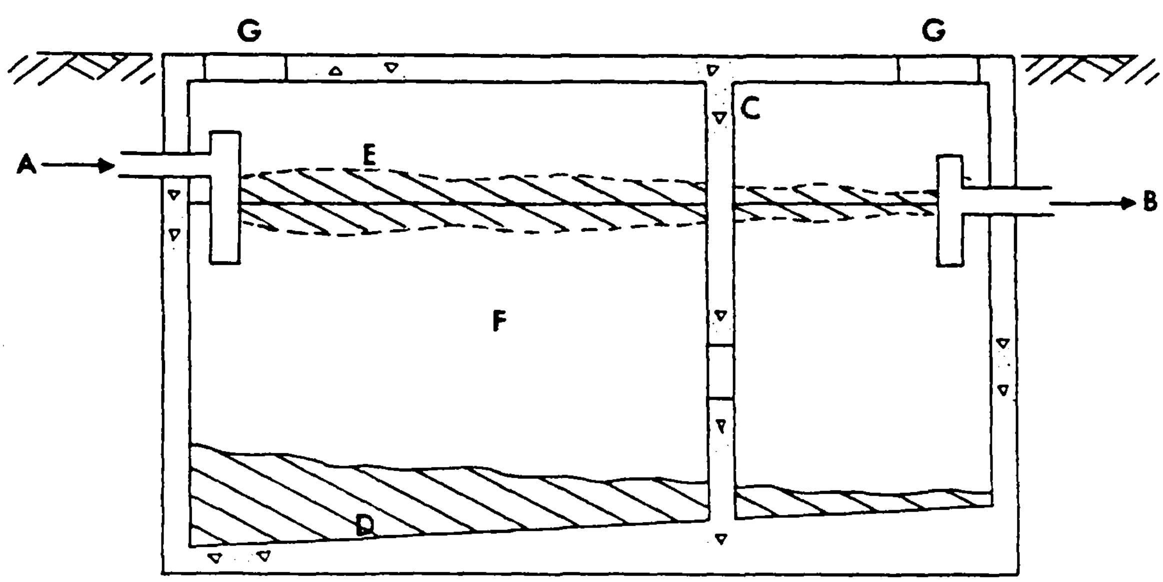

Figure 1. A septic tank

(Key: A = inflow; B = outflow; C = compartment wall; D = sludge; E = scum; F = liquid; G = manhole)

It is important to realize that the settled wastewater which becomes the effluent from the septic tank is potentially harmful and must be safely disposed of.

For a house with flush toilets, the septic tank, in conjunction with its effluent disposal system, offers wastewater disposal with many of the advantages of conventional sewerage. However, septic tank systems are more expensive than pit latrines and are unlikely to be affordable to the poorer people in society.

In low density residential areas it is common for the septic tank to be located away from the house; the building drainage system carries the wastewater to the tank. There must be a reliable household water supply, because a considerable quantity of water is required to flush the waste through the household sewer system to the septic tank. For situations in which water is scarce, a variation of the septic tank has been developed. This is known as the 'aqua privy'.

2. WASTEWATER TREATMENT IN SEPTIC TANKS

One of the most important things to appreciate about septic tanks is that they operate by providing a certain period of retention time (usually about one to three days). During this time the wastewater which is passed into the tank is allowed to settle. The settled liquid is then passed out of the tank and must be disposed of in a satisfactory manner, for example, through drainfields or soakage pits. This secondary treatment makes the effluent from the septic tank less potentially harmful. Many of the most common operational problems with septic tank systems arise because not enough consideration is given to the disposal of the settled effluent from the tank.

Despite the apparent simplicity of the septic tank, the interaction of the physical, chemical and biological processes which occur in the tank is complicated. The most important processes are listed below.

a. Settlement

In still water, suspended solid particles which are denser than water, settle to the bottom of the tank. A principal aim of septic tank design is to achieve stable hydraulic conditions within the tank to assist the settlement process. The settled solids form a layer of sludge on the bottom of the tank which must be reomoved periodically.

Large surges of water entering the tank may cause a temporarily high suspended solids content in the effluent due to disturbance of the solids which have already settled. The longer the retention time, the more solids will, in theory, settle, although the maximum rates of settlement are achieved within the first few hours.

b. Flotation

Material which is less dense than water tends to float up to the surface of the liquid. In addition to solid matter, grease and oils rise to the surface and a layer of scum forms which can become quite hard. The liquid is thus sandwiched between the scum and sludge.

c. Septic Tank Sludge

Organic matter in the sludge and scum layers is broken down by bacteria. The result is that considerable amounts of the organic sludge are converted into water and gaseous methane and carbon dioxide. The rate at which the digestion process proceeds is dependent upon temperature. The bacteria can only be active in certain temperature ranges: the digestion rate increases with temperature up to about 35°C.

An important effect of the digestion process is the reduction in the volume of the solids which are retained in the tank. This is coupled with the consolidation of the sludge due to the weight of liquid and additional solids deposition. The net result is that the accumulation of sludge in the tank is considerably less than the quantity entering as raw sewage solids.

The use of ordinary household soap is unlikely to affect the digestion process, although large amounts of synthetic detergent could increase the biochemical oxygen demand (BOD) of the effluent and inhibit the formation of scum. The use of abnormally large amounts of disinfectant causes bacteria to be killed off and thereby inhibits the digestion process.

d. Septic tank effluent

There is very little data on the removal of pathogens by septic tanks. Experiments have shown between 80% and 90% of hookworm and ascaris eggs are removed. Nevertheless, there still remain vast numbers of pathogens in the effluent from septic tanks which could be a potential source of infection to other people. Thus, adequate disposal of septic tank effluent is essential.

3. DESIGN FEATURES OF SEPTIC TANKS

A septic tank should:

i) provide sufficient retention time (at least 24 hours) for the wastewater in order that settlement and stabilization of the liquid takes place;

ii) provide stable and still hydraulic conditions to assist efficient settlement and flotation;

iii) be large enough to store the accumulated sludge and scum without unduly restricting the operation of the tank; and

iv) provide adequate ventilation for gases, and be unlikely to block.

The important points which have to be considered in operation and maintenance relate to blockage and the accumulation of sludge.

The accumulation rate of sludge and scum depends upon:

i) the frequency with which the tank is desludged (the sludge is removed).

ii) the rate of digestion, which depends in turn on the method of anal cleansing of the users and the temperature at which the tank will be operating.

The number of years between desludging should be between two and five years. This depends to some extent upon how easy it is to get the tank desludged. If there are no problems in obtaining a cheap emptying service, a short desludging interval will be economic; if not, the interval will have to be longer.

The sludge digestion rate depends upon the ambient (surrounding) temperature and the period of time between desludging.

Number of years between desludging	Ambient temperature		
	More than 20°C throughout year	More than 10°C throughout year	Less than 10°C during winter time
1	1.3	1.5	2.5
2	1.0	1.15	1.5
3	1.0	1.0	1.27
4	1.0	1.0	1.15
5	1.0	1.0	1.06
6 or more	1.0	1.0	1.0

Table 1. Sludge digestion rate

The rate of sludge and scum accumulation in litres per year depends upon the material used for anal cleansing and the quantity of wastewater entering the septic tank.

Material used for anal cleansing	Toilet wastes only	Household sullage plus toilet wastes
Water, soft paper	25	40
Hard paper	40	55
Sand, earth stones (aqua privy only)	55	70

Table 2. Sludge accumulation in litres per person per year

The designer of the tank should have calculated the volume required for sludge and scum accumulation in the following way:

Volume of sludge and scum accumulation =

> the number of people expected to use the tank x the proposed number of years between desludging x the sludge digestion rate x the rate of sludge and scum accumulation in litres per year.

Another formula, using the same tables, can be used to calculate when a septic tank needs desludging. This is given in the section on operation and maintenance.

a. <u>Constructional details of septic tanks</u>

It is common practice to construct the septic tank with two compartments separated by means of a baffle wall. The majority of the settlement and digestion occurs in the first compartment, with some suspended material being carried over into the second. The settlement efficiency is affected by disturbances which result from surges of wastewater entering the tank. These surges will have a reduced effect in the second compartment which enables further settlement to take place undisturbed. Studies have indicated that septic tanks with two compartments perform more efficiently than single compartment tanks.

Assuming that the tank is rectangular in plan, the liquid depth should not be less than 1.2 metres, with 1.5 metres being a typical minimum value; this allows for the accumulation of sludge. In addition, a clear space of at least 300mm should be left between the surface of the liquid and the under-surface of the cover slab.

The first compartment should be twice as long as the second. The length of the second compartment should not be less than a minimum recommended width of 0.6 metres.

The inlet and outlet design details are critical to the performance of the septic tank because the wastewater flow must be introduced and taken from the tank with the minimum possible disturbance to the liquid and solids already in the tank. On small tanks 'Tee' pipes are used as shown in Figure 2.

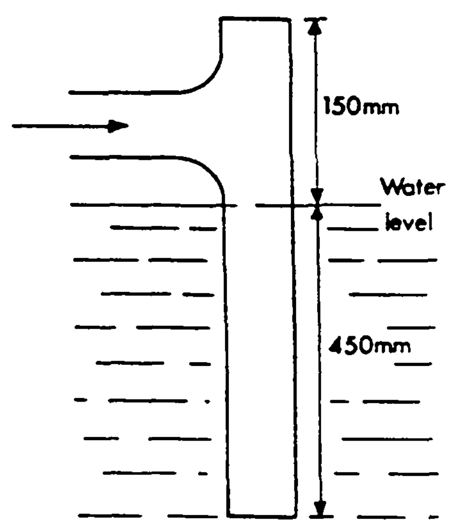

Figure 2. Septic tank inlet pipe

For tanks wider than 1.2 metres, a full-width weir is required to draw off the flow evenly from the whole width of the tank. A scum board, as shown in Figure 3, is also necessary to prevent the scum from washing over the weir.

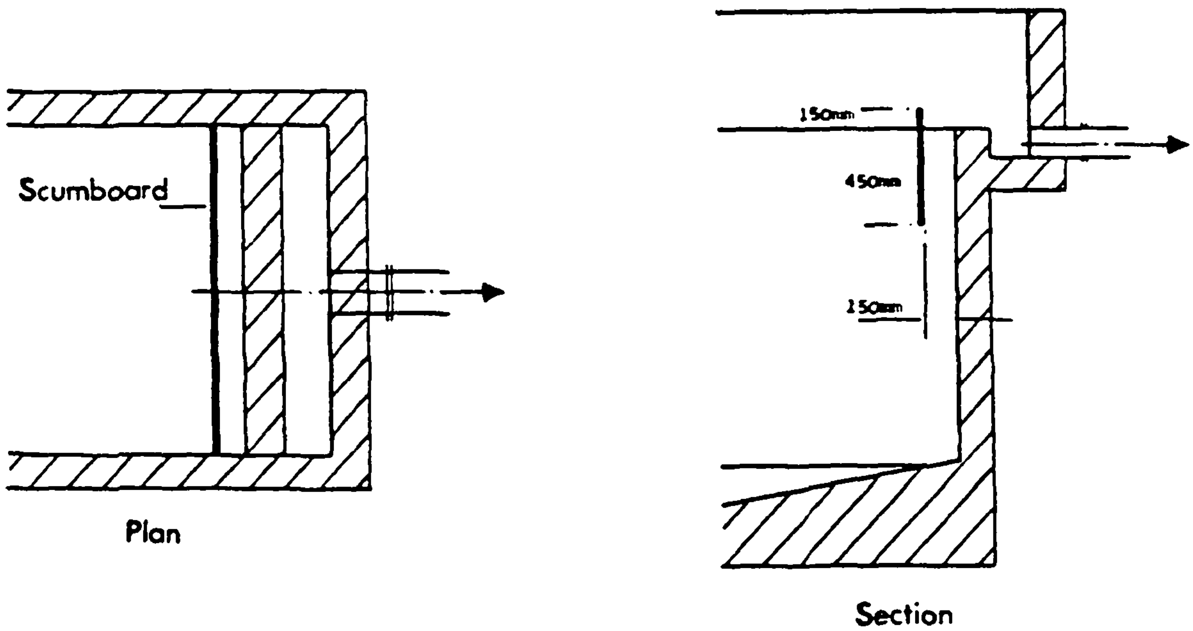

Figure 3. Septic tank outlet using full width weir

The anaerobic processes which occur in the tank produce gases which must be allowed a means of escape. The freeboard (the space in the tank above the water level) provided and the tee-shaped inlet and outlet facilitate ventilation. In many systems the gases can escape back through the inlet sewer pipe and out of the ventilation pipe which is attached to the building drainage system. If this is not possible then the septic tank must be provided with a ventilation pipe. The top of the pipe should be covered by a mosquito screen which should be checked regularly.

The floor of the septic tank should be sloped downwards towards the inlet. More sludge accumulation is likely near the inlet, thus a greater depth is desirable. Furthermore, the slope will assist the sludge to move down towards the inlet. This will make desludging easier as the sludge is then near the access manhole.

The tank cover, which usually comprises one or more concrete slabs, must be strong enough to withstand any loads which will be imposed. Manholes should be provided over the inlet and outlet as it is very important that access is simple in order to allow routine inspections and regular maintenance to be carried out. Manholes which are circular rather than rectangular have the advantage that the manhole cover cannot fall into the tank when it is removed.

4. OPERATION AND MAINTENANCE

a. Starting up the tank

The process of anaerobic digestion of the sewage solids entering the tank can be slow in starting and it is a good idea to 'seed' a new tank with some sludge from a tank which has been operating for some time. This will ensure that the necessary bacteria and micro-organisms are present in the tank to allow the digestion process to start in a short time. The tank should also be partly filled with water before commencing operation.

b. Routine inspection

The inlet and outlet should be regularly inspected to ensure that there are no blockages. The 'Tee' pipe design ensures that blockages can be rodded out by pushing a rod down the open top of the 'Tee'. The sewer linking the septic tank to the house should be fitted with standard inspection manholes so that any blockages in the line can be removed by rodding out or flushing with large volumes of water.

Routine inspection is also necessary to determine the levels of sludge and scum in the tank. One of the features of septic tanks is that they will carry on operating when almost full of sludge and scum. In this situation the incoming flow scours a channel through the sludge and passes through the tank in a matter of minutes rather than the required 24 hours. There will be no improvement to the quality of the incoming wastewater and it is likely that problems will result in the effluent disposal system due to clogging. It is therefore most important that the sludge and scum levels are checked, perhaps twice each year, and desludging carried out when necessary.

c) When to desludge a tank

There are two things that need to be known about a tank when considering desludging:

i) whether it needs desludging NOW;
ii) how often it should be desludged.

Measuring the contents of the tank

Generally, a septic tank should be desludged when the sludge is calculated to occupy one-third of the total volume available for liquid and sludge or when there is not enough space to hold all the liquid put into the tank in a 24-hour period. In order to work this out it is necessary to know the dimensions and volume of the tank.

One method of determining the thickness of sludge is by pushing a stick wrapped with white towelling material through the inspection manhole down to the bottom of the tank. (A hole should be made in the scum first, or the stick should be pushed down at the inlet or outlet as there is no scum there.) When the stick is taken out it is blackened to the depth of the sludge. The volume of sludge is calculated by multiplying -

the depth of sludge x the width of the tank
x the length of the tank

Unfortunately, it is very difficult to measure sludge this way with much accuracy.

Another method of measuring sludge and scum involves measuring the total depth of the sludge, liquid and scum by pushing a stick down to the bottom of the tank. Then a graduated measuring stick with a disc on the end is pushed down gently. It is usually possible to 'feel' the top of the sludge layer through a slightly increased resistance as the disc reaches it. The volume of sludge can thus be calculated. The stick is then gently moved along the tank a little and pulled up slowly. Slight resistance will be felt when the disc reaches the bottom of the scum layer. The scum layer can be measured and its volume calculated. The total volume of sludge and scum is then known.

It is essential that a septic tank provides enough space to retain liquid for 24 hours. Another way of determining when a septic tank needs desludging is to calculate the minimum space required to hold all the liquid put into a tank in a 24-hour period. This can be done by multiplying -

the number of people using the tank x 24
x the water discharged per person per day

By subtracting the volume required for liquid from the total volume available, it is possible to calculate the maximum volume of sludge and scum which can be held in the tank.

The actual volume of sludge and scum can be measured by one of the two methods described above. If the volume of sludge and scum is approaching the maximum allowable, the tank should be desludged.

Establishing a set desludging interval

To set up a routine desludging schedule, it is necessary to know how long it takes for the space allocated for sludge and scum to be filled. This can be determined in one of two ways:

i) by examining the desludging interval proposed by the designer;

ii) by using the following formula.

Desludging period in years =

$$\frac{\text{Volume of sludge and scum accumulation}}{\text{No. of users} \times \text{sludge and scum accumulation rate} \times \text{digestion rate}}$$

The 'theoretical' or estimated desludging interval can be followed until information has been gathered about the actual accumulation rates of individual septic tanks by regularly measuring the sludge levels. Such a monitoring system, carried out over a number of years, will enable the most efficient desludging interval to be calculated for each septic tank.

d. Desludging septic tanks

The most satisfactory method of sludge removal is by using a vacuum truck. The sludge is pumped out of the tank via a flexible hose connected to a vacuum pump which deposits the sludge in a tanker. If the bottom layers of sludge appear to have cemented together, they can be jetted with a water hose, or broken up with a long-handled spade before being pumped out.

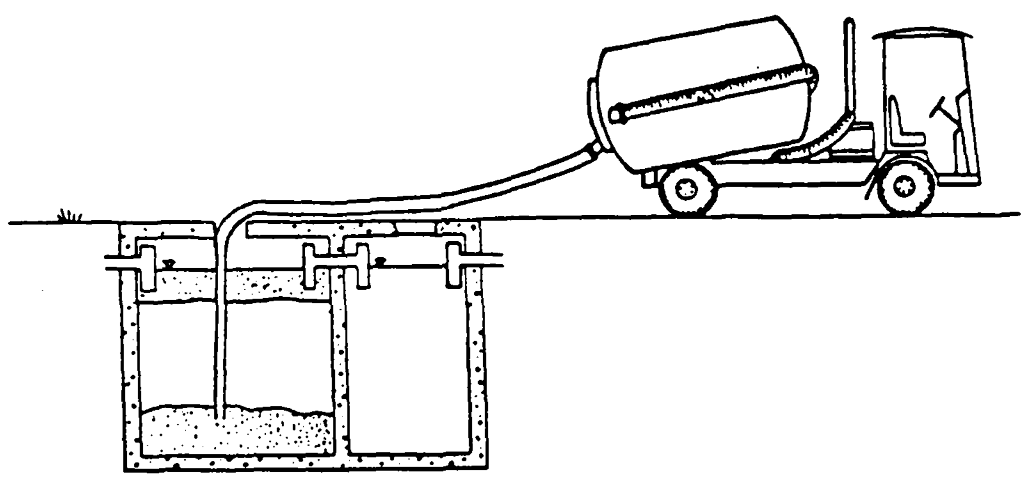

Figure 4. Vacuum tanker desludging a septic tank

If a vacuum tanker is not available the sludge must be baled out manually using buckets. This is obviously unpleasant work which will expose the operatives to a considerable health hazard. In addition, it is likely that sludge will be spilled all around the area of the tank and care must be taken to ensure that the sludge is taken away and suitably disposed of.

The sludge should not be immediately used as a crop fertilizer because of the presence of persistent pathogens. The sludge will contain a mixture of well-digested material which is harmless and fresh excreta which is potentially harmful. It should be adequately disposed of, for example, by burying in trenches, drying in sludge beds, or composting with other vegetable waste matter.

When the tank has been desludged it should not be fully washed out or disinfected. A small amount of sludge should be left behind in the tank to ensure continuing anaerobic digestion.

5. EFFLUENT DISPOSAL

a. Introduction

It is important to remember that a septic tank is no more than a combined retention tank and digester and that, excepting losses through seepage and evaporation, the outflow from the tank will equal the inflow. The effluent is anaerobic and likely to contain a large number of harmful pathogenic organisms and to have a high suspended solids content. It is not possible to predict effluent characteristics because of the complexity of the processes which occur in individual septic tanks. The need for safe disposal of septic tank effluent is paramount. Discharge to storm drains without any prior treatment is likely to pose a health risk.

Effluent is usually disposed of in the ground via soakage pits or drainfield trenches.

b. Disposal to the ground

The septic tank effluent is dispersed into the top layer of the ground; as it percolates away it is acted upon and purified by aerobic bacteria in the soil. This method obviously can only be used if the subsoil is porous and the ground water table is more than about 1.5 metres below ground level.

One of the main difficulties is in predicting exactly how much effluent a given area of ground will accept. The mechanism of infiltration of the effluent over a long period is extremely complicated and is significantly different from the percolation of clean water into the ground. Soakaway design criteria are often based upon the assumption that the effluent infiltration rate is in the range 10 to 30 litres per day per square metre of soakaway surface area (unless the ground is sand, when the rate would be higher).

c. Drainfields

A common method of dispersing the effluent is through a drainfield comprising a number of trenches connected in series. The effluent infiltrates into the surrounding ground from open-jointed drain pipes as shown in Figures 5 and 6.

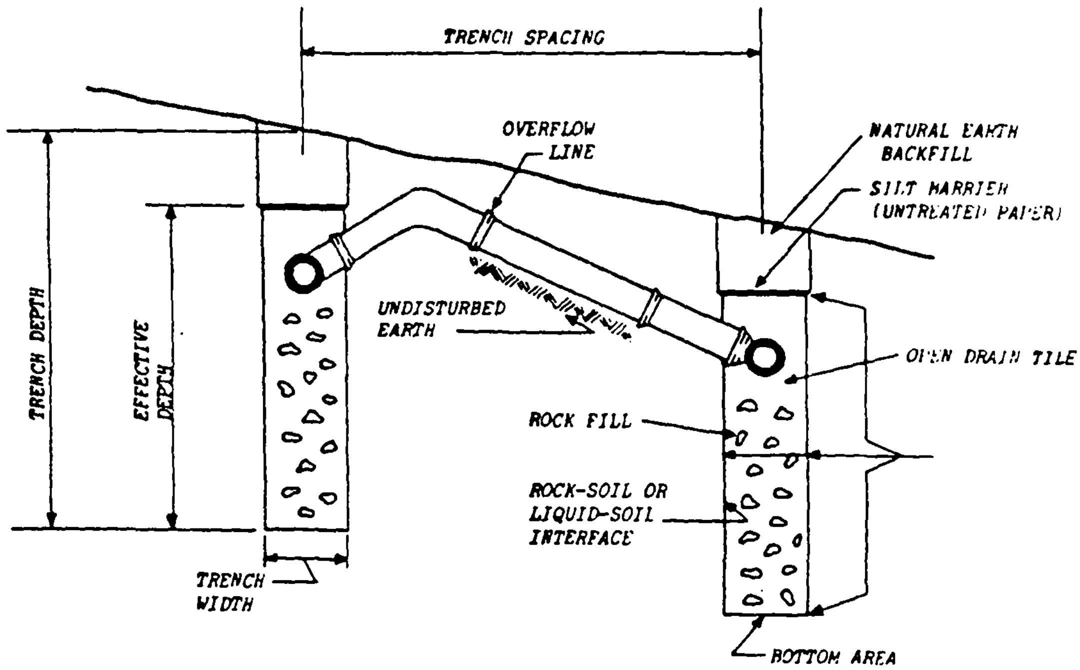

Figure 5. Drainage trench

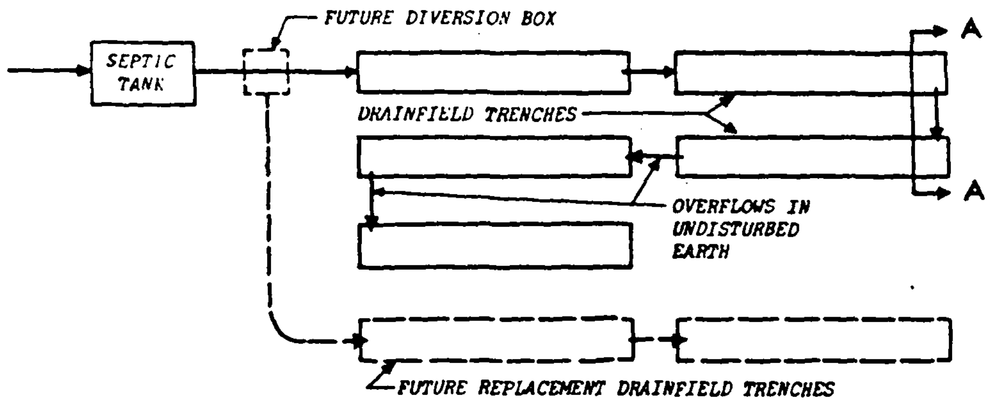

Figure 6. Drainfield trenches in series

It has been found that most of the infiltration into the surrounding ground takes place through the sidewalls of the trench with only a negligible amount through the base of the trench.

d. Soakage pits

Another method of dispersing the effluent in the ground is through a soakage pit. A typical design is shown in Figure 7. seepage pits can be used if the soil percolation rate is less that 12 minutes per centimetre. If it is greater than this, the trench drainfield system is recommended.

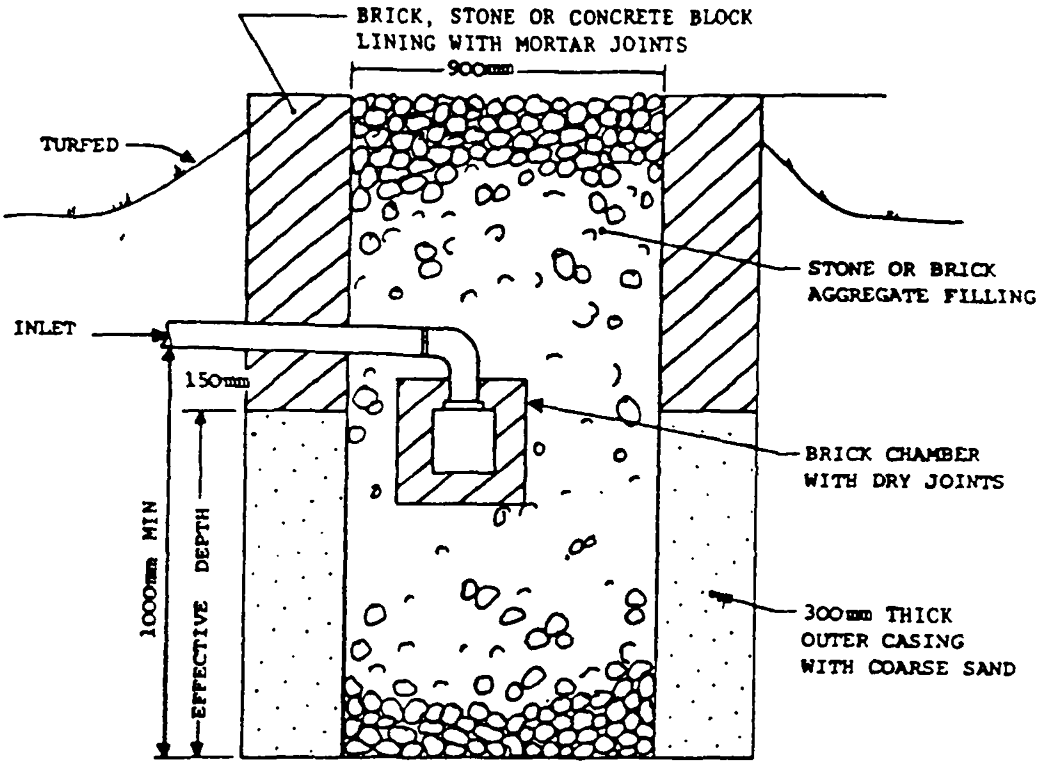

Figure 7. Unlined soakpit

e. Maintenance of ground disposal systems

The rate of infiltration of septic tank effluent into the ground is fairly low even in soils which exhibit an apparently high percolation rate. This is because an organic 'mat' forms at the liquid-soil interface and proves to be the controlling factor in the effluent infiltration rate. Suspended matter carried out of the tank will cause the soil pores to become clogged.

Continuous use of the ground disposal system eventually results in anaerobic conditions. Aerobic conditions can be restored by 'resting' the system: this ensures a faster rate of decomposition of the septic tank effluent. A process of alternate resting and dosing of a ground disposal system will prolong its useful operational life. The resting period may need to be one or two months, which would mean that, in practice, a parallel system into which the effluent could be diverted would be necessary.

The cumulative effect of clogging of the soil pores is to reduce the infiltrative capacity of the ground disposal system below that required. If this happens then pools of effluent may appear on the ground around the drainage field. A second system must be constructed in parallel if this occurs. This will enable the original system to be 'rested' as described above. A procedure of alternate 'dosing' and 'resting' of the ground disposal system should give a prolonged useful life.

6. THE AQUA PRIVY

The aqua privy is a special form of septic tank applicable to situations in which there is a limited water supply. The main feature of the aqua privy is a chute which leads directly from the squatting plate or seat down into the tank at least 100mm below the liquid level. A typical household aqua privy is shown in Figure 8.

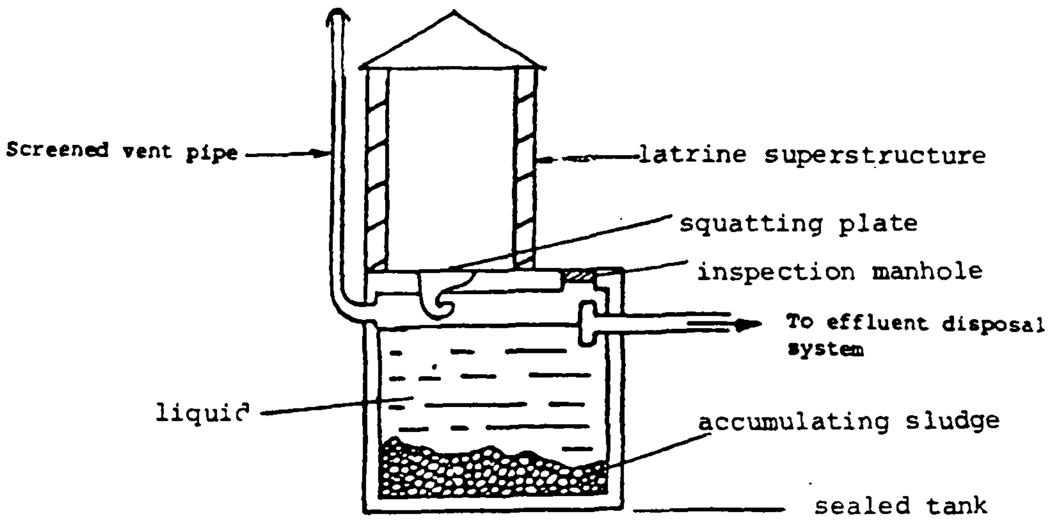

Figure 8. Aqua privy

Sludge accumulation rates can be calculated by the methods outlined in Section 3. Regular inspection and periodic desludging are in accordance with the details given in Section 4.

It is critical that the lower end of the chute remains submerged beneath the liquid in the tank as this forms an effective water seal. If the water level drops, gases will pass up the chute causing unpleasant smells in the toilet. It will probably be necessary to top up the water level in the tank on a daily basis to make up for seepage and evaporation losses.

The water level can be topped up by locating a standpost with a drainage apron near to the aqua privy and allowing surplus water to drain into the aqua privy tank.

Alternatively, a toilet with a U-bend can be used, as illustrated.

The effluent from aqua privies is usually extremely strong, and adequate treatment and disposal is essential

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE TEN - INSTRUCTOR'S NOTES

SEPTIC TANKS AND AQUA PRIVIES

SUGGESTED METHOD OF INSTRUCTION

1. Find out what is the par icipants' perception of the advantages of septic tanks and their operation.

2. Explain the processes outlined in section 2 (wastewater treatment), making sure, by questions to participants, that all understand settlement, flotation and sludge digestion. If these processes are not fully understood at first, repeat the explanation.

   As an aid to the understanding of settlement and flotation, make up a dilute mixture of light and heavy solids in water. Keep the mixture in a bottle. Shake it up to obtain thorough dispersion and then pour it gently into a glass one litre measuring cylinder. Point out how the heavy solids settle and light solids rise.

3. Explain the design of septic tank volume. Emphasize the need for sufficient volume so that liquid is retained in the tank for at least 24 hours (the retention time) when sludge and scum has accumulated.

4. Get the participants to calculate the required tank capacity for a number of situations with various numbers of people contributing, with different water usage, with different winter temperatures and with or without sullage.

5. Describe the constructional details, paying particular attention to inlet and outlet devices.

6. Ensure that participants fully understand the need for inspection. Give them one or two more calculations to do, to reinforce their understanding of the need for sufficient volume for sludge/scum accumulation and liquid retention.

7. Discuss desludging as practised locally. Emphasize the health dangers of contact with fresh sludge and of using fresh sludge as a fertilizer on vegetables.

8. Discuss local difficulties in disposing of septic tank effluent. Emphasize that the effluent is only partially treated and is likely to contain a heavy load of faecal organisms which may spread disease.

9. Unless there are known to be aqua privies locally, deal with section 6 very briefly.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 11

SOLID WASTE MANAGEMENT IN SMALL COMMUNITIES AND RURAL AREAS

The module seeks to explain what is solid waste, how it is generated, what are its constituents and what are the potential health hazards. Methods of storing, collecting and disposing of solid waste in small rural communities to avoid these hazards are presented. The choice of methods is shown to depend on the waste composition, the volumes generated, population density and the environment. Whether solid waste management is left to individual households or is organised at the community level, a simple sustainable system is needed, backed up by an understanding by its users of the health implications of proper management.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE 11

SOLID WASTE MANAGEMENT IN SMALL COMMUNITIES AND RURAL AREAS.

1. INTRODUCTION

All human activities create waste products. The term solid waste is taken to cover all waste materials arising from domestic, commercial and agricultural activities, which are not waste-water discharges or gasses. The term waste implies that it is of no value, but while it may be useless to one individual, it may, however, be a resource to another or to society and can be recycled or converted into fertilizer or used in land reclamation.

Solid waste management embraces the management of activities associated with waste generation, storage, collection, transfer, processing and disposal.

The risks of inadequate collection and disposal are environmental damage, water and air pollution, poor drainage and flooding, direct health risks through improper handling of the solid wastes, and indirect health risks from the breeding of disease vectors such as flies and rats in the wastes or mosquitoes in water collecting in waste items.

The collection and disposal of solid wastes becomes a growing problem as the size of communities increases, but the basic principles regarding health, the environment, handling and disposal remain the same, whether one is considering a small rural community or a large urban centre although the resources employed will vary. As reference, the solid waste management activities discussed here will be applicable to rural communities up to a size of about 2,000 people.

2. CHARACTERISTICS OF SOLID WASTE

a) Sources

Solid waste stems from various sources and the composition varies accordingly. The most important sources in rural communities are:

- Household refuse which constitutes the bulk of waste generated and may include food wastes, sweepings, paper and packaging, old furnishings and clothes. It may also include faeces. In developing countries, a large proportion is kitchen wastes which are organic and dense in character.
- Commercial refuse from stores, restaurants and other establishments. Market wastes may contribute a major portion in this category in developing countries, and have a high organic content and density.
- Other wastes stem from industrial premises, street sweeeping, construction work and concentrated agricultural activities.

Depending on the origin or source, the living standards and climate, so the characteristics of the solid wastes generated will vary. They may be described by weight generated, density and composition.

b) Weight Generated

The weight of solid waste generated per person is less in low income countries than industrialised countries. It is also less in rural areas than urban areas due to less packaging and use of processed goods. For planning purposes, the solid wastes generated in small rural communities can be taken as about 0.3 - 0.5 kg per person per day. There will be very little packaging present, much organic matter may have been removed as animal feeds or for composting, and given the lower population densities in these areas and on-plot sanitation facilities faeces should not be present in the wastes. However, the small quantities of solid wastes that are generated will still attract health hazards and present pollution problems.

c) Density

Generally, the more organic, lower quantities of wastes produced in developing countries will have a higher density than the larger quantities of wastes produced in industrialised countries where there is a higher percentage of non-putrescibles such as paper, plastics and packaging. Typical density values are 400-600 kg/m^3 for low income countries.

Density and weight information is of use in estimating the capacity requirements for collection equipment and frequency of trips. It also indicates the reduced need for compaction of wastes in developing countries. Special compaction equipment can achieve significant changes in volume (4 : 1 typically) on wastes from industrialised countries but will make little difference to the higher density wastes from small communities, and should not be considered.

d) Composition

Composition of the waste varies from country to country and this will be reflected in the wastes' characteristics and the selection of suitable handling and disposal methods.

Typical percentage composition data for a rural community in a developing country is given below, with the corresponding data for an industrial country for comparison purposes.

Type Of Material	Industrialised	Low Income
Paper	30	2
Glass	7	4
Metals	8	3
Plastics	5	2
Textiles, Wood etc	3	7
Non-food Total	53	18
Vegetable-Putrescible	33	60
Miscellaneous compostable	14	22
TOTALS	100	100

This data can give an indication of the potential for certain resource recovery activities or suitability for composting or incineration of the wastes. Waste moisture content in the range 50-60% assists composting, and the higher organic content wastes from developing countries often are within this range. This moisture content can make a significant contribution to the overall density of the waste. While aiding composting, these moisture content values would hinder incineration as a disposal method.

e) Sampling

Given the wide range of solid waste characteristics, sampling of wastes is recommended before making any detailed recommendations for collection and disposal.

Domestic storage and collection requirements can be estimated by sampling groups of residences within certain areas and weighing and analysing the wastes collected. Communal points and deliveries to the disposal site can also be repeatedly sampled to give representative figures. Overall density and generated volumes of the wastes and proportions of the main material types by weight are the most important data.

3. STORAGE AND COLLECTION

Storage requirements will depend on whether households organise their own disposal or a collection system is operated. Often only a small portion of the waste is collected by house-to-house methods in developing countries due to vehicular access restrictions, housing density, lack of equipment and costs. Communal storage points serving a group of houses are commonly employed instead. The space requirements for storage will depend upon the frequency of collection and the number of households served. Alternatively, disposal may be by the household and storage requirements will depend upon frequency of removal of the wastes.

a) Collection Frequency

The frequency of collection or removal of wastes will be influenced by:

- Character of the wastes and climate; high temperatures and organic contents will increase the speed of decomposition and odours and fly breeding.

- Communal or home storage space available.

- Cost, which increases with increasing frequency of collection. Social and political acceptability and pressures.

Organic wastes provide a suitable breeding medium for flies and collection should be sufficiently frequent to break the breeding cycle, which is about seven days in tropical countries.

```
Housefly eggs hatch --> Lavae feed and grow --> Pupation
     (1 day)                 (4-5 days)            (2-3 days)
```

However, decomposition of the wastes and production of offensive odours start to take place within two days in warm climates, and are likely to be more critical.

Hence, given suitable storage areas and adequate funding, waste collection or removal frequencies may be:

- communal storage; daily collection or at least three times per week

- individual premises with storage space; twice weekly collection or removal with provision of a closed portable container.

- individual premises without storage; daily removal and disposal or use of a communal storage facility.

In many situations where disposal by the household is not possible, communal storage and provision of an intermediate form of waste collection transport is the only satisfactory alternative.

b) Domestic Storage

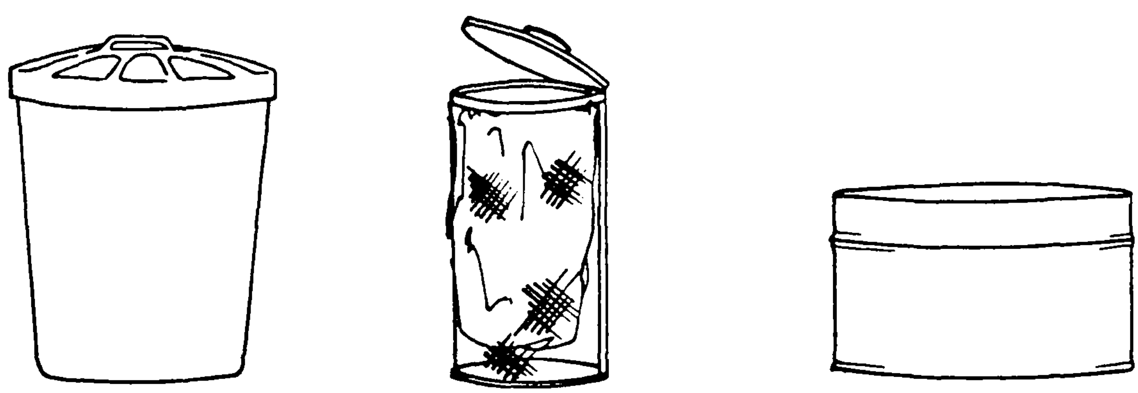
A typical 6-person family would generate wastes as follows:

Waste density taken as $500 kg/m^3$
Waste generation taken as 0.5 kg/person/day
Volume of household wastes $= \frac{0.5 \times 6 \times 100}{500}$

$= 6 lt/day$ or 42 lt/week

With a twice weekly removal of wastes or collection service, the storage requirements are in the range of 20 - 50 litres.

This may be usefully provided by plastic buckets with lids (50 - 70 lt), plastic sacks (relatively expensive in developing countries), half oil drums (very common but are open, heavy and lack handles), galvanised iron bins, wooden boxes or containers made from old rubber tyres.



Plastic bins (50 - 70lt) | Plastic sacks (wire mesh to protect sack from animals) | Half oil drum (up to 100lt)

Domestic Storage Systems

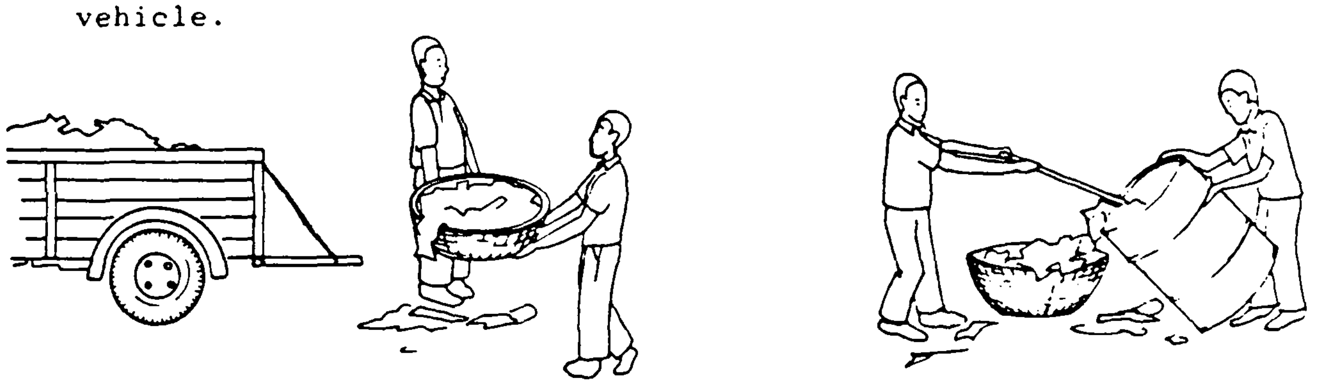
There is a practical upper limit on the size of container dictated by ease of handling (50lt container weighs 25kg plus weight of container) and advantages in standardised designs, but their enforced use is generally not possible in poor areas, and theft of containers also presents problems.

In low density rural areas, organic matter may be separated out by hand and composted and the remainder burnt or buried either at the household or small community level, but household storage facilities will still be required for the wastes as they are generated. If composting or burying is undertaken by the household, it should be properly carried out at least once every three days to avoid fly and odour problems, and the wastes stored in the meantime in closed containers as indicated above. Loose accumulations of waste must be avoided.

c) Communal Storage

Frequently, communal containers are provided where wastes are deposited by residents. The spacing of containers is determined by their capacity and there are also limits to the distances residents are prepared to carry their refuse. If distances are much greater than about 150m people will be tempted to dispose of their wastes in unauthorized locations.

Small communal containers may be portable steel bins (up to 100 lt), or commonly ,old oil drums (200 lt), although if completely filled these are too heavy (100 kg) to be lifted by two men especially as they lack handles and lids. However, they are cheap, not likely to be stolen and do contain the wastes. They are often emptied by tipping the wastes on to the ground and then into wicker baskets for loading on the the collection vehicle.

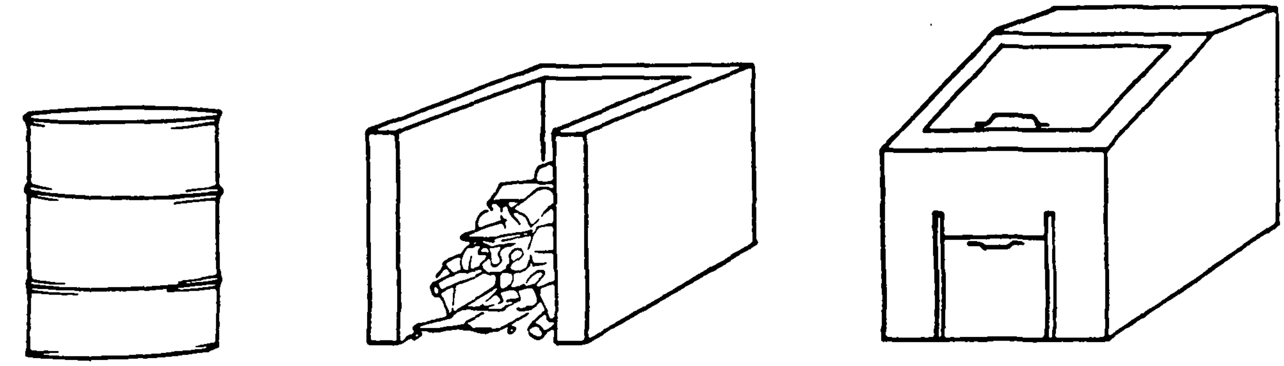


Double handling of wastes

The use of smaller half drums (up to 50kg) can avoid this time consuming double handling, which is often associated with spillages. As walking distances for residents are reduced, this size container is to be preferred, especially if fabricated lids are also used.

1 household produces 6 lts of waste daily
Collection is minimum of 3 times weekly
One half oil drum can serve $\frac{100 \times 3}{6 \times 7}$ about 6-8 houses

Likely walking distance about 20m on average.



Oil drum (200lt) | Concrete enclosure (1 - 2 m^3) | Steel storage bin (1 - 2 m^3)

Small Communal Storage Systems

Fixed storage enclosures of 1-2 m^3 capacity of blockwork, concrete, wood or steel positioned at intervals along the road are commonly used. They tend to have one open side through which waste is deposited by residents and raked out by the collectors, and loaded into baskets. The garbage however is often not properly deposited in the enclosure and spoils the surroundings, and it is open to animals, flies and rain. An improvement is storage bins where the openings at the side and top are covered by flaps through which the wastes are deposited and raked out, but emptying remains an awkward process.

A typical communal facility of this type would be:

Fixed storage container of 1 m^3
Household waste of 6 lt daily
Collection frequency is 3 times weekly
Service area is about 70 houses
Maximum walking distance is about 175 m (medium density)

Generally speaking it is unlikely that people will be prepared to walk more than 150 m to deposit garbage so 300 m is therefore about the maximum practical spacing of communal containers unless a supplementary collection system, such as hand-carts, is used to carry wastes from the households to the storage point. This would be the case where central communal storage facilities such as fixed enclosures, tractor trailers or portable metal skips are used in larger communities.

Where disposal of solid wastes by individual households so not practised, some form of communal storage facility is required but <u>all</u> communal containers have their failings. The best choice for small communities is probably half oil drums with lids where wastes are deposited directly by residents and collection is thrice weekly, or larger covered storage enclosures with an intermediate (hand-cart) collection system making collections 3 times per week.

4. COLLECTION SYSTEMS

a) Methods of Collection

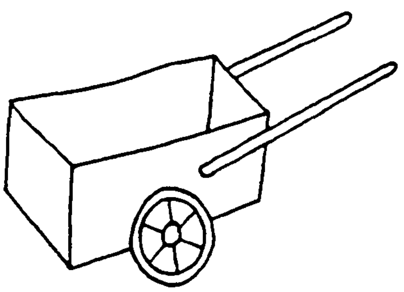
Where individual households do not directly dispose of their wastes, they must be collected in order to transfer them to the disposal site. A wide range of methods are available from simple handcarts to large 30 tonne compaction trucks, with the choice dictated by costs, service requirements and what is appropriate for a rural community.

Factors that will influence the choice are:

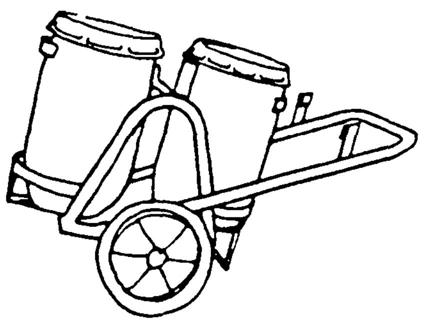
- Volume and density of wastes generated,
- Distances between collection points and disposal site,
- Storage facilities (household or communal),
- Labour and equipment costs,
- Frequency of collection.

b) Hand-carts and Tools

Various different types of handcart are used ranging from open boxes on wheels, wheelbarrows with two or three wheels and carts holding up to eight individual bins.



Open-box hand-carts
(200 - 500 lt)

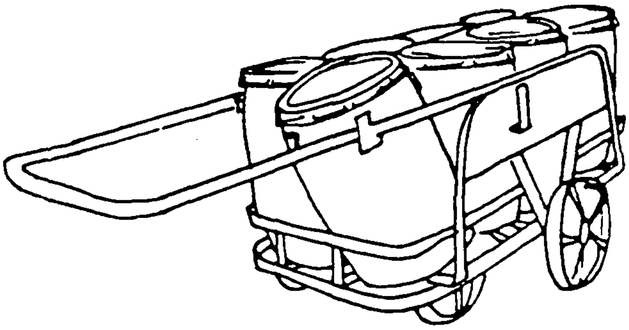


Two bin hand-carts
(2 x 100 lt bins max)

Handcarts can be used to serve widely spaced communal storage containers, where vehicle access is difficult and for cleaning public areas such as markets and streets.

Open designs (box-type, and wheelbarrows) are satisfactory if they go directly to the disposal site where the wastes can be tipped out, but if the wastes have to be dumped out before they can be transferred to other containers or vehicles, double-handling is required which is inefficient. These carts however are simple and cheap to make.

The two bin cart is restricted by its limited capacity as the bins must be small enough to be easily handled by a man (up to 100 lt maximum) which restricts the service area to only about 35 houses per trip for daily collection. It is however only about 1m in width and ideal where access is restricted to foot-paths. It is also commonly used for street sweeping and would require emptying 2 - 4 times per day. Larger six bin units with capacities up to about 500 lt can serve bigger areas between transfer units but practical considerations may limit the size, such as access and the slope and surface condition of roads. The full cart could weigh more than 300 kg. Given the typical rough working conditions wheels should be sturdy, not too small in diameter (500 mm) with preferably pneumatic tyres for easy pushing. Axles should be positioned to allow easy manouvering with the handle and cart sides set at a comfortable working height. Operatives should also be equipped with brooms and shovels which can be easily stowed.



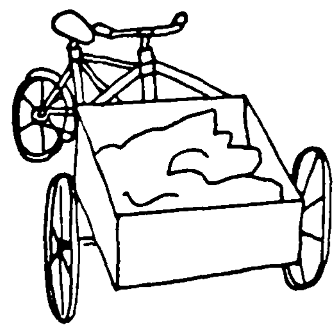
Six bin hand-cart
(capacity 6 x 50-100lt
bin max)

A suitable locally made small collection hand-cart.

c) Animal-drawn Carts.

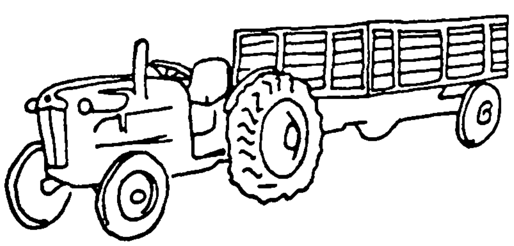
Carts of 2 - 4 m^3 capacity drawn by horses, mules and bullocks may be used if they are readily available in the locality. They are low cost, particularly suited for slow household collection, only require limited access, and with carefully designed cart bodies (low-loading, protected steel plate, tipping bodies with sliding shutters, and pneumatic tyres) can be a very effective element in the collection process serving small communities (2,000 - 3,000 population). Carts require a two-man crew, with the driver also assisting in loading.

d) Tricycles.



If pedal cycles are traditionally used in the area, these can be employed with box structures at the front or back to carry loose garbage or bins but have limited capacity (up to 200 houses). Alternatively motor-cycle tricycles can be used if locally available and would provide a slightly bigger service area (capacity up to 2 m^3). However, it is important that these are commonly used modes of transport in the area if maintenance is not to be problematic. Again they could directly serve a local disposal site (say, within 1km) or transfer stations.

e) Agricultural-based Equipment.



Tractor-trailer combinations are commonly available in rural areas and are rugged, easily maintained and relatively low cost, although they are slow and better suited for heavy farm use rather than transporting relatively light solid wastes. However, they are very efficient for pay-loads up to 6 m^3 with suitable trailers. These may be shuttered side-loading units which can tip hydraulically, discharging through rear-opening doors. Several trailers may also be served by one tractor allowing the trailers to be used as transfer units. They are particularly useful in areas such as markets where the trailer can be left as the storage container, or in small villages where it can be served by hand-carts or animal-carts, and used for transferring the wastes from a central point to the disposal site. It becomes less efficient with increasing loads and distances. The tractor unit is also available for other uses after the refuse has been collected.

f) Other Vehicles

Converted dump trucks, purpose-built side loading refuse collection vehicles and container hoist vehicles are all used in developing countries for collecting solid wastes, but to be economic their capacity must be fully utilised. This will generally preclude small rural communities, but if these types of vehicles are to be considered, important features are:

- a low chassis with a loading height not exeeding 1.6m to avoid double handling;
- a tipping mechanism for disharging unless wastes are in portable containers;
- covered loads for speeds greater than 30kph;
- design features for ease and simplicity of operation;
- standardised equipment for ease of maintenance and spare parts stocking.

g) Collection Systems

The collection system for an area may well be a combination of several of the above-mentioned methods. Handcarts and animal carts could be used to collect from houses or small communal storage points and deliver to transfer stations or directly to a nearby disposal site or a tractor-trailer unit could collect from the transfer station and take refuse to the disposal site.

The recommended system must take into account:

- household refuse generated, population density collection frequency, individual storage and access;
- communal storage areas, their access and capacity, and collection frequency;
- distance to disposal site, access and type of disposal.

The system must be planned around this basic data and activities timed to assess equipment and labour requirements and the need for and location of transfer stations. Productivity and costs need to be carefully compared and balanced against health and environmental considerations to determine the optimum collection systems.

Collectors should be aware of the risks associated with the handling of solid waste, particularly where faecal matter might be included. They should be given suitable protective clothing, especially gloves, and simple tools to make their task easier such as brooms, spades, wooden boards and light handling baskets.

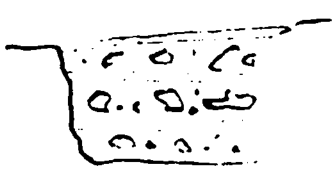
5. TREATMENT AND DISPOSAL

Crude dumping is to be deplored. Dumped wastes not only create an eyesore but they provide an ideal breeding environment for flies and rodents. The threat of the spread of disease is further increased if faecal matter is included in the wastes. Animals and human beings scavenging in the exposed wastes will come into contact with these disease vectors and their activities will spread the wastes over a greater area. The wind will also spread the wastes and water collecting in voids in the waste will provide ideal breeding habitats for mosquitoes.

Open burning or the setting fire to dumped waste is also to be deplored as the high organic content in the waste does not permit rapid burning, and slow smouldering fires develop which only partially consume the wastes and create prolonged environmental damage. At the household level burning can be satisfactory if it is carried out under controlled conditions on the selected, readily-combustible portion of the refuse, or at the municipal level through carefully controlled incineration, but otherwise is not a satisfactory means of disposal. Acceptable means of disposal are dealt with in the following sections.

a) Disposal by the Household.

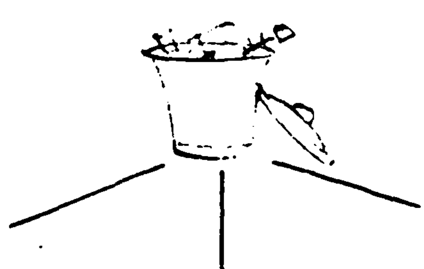
The most straight forward method of disposal is burial of all the wastes generated by the household. This would have to be done regularly (2 - 3 times per week) to prevent decomposition and odours, and fly breeding. For the same reasons, the wastes would have to be covered by inert material (soil) immediately after deposition. Space is therefore required, about 6m² for a typical household, preferably in the form of a depression or else a pit must be dug, and an adequate amount of cover material must be available. Regular burial is required and there are no useful by-products.



Burying in layers

Space requirements are reduced if burning or composting is adopted, but all the waste cannot be disposed of in this manner.

Composting may be carried out if the inorganic portions are separated out (see this section). Alternatively, the organic portions may be used as feed for animals (sheep and goats). The remaining portions may be buried, or the combustible portion (paper and card) burnt while the glass and metal recycled.



In low density rural areas where there is plenty of land available to households, burial should not present problems provided residents are informed of correct procedures through education campaigns. Where less land is available (say less than 200m²/household), there will be pressure to use all the plot area productively and indiscriminate dumping will result if community based collection and disposal is not organised.

b) Seperation

The most commonly used form of communal disposal is in sanitary landfill sites, but in all types of disposal some elements of the refuse are inevitably removed for recycling prior to final disposal. Salvaging may be carried out at the household, at storage containers, during collection and transfer and at the disposal site itself. Because salvaging is so common in developing countries there is little scope for communities to organise any formal recycling because little of any value will be left in the wastes. Most frequently recycled elements are glass, metals, cardboard and rags.

c) Sanitary Landfill.

This is the reclamation of land through the controlled use of solid waste as a filling material as opposed to indiscriminate dumping of wastes. In order to extract full benefits from the filling process, careful control of activities is essential. In particular, wastes must be deposited and levelled in layers not exceeding 2 metres high to allow proper compaction, avoid instability of the filling faces and prevent the risk of fire spreading. Each layer of waste should also be covered with soil the day it arrives to prevent access by insects and rats, to contain odours, and to encourage decomposition through the build-up of heat, which will also destroy fly larvae and pathogens. Although the process is simple, strict management of a site is necessary to avoid the hazards associated with open dumping (odours; fires and smoke; breeding grounds for flies and rodents; pollution of water sources). This applies equally to both large sites and small ones with minimal equipment.

i) Processes within a landfill site

Organic wastes once deposited start to break down, initially through the action of aerobic bacteria and then, as oxygen is depleted in the wastes, by anaerobic bacteria. This decomposition process results in a build-up of heat, which will kill off any pathogens and insect lavae in the wastes, and the release of gases, in particular carbon monoxide and methane. Any buildings on the site should be well ventilated to avoid the risk of methane build up and explosion. Water percolating through the wastes will leach out certain waste matter present and also the products of decomposition. This leachate can be extremely polluting and up to 20-30 times the strength (BOD) of domestic sewage. It follows that the control of surface and ground water pollution from the site is very important.

ii) Landfill Site Selection

Possible sites are natural low lying areas which would be improved by filling, and abandoned man-made developments such as quarries.

Particular consideration should be given to:

Location - Sites should be a distance of more than 200 m away from housing to minimise nuisance. However, extra distance from the waste generating sources adds to transportation costs.

Access - easy road access reduces site development costs.

Unit costs - affected by land purchase costs, site capacity and site development costs.

Pollution - surface and ground water sources must be protected.

iii) Safeguards at Landfill Sites

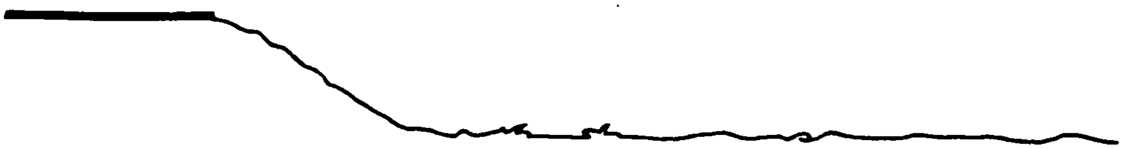
Careful covering of tipped wastes with at least 150 mm thickness of inert material (soil) will encourage heat build-up and destroy pathogens and the breeding cycle of insects. It will also deter rodents and, by isolating the waste into compartments, will limit the risk of fire spreading. Air-borne litter can be controlled by the use of fences, portable screens, and by limiting the size of the working face. Surface water pollution can be avoided by the construction of diversion ditches, embankments and realigning streams and rivers to prevent rainwater and surface water unnecessarily crossing the site and draining to the water channel.

Groundwater pollution can best be avoided by siting the landfill on impermeable soils. Where the water table is at reasonable depth of, say, more than 5 m, sandy soils may provide some degree of filtration and may be considered, but any cracks or fissures present in the ground would enable the polluting leachate to travel freely and must be avoided.

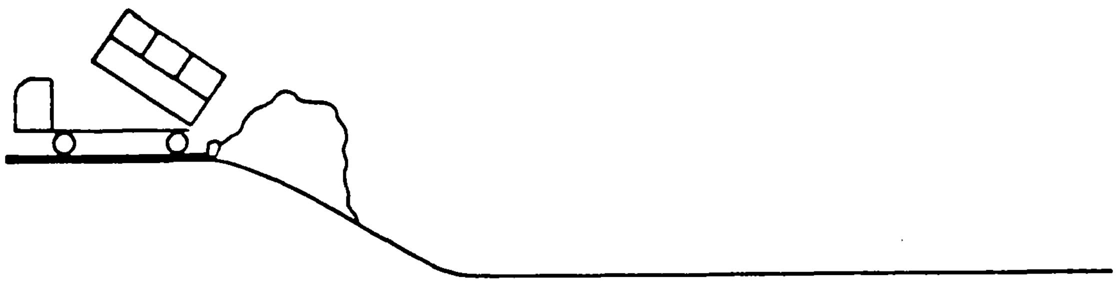
iv) Small Site Operations

In small communities, sanitary landfill sites can be operated efficiently by manual methods. Adequate compaction can be achieved by passage of collection vehicles on the wastes and covering material may be spread by hand. Wastes may be spread and levelled on the working faces by the use of rakes rather than machinery.

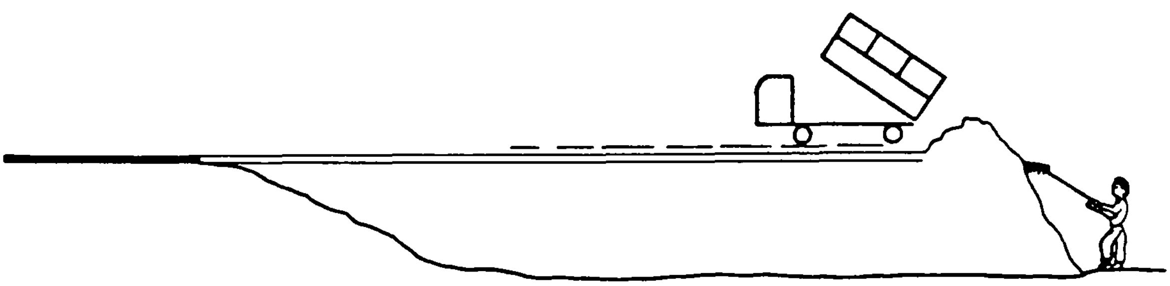
Small Site Manual Operations



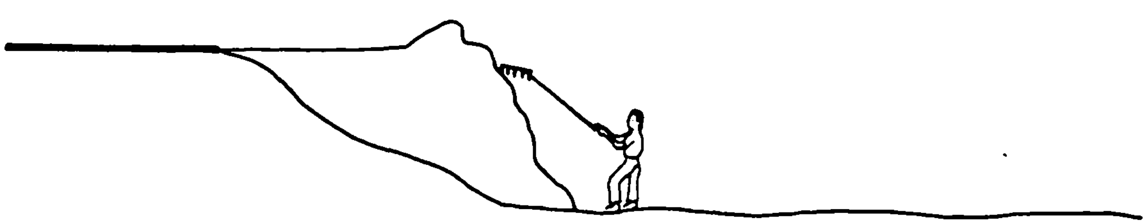
Access road and tipping face about 2m high.



Wastes tipped at top of inclined face.



Wastes raked down manually to a 45° slope.



Levelled wastes are covered with 15-25 cms of soil. Vehicles always tip directly at working face. Use steel sheets or extend road as necessary to support vehicles.

Small landfill sites serving villages and small towns are well suited for manual methods, and one man can successfully handle up to 5 tonnes/day (equivalent to up to 10,000 population), digging and placing all the covering materials from the base of the site.

d) Composting

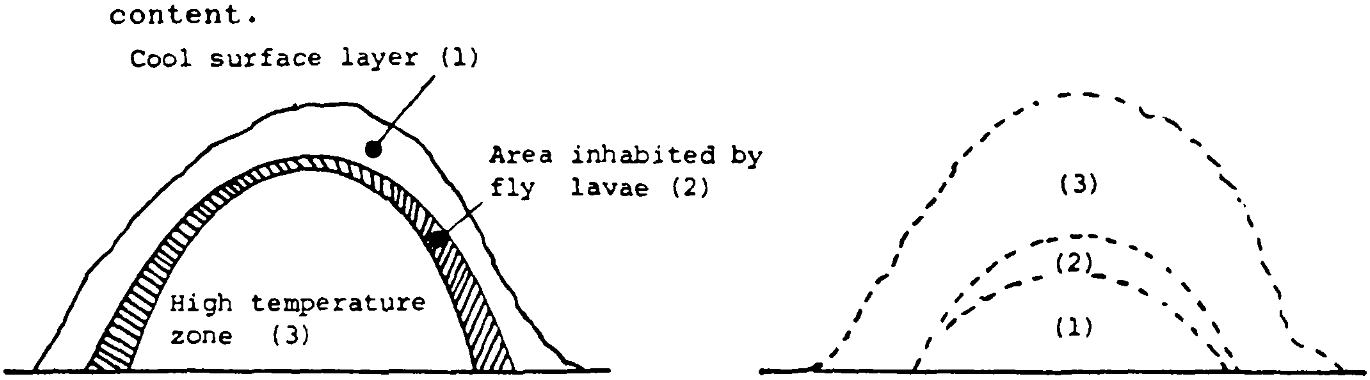
Organic material may be allowed to decompose in a controlled manner to form compost. Generally, the higher organic content and moisture content (50%) of wastes from developing countries will permit composting and the production of good quality organic manure, provided there are sufficient nutrients such as nitrogen and phosphorus available in the waste. For this reason sewage sludge often facilitates the composting process.

It is, however, a lengthy and time consuming operation and a market for the compost must be established before considering composting. There are three products from the process - the organic fertilizer, materials salvaged for recycling and residue materials of no value which must be confined to a landfill site, although they rarely exceed 20% of the original weight.

Although composting may take place in either anaerobic or aerobic conditions, aerobic composting is preferred because:

- decomposition is more rapid (2 - 4 weeks), hence land requirements are less
- high temperatures are attained which quickly destroy pathogens, insect eggs and weed seeds
- offensive odours are minimised

This means that oxygen must be freely available for the aerobic bacteria. This is ensured by composting in small heaps or 'windrows' and regularly turning over and reforming the windrows (every 3 - 6 days), to increase the oxygen supply and ensure that all parts experience periods of high temperature decomposition. The process is aided by wetting the wastes to maintain the moisture content.



Zones within windrow

Zone positions after turning

Windrow Composting

Temperatures will fall once the composting has been completed, and the compost must then be screened or hand-picked to remove the non-organic materials. Unless the 'windrow' process is carefully controlled as noted above, the aerobic process will quickly give way to anaerobic, temperatures will drop and insect lavae start to hatch out and odours develop. Composting proceeds more satisfactorily if the refuse materials are relatively small in size (say 50% less than 50 mm) and some hand breaking or removal might be needed.

In rural areas, farmers and households may undertake anaerobic composting, which can be satisfactorily carried out by placing the wastes in trenches which are sealed and left for several months, but provided the labour is available, a small aerobic composting scheme is preferable in terms of time, space and finished product.

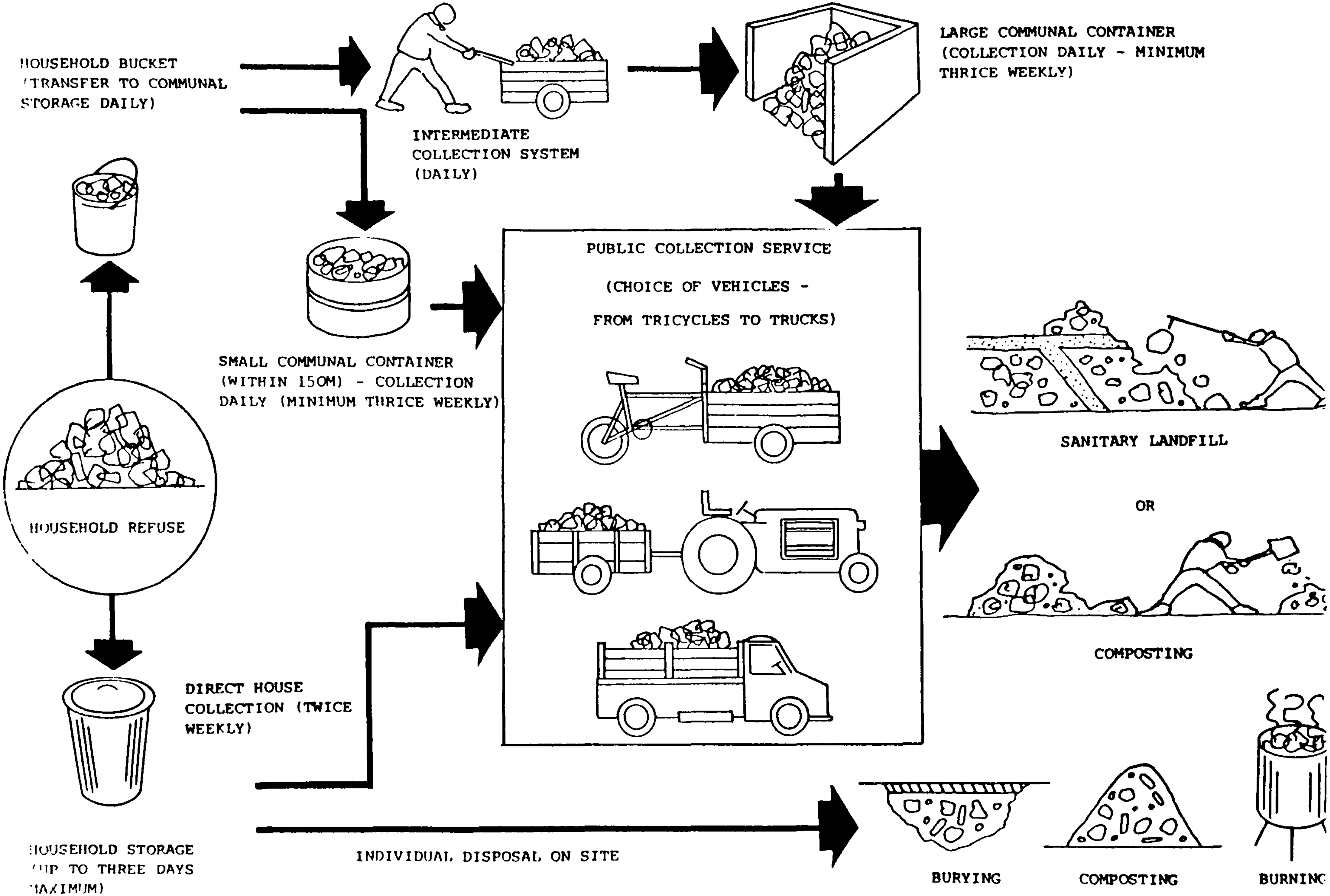
The choice of disposal either by sanitary landfill or by composting is invariably based on cost, and due to the more labour and plant intensive nature of composting, is therefore largely dependent on establishing a market for the compost. It may be attractive to farmers or rural households with large plots where they can use their own compost. Removal of any glass, metal or other inert materials prior to composting will increase the usefulness of the product. Raw refuse applied to farmland will still contain these materials and has the further disadvantage that, as it decomposes, the refuse will draw nitrogen from the soil.

e) Incineration

The burning of refuse has already been referred to as another means of disposal but, whether it is carried out at the household or community level, it must be undertaken in a controlled manner in an enclosed incinerator. However, while the high organic and moisture contents of typical wastes from developing countries are well suited for composting, they have low calorific values and generally cannot sustain combustion on their own without the addition of auxiliary fuels, and therefore it cannot be recommended as an efficient means of disposal. It can however be usefully employed by farmers or rural communities as a support to a small composting scheme, where the non-organic elements are separated out for burning.

6. CONCLUSIONS

The choice of methods for storage, collection and disposal of solid waste will depend to a large extent on the nature and size of the area served, and may be based upon several compatible systems according to local circumstances. The important principles remain the need



SUMMARY OF MAIN STORAGE, COLLECTION AND DISPOSAL OPTIONS APPROPRIATE FOR SMALL COMMUNITIES for regular removal of solid wastes, adequate storage facilities, and the sanitary disposal of the wastes to minimise nuisance and health hazards. Simple though the systems may be, they need to be operated in a regular and sustained manner to achieve the desired results. A summary of the various collection and disposal options that are appropriate for small rural communities is shown in the accompanying diagram

Recommendations for further reading

- Flintoff F. Management of Solid Wastes in Developing Countries, World Health Organisation.

- Holmes J.R. (ed) Managing Solid Wastes in Developing Countries.
  Wiley.

- Bhide A. D. and Aundavesan B. B. Solid Waste Management in Developing Countries.
  Indian National Scientific Documentation Centre.

Water Engineering
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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE 11

SOLID WASTE MANAGEMENT IN SMALL TOWNS
AND RURAL AREAS

NOTES FOR THE INSTRUCTOR

INTRODUCTION

This module describes the characteristics of solid waste and its associated health hazards, and how the wastes may be stored, collected and disposed of effectively.

The various handling and disposal options suitable for small communities are discussed.

On completion of the module, participants should appreciate:

- how solid waste is generated, what are its components and what are the potential health hazards;

- how storage and collection of solid waste may be organised to avoid these hazards;

- what storage and collection options are available, and how the choice will depend on the waste characteristics, volumes generated and population density;

- what disposal methods are suitable, and how the waste composition and local environment may affect the choice.

TEACHING THE MODULE

This module will be taught as a lecture with various short exercises and examples undertaken by the participants working in small groups. At the end of the session, a short case study on solid waste management for a local village should be presented which will draw on different aspects of the module material.

TEACHING STAGES

I Discussion

Begin the session with a short discussion on different aspects of solid waste management.

- What is solid waste and where does it come from?

- What sort of problems might develop if solid waste is not removed regularly from the house plot?

- Is it possible to make good use of the properties of solid waste in its disposal?

II Lecture

Distribute a copy of the module notes to each participant.

MAIN POINTS TO NOTE WHEN TEACHING THIS MODULE

1 Introduction

Make sure that the terms solid waste and solid waste management are understood and also refer to refuse (household wastes) and garbage (American term generally covering food wastes).

2 Characteristics of Solid Wastes

- Ask participants for ideas on how solid wastes in rural and urban areas in developing countries and those in developed countries might differ in composition. Emphasise how this would affect the characteristics (quantity, density, moisture content, amount of organic and combustible matter).

- Explain what is meant by compostable and combustible.

- Refer to a typical solid waste density of 500 kg/m3 and a generation rate of 0.5 kg/person/day giving a volume of 1 lt/person/day for use in future calculations.

3 Storage and Collection

- Consider the fly breeding cycle and rate of waste decomposition, and how this will influence collection frequency.

- If household solid waste collection is twice weekly, ask participants how much storage capacity a family of 8 would require. (1 lt x 8 persons x 4 days = 32 lt).

- Consider the volume of a handy object (waste paper bin etc) and likely weight when full of solid waste.

- Emphasise that if communal storage containers are too large and widely spaced, people will not use them. Consider a 1 m3 container and ask participants to work out the service area and possible walking distance (see example in text - use a residential density of 250 persons/ha).

- How far is it reasonable to expect people to walk with their refuse?

4 Collection Systems

- If walking distances are large, an intermediate collection system, such as hand-carts is required. Ask participants to list good design points for such a hand-cart and discuss.

- Ask participants to roughly calculate the number of households that could be served daily by a hand-cart with 6 x 75 lt bins and a centrally located transfer point (say 75 households/trip, 4 trips/day, service area about 7 ha).

- Clearly establish relationship between capacity of different collection vehicles and the area that can be served.

- Note that most suitable collection systems may well be a combination of different methods. As these activities are repetitive and use considerable resources, careful and efficient planning is essential.

5 Treatment and Disposal

- Emphasise the difference between sanitary landfill and crude dumping (covering of wastes, use of cells, avoidance of pollution, etc).

- Make sure that the composting process is understood and why aerobic composting is preferred.

- There must be a ready market for compost if composting is to be viable. Hence, it is best suited for communities where there is near-by agricultural land.

- Emphasise the options that are available for on-plot disposal and how good practises may be encouraged.

III Questions

Ask questions to check the understanding of the participants of key points.

IV Case Study

Distribute copies of a plan (1:500 scale) of a local village (population about 2000), and ask groups of 3-4 participants to consider suitable methods for collecting the solid waste for disposal at a near-by (1 km) landfill site, and present their proposals. Discuss implications in terms of practicality, sanitation and cost.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 12
VECTOR AND RODENT CONTROL

This module deals with methods for reducing the populations of houseflies, mosquitoes and rats. Information is given for each on the hazards and nuisances they cause, and on their breeding grounds, life cycles and habits. Control measures involving enviromental modifications to their breeding grounds and the use of chemicals are discussed.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE TWELVE

VECTOR AND RODENT CONTROL

1. INTRODUCTION

Vectors are the means by which disease-causing organisms are carried from one place to another, and so are responsible for the transmission of many infectious diseases. In most countries the most significant vectors are the housefly and the mosquito, but there are many other insect vectors and some of these others transmit diseases which have a very severe impact on the local inhabitants. These notes will only consider the housefly and the mosquito amongst insect vectors, and of the rodents only the rat will be considered because it is the most important of the rodents from a public health viewpoint.

There are two main means of controlling the populations of these species: chemical poisons and environmental modifications.

In general poisons should only be used as a short-term measure because they have several disadvantages:

(i) They can lose their effectiveness as the target insects develop resistance to that particular product (but the poison may remain effective against insects which are the natural enemies of the target insect so that numbers of the unwanted species actually increase).

(ii) Some are dangerous to humans or cause long-term pollution of the environment.

(iii) They are often expensive and may need to be imported.

Recommendations for specific insecticides and rodenticides are not made in these notes because the selection of the best chemical to use depends on many factors and should be made by an expert. In some areas, for example, a particular insect may have developed resistance to a particular insecticide, but in another area the same chemical may be very effective against the same species of insect. The safety precautions that must be observed for one chemical may be different from those necessary for handling another, and there is not space here to detail the requirements for each product. In general, skin contact with insecticides and rodenticides should be avoided, protective clothing should be worn and laundered regularly, and persons using these chemicals should not eat or smoke until they have thoroughly washed their hands. It is sometimes necesary to limit the working day to control the exposure of the workers.

The toxicity of insecticides to mammals is expressed in terms of the dose required to kill 50% of the exposed population in a specified time - LD50 - and is usually expressed in terms of mg of insecticide per kg of body weight. Experiments to determine the lethal dose are performed on rats, mice and rabbits.

Environmental modifications - such as the draining of bodies of standing water or the sanitary disposal of solid waste - are usually effective because they reduce or remove the breeding sites or food supplies so that long-term improvements result. Knowledge of the life cycle and habits of an insect is needed in order to determine how to control it.

2. THE HOUSEFLY

a. Introduction

The housefly lays its eggs in human and animal faeces and is often found in kitchens; it is therefore a major means by which food is contaminated and enteric diseases are spread. (Some other types of fly also lay their eggs in faeces, but they are not of such great public health concern because they rarely come inside houses and so do not contaminate food.) Houseflies carry germs on hairs on their legs and bodies, and also contaminate food when they vomit and defecate on it while they are feeding. Reduction in the numbers of houseflies can reduce the incidence of diarrhoeas. Flies are attracted to used dressings, open wounds and eyes (especially of children and sick people) and so can spread disease directly in this way.

The best means of controlling houseflies is to deny them access to suitable egg-laying sites. They prefer to lay their eggs in faeces of horses, pigs or man, but also use moist decaying vegetable matter. Therefore, to reduce the numbers of flies, their breeding sites must be identified and ways must be found of keeping the flies away from the material they are looking for, or of changing the material so that it is no longer suitable for breeding and as food. Another method of control is to kill the insects in the development stages, before they are fully developed and can fly away. Some information about the development of the housefly, from egg to adult, is necessary to determine how to prevent breeding. Adult flies have been observed to have travelled up to 30 km from where they developed, but in towns they do not need to travel great distances to find food and breeding sites and so may spend all their lives within a few hundred metres of where they developed.

b. Life Cycle

Figure 1 illustrates the stages in the development of the housefly. The female fly lays up to 120 eggs at a time in cracks in the selected material. The eggs look like tiny, polished grains of rice, about 1mm long. In about a day tiny white larvae or maggots emerge from the eggs and start feeding on the faeces or vegetable matter in which the eggs were laid, usually near the surface because decomposition processes make the interior too hot. As the maggot nears maturity it crawls off to find a drier place to undergo the pupation stage, generally burying itself in adjacent soil to a depth of 70 to 600mm. After a few days the adult emerges from the pupa casing and burrows its way to the surface where it stays for about an hour until its wings are ready for flight. The time taken for these processes varies with temperature; the adult emerges about eight days after the eggs are laid at a temperature of 35C, but at 16C it may take fifty days. A further three to fifteen days are required before the female is ready to lay eggs.

c. Environmental Control

There are three types of fly breeding sites that should be considered in any control programme: animal excreta, human excreta and refuse (or solid waste). It is usually obvious if a particular deposit of waste is being used for breeding because there are flies around it; sometimes small white larvae can be seen. A fine net attached to a frame and placed over the waste can be used to reveal if flies are breeding there if it is left long enough to catch the adults when they emerge.

Animal excreta is likely to be used more than refuse as a breeding medium in rural areas where there are many horses or pigs. There are several ways of reducing the potential for fly breeding of these wastes:

(i) If the excreta dries quickly it will be less attractive to flies than if it remains moist, so in dry climates effective control may be achieved by spreading the waste in thin layers and allowing it to dry.

(ii) Digesting the waste in a biogas digestor can make the excreta much less suitable as a breeding material as well as producing useful gas. The retention time within the digestor must be sufficient so that discharged material is well digested.

(iii) Covering the waste with tightly-packed soil prevents flies from laying their eggs in it, but may not prevent the larvae (or maggots) from escaping.

(iv) If the excreta is formed into a pile at least one metre high, kept moist, and turned with a fork several times at intervals of about three days, the material will undergo aerobic composting (a process in which aerobic bacteria process the waste to make it less offensive, more stable, and less attractive to flies). Considerable heat is generated during this process, and the high temperatures developed (60 to 70C) are sufficient to kill fly eggs and larvae. Composting of animal excreta involves strenuous and unpleasant manual work. Therefore it is unlikely to be done except where those involved are highly motivated

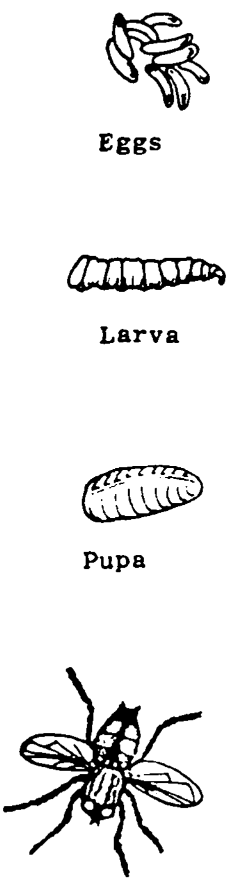

Figure 1 The Life Cycle of the Housefly

because they are very concerned to control the flies or because they value the composted material as a soil conditioner.

Human excreta is very suitable for fly breeding, whether it is deposited on the ground or in an unsatisfactory latrine. The design and construction of latrines that do not allow fly breeding have been discussed in other modules.

Domestic solid waste favours fly breeding, especially if it contains moist vegetable matter. There are several ways by which fly breeding in solid waste can be controlled - some depend on public co-operation and others are related to the effectiveness of the agency that collects and disposes of the waste. The most important practices are as follows:

(i) Refuse should be stored in a container with a tightly-fitting lid to reduce the opportunities flies have of gaining access to the waste to lay their eggs. This is only practicable when someone is responsible for the container; communal containers are usually not supervised by anyone and it is unrealistic to expect all members of the public to replace the lid on a container after depositing their load of refuse. Some large wheeled bins have hinged lids which are supposed to keep the refuse covered, but often they are not effective in excluding flies.

(ii) Refuse should not be deposited on soil because this will give the larvae an opportunity to crawl away from the refuse and burrow into the soil so that when the refuse is taken away, the larvae will remain to develop into adult flies.

(iii) Refuse should be completely removed from the storage point and disposed of in such a way that the development of flies is prevented. The time that is necessary for this development to take place should be considered when the frequency of collection is being considered. The time requirement depends on the temperature and can be as little as eight days at high temperatures. Therefore in hot climates the collection should be at least twice a week, to allow a few days for the destruction of the flies in the disposal process.

(iv) There are three ways of disposing of solid waste so that flies are destroyed, but unfortunately the most common method of disposal (open tipping) is not one of them. If refuse is burned thoroughly the fly larvae in it will be destroyed. (Casual burning on open sites may not affect all of the refuse until some time after it is deposited.) Composting (as described briefly above) is also effective if the refuse is turned after two or three days because of the high temperatures generated (flies cannot survive in temperatures above 46C). Furthermore the composting process turns solid waste into a stable humus which is not suitable for egg laying. Covering the refuse, as in sanitary landfilling (otherwise known as controlled tipping) is effective in killing flies because the covering layer acts as insulation, retaining the heat generated by the bacterial decomposition of the waste. If the cover is sufficiently compact it also prevents adult flies from emerging.

d. Chemical Control

Insecticides are used in a number of ways: they are sprayed as a general fog, they are sprayed onto specific surfaces where flies are likely to gather and they are used to impregnate paper or string which is then suspended out of the reach of children and domestic animals.

The simplest form of fogging spray is the household aerosol can which uses a chemical similar to one obtained from pyrethrum flowers. On a much larger scale, fogging machines are used to produce a lingering mist of insecticide, both inside and outside. The chemical used should pose no threat to humans and animals and yet should be effective against the target insect (that is, if flies in the area have developed resistance to the insecticide there is no benefit in using it). Fogging outdoors should be carried out when there is little or no wind. The procedure should be repeated daily for at least two weeks to ensure that a complete generation of flies has been killed. Thereafter, the treatment should be repeated every ten days. All residents in the area should be informed in advance that the fogging will take place and what precautions are necessary so that they are not unduly alarmed.

Residual insecticides are used for spraying onto surfaces. These can remain toxic for several months under the right conditions, so that flies landing on a surface that has been sprayed within the preceding few months will pick up some of the insecticide and die in a matter of minutes. The nozzles used for this type of spraying should produce larger droplets than fogging nozzles and should be of the 'fan' type, to spread the insecticide over a strip about 750mm wide when held at a distance of about 450mm from the surface. Insecticide should be sprayed on the following surfaces (which are frequented by adult flies): doors, window sills, exterior walls, kitchen walls, porches, latrines, animal shelters and fences. Residual sprays are sometimes used to kill adult flies on refuse tips - the flies pick up insecticide when they come to lay their eggs or after they emerge and before their wings are ready for flight. The normal application rate is 4 to 8 litres per 100 sq. m.

Resistance to many organochlorine compounds is now widespread and in some areas flies are resistant to some of the more dangerous organophosphorus insecticides. Therefore the choice of chemical must be made by an expert who has local knowledge of the resistances that have developed, or after trials in which fly populations have been counted and lack of resistance has been demonstrated. Other considerations affecting the choice of chemical are the possibility of humans and domestic animals coming into contact with the insecticide and the degree of training and supervision given to the people who are applying the insecticide.

e. Other Methods

Strips of waxed paper coated with adhesive are sometimes used; flies are attracted to the paper and unable to detach themselves from it. Such strips may not be acceptable inside houses because of their appearance.

Devices which electrocute flies are used in restaurants, shops and food processing factories.

Screening of doors,windows and ventilation openings with mesh that has apertures of approximately 2 mm is a useful measure in excluding flies from buildings.

3. MOSQUITOES

There are many species of mosquito, of which the Anopheles and culicine (Culex and Aedes) are the most important as regards disease transmission. Anopheles mosquitoes transmit malaria and filariasis and the culicine species are responsible for the spread of filariasis, yellow fever, encephalitis and dengue fever.

a. Life cycle and habits

The female mosquito lays its eggs in water. The water should be still, but the edges of slowly moving rivers can be suitable if there is vegetation or debris that provides near-stagnant conditions. Some species lay their eggs in rafts about 3mm long, and others lay their eggs so that they float singly. The individual eggs are too small to be seen easily. A female lays between 50 and 200 eggs at a time, and may do this several times.

After a few days the eggs hatch into larvae, as shown in Figure 2, and these can easily be seen with the naked eye, as they wriggle up and down in a jerky fashion. A few days later these become pupae (Figure 2) which in turn become adult mosquitoes. The whole development can take as little as 7 days under optimum conditions. The adult is thought to live for only a few weeks, the actual period varying considerably from one species to another. Adults live mainly on juices extracted from plants; only the females bite humans and animals, needing to feed on blood before they can lay their eggs. Habits and resting places vary from one species to another.

b. Anopheles mosquitoes

Anopheline mosquitoes lay their eggs in clean water. They

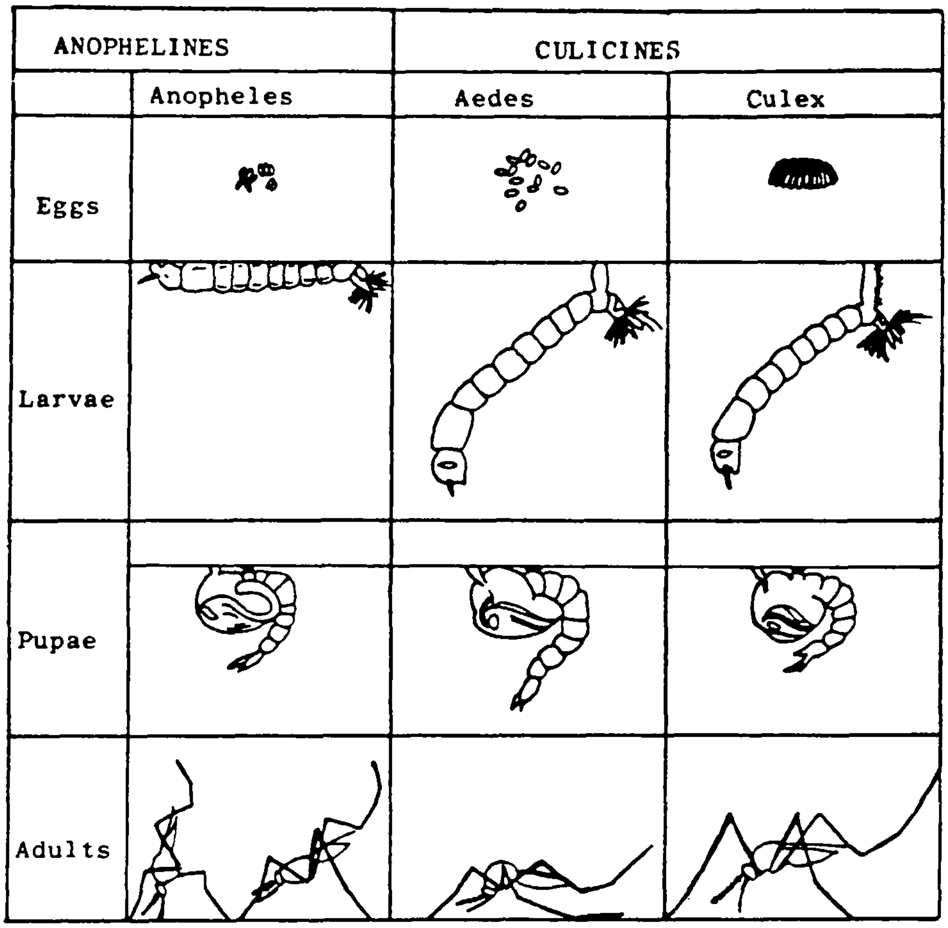

Figure 2 Life Cycles of Mosquitoes

can be recognised from the way the larvae lie parallel to the water surface and from the steep forwards angle of the body of the adult. Most strains spend most of their time indoors and so can be controlled by residual spraying.

c. <u>Culicine mosquitoes</u>

Culicine mosquitoes usually lay their eggs in water that contains a considerable amount of organic matter. Aedes aegypti lay their eggs in small bodies of water near houses; other strains lay their eggs in wet pit latrines, and in larger bodies of polluted water. Some strains spend the day in buildings, others on vegetation sheltered from the sun. Some bite only in the daytime or in artificial light (for example Aedes aegypti) and others bite only at night (for example Culex pipiens). Some strains travel only short distances (Aedes aegypti is thought to have a range of only a few hundred metres) whilst others can travel several kilometres.

d. <u>Control by environmental modifications</u>

The main approach to controlling mosquitoes is to remove or cover breeding sites. Some bodies of water are entirely unnecesssary (such as waste containers and tyres filled with rainwater, depressions, and blocked drains) and so measures should be taken to empty them and prevent water from collecting there. Wastes that contain water should be buried, containers can be turned upside down to prevent water collecting in them, depressions should be filled in with soil (or, if done carefully, with solid waste), and blocked drains should be cleaned. Tanks for storing water should be covered to deny mosquitoes access to the stored water.

Eradication of breeding sites in a town or village requires detailed inspection of each property to identify possible breeding sites and to take the necessary action. Many breeding sites, however, may be in public areas, and water points and drainage systems should be checked carefully.

Unless a waterpoint has a well designed apron which leads any unused water to a disposal pit or to a well-managed cultivated plot, it is likely that there will be a pond of stagnant water nearby, with a large colony of larvae and pupae in it. Attention should be given both to reducing the wastage and to improving the disposal of any wasted water.

Open storm drains that contain solid waste or silt are ideal places for mosquitoes to breed, especially if they carry small flows of sullage throughout the year. In most cases the only solution is to keep the drains clear so that the water in the drains is always moving, unless the drains are dry between storms. Covering drain channels with concrete slabs is rarely a solution to the problem of solid waste in drains; the refuse still seems to find its way into the drains, but inspection and cleaning are made more difficult by the covers. The first step in maintaining the drains in a clean condition is to provide containers and a reliable removal service for the solid waste so that the public have an alternative and hygienic place to deposit their refuse. It is then necessary to educate the public to use the containers. Then the drains must be cleaned. Legislation by itself is not effective.

Earth drains are usually not uniform in slope so that puddles remain in depressions. Culverts should be laid with special care, because if the culvert invert is lower than the downstream drain, water will stand in the culvert, and if the culvert is higher than the upstream section, water will be trapped upstream; in both cases there will be stagnant water in which mosquitoes can lay their eggs. Careful attention should be paid to the cleaning of culverts; special tools are available for removing silt and debris that accumulates in them.

Measures should be taken to prevent mosquitoes from laying their eggs in latrines.

Large bodies of water such as reservoirs, wastewater treatment lagoons, lakes and marshes require special measures. Apart from spraying with larvicide or oil, one or more of the following environmental modifications may be possible:

(i) Vegetation at the edges of large bodies of water protects larvae from wave action. (Waves can swamp or drown the larvae.) Therefore edges should be kept free of vegetation and as steep as possible to take advantage of this effect.

(ii) In some cases it may be possible to vary the elevation of the water surface so that larvae are stranded on the dry edges and vegetation cannot become established. A change of water level of about 300mm in three days has been proved effective. Floating debris (which reduces the effectiveness of sprayed larvicides) may also be stranded.

(iii) Certain species of fish feed on mosquito larvae; if they are introduced into the water they may be effective in controlling numbers of mosquito larvae. Gambusia, Lebistes, Tilapia and Chinese grass carp are suitable for this purpose.

e. <u>Spraying</u>

Again, wherever possible, the main effort should be concentrated on denying the mosquitoes access to breeding sites. Where this is not possible a carefully devised spraying programme is required. It is useful to have some information about the type of mosquito that is prevalent and needs to be controlled; the species can often be determined by taking a sample of the water in which the mosquitoes are breeding and examining the larvae, or by catching adults (by placing a tube containing a wad of cotton wool soaked in chloroform over a resting mosquito so that it falls into the container and can be examined without suffering any physical damage). The preferred resting places of the mosquitoes must also be observed if spraying is to be directed to the right places.

Spraying may either be directed against the larvae in the water (using larvicides) or against adult mosquitoes (using residual insecticides directed at resting places, fogging or dusts). Spraying equipment may be portable and carried by the worker, or may be mounted in a boat or an aeroplane.

Larvicides should be dosed once every five days in hot climates to ensure that all larvae are treated. Oil-based larvicides are not suitable for water containing suspended organic matter; for such waters dusts, emulsions or pellets should be used. One particular larvicide - Abate - has been used successfully around the edges of lakes because it has a very low toxicity to mammals.

Kerosene is an effective larvicide, poisoning the larvae rather than just suffocating them. It suffers from the disadvantages that it evaporates quickly and is colourless, so that it is difficult to discern which parts have been treated. Heavier oils may be cheaper and easier to see than kerosene, but some do not spread sufficiently well. The pollution caused by heavier oils is often unacceptable.

f. Other methods of control

Mosquito nets are used to protect people from mosquitoes rather than as a means of control of their numbers, though it could be argued that making it more difficult for female mosquitoes to obtain the blood they need for their eggs is a method of control. The netting should have about 8 meshes to the centimetre if it is to exclude the Aedes mosquito. Soaking mosquito nets in an insecticide (permethrin) provides even more effective protection; mosquitoes coming into contact with the nets for a period of 3 to 6 months after treatment will be killed.

Mansonia mosquitoes, the main vector of rural filariasis in Sri Lanka, have been controlled by killing the plant to which the larvae attach.

4. RODENT CONTROL

a. Introduction

There are 2000 species of rodent, varying in size from the pygmy rat (which is about 10 mm long) to some which are the size of a dog. However the rodent which is of most concern from a public health viewpoint is the rat. There are two main species of rat - the common rat (rattus norwegicus, or Norway, brown or wharf rat) and the smaller roof rat (rattus rattus, or ship or black rat). Rats are a nuisance for the following reasons:

(i) They spread disease, including rabies (carried by the common rat), rat-bite fever, salmonella, leptospirosis (also called Weils disease), plague, typhus, sleeping sickness, pneumonia (carried by the ship rat with sandfly) and tape worms.

(ii) They consume millions of tons of food crops per year, especially root crops. (It is estimated that in some parts of Africa 15% of the food crops are eaten by rats.)

(iii) They cause injury and disfigurement when they bite humans, especially babies.

(iv) They cause damage to buildings, pipes and cables because they must continually gnaw with their long front teeth so that these teeth do not become too long and so prevent them from eating. In doing this they make holes in plastic and lead pipes, damage doors and other woodwork and even concrete, and chew through insulation on power and communications cables. They have been known to damage vehicle tyres and undermine concrete slabs.

b. Life cycle and habits

The common rat is mature enough to breed after 8 to 12 weeks and can give birth once every 24 to 28 days to a litter of around 8 baby rats. The potential number of rats descending from one pregnant female rat is 2000 within one year but a more typical survival rate is 200.

Rats require shelter, food and water to survive and so can live successfully in undisturbed piles of refuse and in disposal sites, provided that there is water nearby. They move around in search of food and water mainly at night so that it is not possible to tell from casual daylight observations whether rats are present in large numbers in a particular place. It is sometimes possible to determine whether there is a large colony of rats by looking for rat faeces (which are 12 - 15 mm long), rat holes or rat runs (paths made by rats always running along the same route, often next to a wall) or recent damage to door posts, containers etc. Where the colony is very large some rats may be seen in the daylight as they return to their nests after having travelled a long way in search of food.

c. Control in general

Large colonies of rats can only be killed by means of poisons. There are two types of poison - acute poisons which kill soon after they are swallowed and chronic poisons which must be eaten over a period of several days if they are to be effective. In both cases the poisons must be used carefully (following the instructions and wearing the necessary protective clothing) and intelligently to be successful and to minimise the dangers to humans and domestic animals. Once the population of rats has been drastically reduced it is then possible to modify the environmental conditions so that the area is less suited to further colonisation.

d. Acute poisons

Acute poisons are dangerous to all living things. One dose is enough. First the site must be studied carefully to identify places where bait can be laid so that rats are likely to feed on it and other animals are unlikely to come into contact with it. In some cases rat holes can be identified, in others it is possible to see runs. Rats do not like to be in exposed places, preferring to be under cover or next to a wall. Before any poison is used, bait should be put down in the appropriate places until the rats become accustomed to this new source of food. Grain is the usual bait. Then the poison is mixed with the bait. After 24 hours the site should be cleared of dead rats and unused poison because of the danger to other animals (whether they eat the rats or the poison) and to children. It is therefore necessary to record the locations of all places where bait has been laid so that the unused poison can be collected up. When acute poisons are used the carcasses are easily seen on the surface and so the success of the campaign is evident.

Sodium cyanide can be used to gas rats in their holes where the soil is moist, but it should not be used by anyone who has not had special training in how to handle it.

e. Chronic poisons

Chronic poisons take effect over a number of days or weeks, and because the rats generally die underground the effects of the programme are not as obvious when compared with the use of acute poisons. However chronic poisons are safer to use because they need to be swallowed on a number of occasions and an antidote is generally available. The most common chronic poison is "Warfarin" - an anticoagulant which kills rats by preventing their blood from clotting.

Poisons may be purchased already mixed with bait or separately. Ready-mixed bait is often coloured blue so that it is not eaten by humans. The mixture may be made by adding a little vegetable oil to grain and mixing it with the correct proportion of poison (often in the ratio 19 parts of bait to one part of poison). Soaking the grain in water or adding some fine sugar may make the bait more palatable. Powdered food is not suitable as bait because the rats must be able to pick it up with their paws. Again it is essential that the instructions provided with each product should be followed carefully. Operators should wear gloves and avoid inhaling the powder whenever they handle the bait.

The bait should be laid near rat holes or along rat runs, in boxes or tubes or otherwise under cover so that the rats can feed in a sheltered place, and the bait is inaccessible to birds and other animals, and protected from the weather. On the first day about 200g of bait should be placed at each baiting point. The next day and on each following day all the baiting points should be checked; where all the bait has been eaten twice the previous quantity should be put down ; where some remains what has been taken should be replaced. This procedure should be continued until bait is no longer being consumed - that is, when all the rats feeding on the bait have been killed.

It is advisable to maintain a permanent baiting station near the site where the rats have been living to discourage further infestation.

f. <u>Environmental modifications</u>

Environmental modifications can be made to make the site less attractive to rats. In towns and villages solid waste should be stored in bins with lids and any piles of rubbish on the ground should be cleared away within a week. (Paper is an ideal nesting material for rats.) At solid waste disposal sites a layer of soil or inert material should be placed over the compacted waste, and vegetation (which provides shelter for rats) should be cleared away from the area surrounding the deposited waste. Food storage facilities should not be located near to refuse tips from where rats might migrate (it is thought that rats may travel up to 3.5 km at night in search of food), and the food should be stacked with gangways between each pile so that the whole storage area can be monitored regularly for rat runs and rat faeces.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE TWELVE

INSTRUCTOR'S NOTES

a. Main points

(i) Students may tend to think of chemical control as the normal means of controlling pests; the advantages of control by environmental measures must be emphasized both in the lecture and the discussion that follows.

(ii) Some students may have difficulty in understanding the concept of resistance to insecticides, particularly how spraying with insecticides to which the target insect is resistant can actually increase the numbers of the target by killing its natural enemies. The concept of resistance is very important and should be covered carefully.

(iii) The presentation should also emphasize the benefits of studying the vectors concerned in order to know which species they are and to become familiar with their habits. This is necessary because of the variations between one species and another and because of variations from one area to another.

b. Preparation and site visits

(i) The instructor should discuss local conditions and local use of insecticides with any personnel familiar with the local situation. Examples of handling instructions for pesticides should be obtained.

(ii) Breeding foci for the three vectors in the local area should be identified. Students should be taken to visit these sites to observe the habits of the vectors and, if possible, collect samples for identification. Examples of damage by rats and resting places of mosquitoes should be pointed out.

(iii) Statistics related to infectious diseases transmitted by flies, mosquitoes and rats could be collected to illustrate the importance of control.

c. Questions for discussion

(i) How should the insecticide be chosen for a particular situation?

(ii) How can one determine whether a particular species of insect or rat in a particular area has developed resistance to a particular insecticide?

(iii) Why is the cooperation of the local community important if a vector control programme is to succeed?

(iv) How can the cooperation of the local community be obtained for a vector control programme?

(v) "Prevention is better than cure." Discuss this statement both as it applies to the need for vector control programmes, and as it applies to the way that a vector control programme is carried out.

d. Further Reading

1. Ross Institute, The housefly and its control, Ross Institute bulletin no. 5, 1975 (Currently under revision)

2. Ross Institute, Insecticides, Ross Institute bulletin no 1, 1979

3. Schreck, C.E. and L.S.Self, Bed nets that kill mosquitoes, World Health Forum, 6, 342-344, 1985

4. Meehan A.P., Rats and mice, Rentokil

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 13
PRODUCTION OF CONCRETE

This module provides practical advice to those responsible for the production of small quantities of concrete, either for building small structures or for use in repairs to existing concrete structures. Simple procedures are described for the selection and measuring of materials, and for the mixing necessary in order to make concrete suitable for a range of applications. In addition, this module describes how small repairs may be made to damaged concrete structures, and what precautions should be taken to ensure that concrete, when placed, is durable.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE 13

CONCRETE

1. INTRODUCTION

It is often necessary to produce small amounts of concrete to carry out repairs or to build small structures.

To the bystander, the production of concrete appears to be easy - the mixing together of cement, stone and sand with sufficient water to make the resulting concrete soft (or 'workable') enough to be easily moulded into place. However, the appearance of immediate or long-term defects in concrete is often the result of it having been badly made. Good quality concrete can be produced by following a few simple rules and procedures.

2. MATERIALS OF THE MIX

To make concrete you need the following materials.

a. Aggregates

A concrete mix can be thought of as a paste of cement and water, which combines chemically and binds together a larger volume of sand and stone. This sand and stone is known as the aggregate.

The aggregate is divided into 'coarse' and 'fine', which is the same as 'stone' and 'sand'. Aggregate is identified according to the sizes of square sieve apertures through which the aggregate particles can pass. For example, a 40 - 20 stone consists of pieces of stone which all pass through a 40mm square hole but cannot pass through a 20mm square hole.

There are three standard sizes of coarse aggregate, 40 - 20, 20 - 10 and 10 - 5. 40 - 20 aggregate is used for heavy construction such as roads. For minor works it is likely that the aggregates used would be a mixture of 20 - 10 and 10 - 5, which is called 20 - 5.

All material finer than 5mm is fine aggregate or 'sand'.

For small repair work it is advantageous to use aggregates which can be got locally. However, they must:

(i) be free from impurities such as clay, vegetation and rubbish;

(ii) have little dust content;

(iii) be consistent - that is, all the particles should be about the same quality or size;

(iv) be 'sound' - that is, all the particles should be 'cubical' or 'round', with no thin elongated (flakey) particles or 'friable' (easily crumbled) material. material;

(v) not contain too much silt - silt may be found in sand. A simple test is to squeeze some moist sand in your hand. If there is too much silt, your hand will be stained by it.

You can easily learn to judge aggregates by looking at them and you should reject any deliveries which are not satisfactory.

If aggregate is stored for some time, the larger stones will sink to the bottom of the heap. Always remix the aggregate before adding it to the concrete mixture.

b. Cement

This module will be concerned only with Portland Cements which include Ordinary Portland and Rapid Hardening Portland cements. Both Ordinary and Rapid Hardening cement will produce concretes which will set (change from fluid to solid state) at about the same rate. But after setting a Rapid Hardening Portland cement concrete will become stronger more quickly than an Ordinary Portland Cement concrete.

Cement is available in bags of 50kg (approximately 1 cwt.). Cement should be used fairly soon after delivery as it begins to lose strength after 4 - 6 weeks unless it is kept in airtight containers. Bags of cement must be stored off the ground and covered against rain. Damp air can do as much harm as direct moisture. Lumps in cement indicate that the bag has become damp and the cement has begun to bond chemically. As a rough guide, lumpy cement which cannot be easily crumbled between the fingers should not be used to build with. It may not even make effective repairs. If it is decided to use it then the amount of cement in the mix should be increased by 10 - 20% as lumpy cement will have lost some of its strength.

c. Water

Water used to mix concrete must be clean. Generally, if it is fit for drinking, it is suitable for mixing concrete. Impurities such as suspended solids, organic matter and dissolved salts can affect the setting and hardening of concrete.

The water serves two purposes:

(i) to combine chemically with the cement to cause setting and hardening;

(ii) to lubricate the fresh mix so that it can be easily placed and compacted with the tools available, (ie, to give the mix 'workability'.)

The more water there is in a mix, the less strength the concrete will have.

Of the total water added, only about half is required for the chemical reaction. Some water may be absorbed into the aggregate. The water which is <u>not</u> absorbed into the aggregate is known as the 'free water'. If all the aggregates are thoroughly saturated and allowed to drain off before mixing, then all the water added when mixing will be 'free water'. If the aggregates are not pre-saturated, some of the total water will be absorbed by the aggregate. This leaves less free water to lubricate the mix.

To be sure of a good, workable concrete, saturate and drain the aggregate before mixing. Pour or, better still, spray, water over the pile of sand or stone until water begins to come out the bottom. The water also helps to cool the aggregate. This is important because the warmer the concrete is, the quicker it will lose its workability.

Figure 1.
Wetting aggregate

d. Admixtures

A range of chemical products are available commercially. When added to the mixing water they can improve certain properties of concrete. As a general guide it should be noted that no admixture will make a poor concrete into a good concrete, but may make a good concrete better.

When carrying out repairs, the use of commercial products containing acrylic emulsion or expoxy resin are effective in increasing and maintaining the bond between the old and the new concrete. However, these admixtures are difficult to get in rural areas and they are very expensive. They should only be used for very small areas of repair.

3. MIX PROPORTIONING

When mixing concrete, it is very important to get the proportions of mix materials right. There are a number of ways in which the relative amounts of mix materials can be measured.

If the proportions of a concrete are described as 1 : 2 : 4, this means that the mixture (or mix) contains 1 part cement, 2 parts sand and 4 parts aggregate.

The following table shows the most common concrete proportions and the situations where they would be used.

Cement	Sand	Stone	Water	Strength	Uses
1	2	4		Strong	Structural Roads
1	3	6		Medium	Slabs at ground level Mass concrete
1	4	8		Lean	Non-structural Protecting pipes

Table 1. Mix proportions for concrete

There are two methods of measuring the materials - by WEIGHT or by VOLUME.

To <u>weigh-batch</u> the equipment required would be a platform scale of the steelyard type. This is the kind or scale which is used for weighing sacks or animal carcases.

Typical weights relative to one bag of cement:

1 bag cement (50 kg) 100 kg sand 200 kg stone

These would be mixed with approximately 23 litres of water for medium 'workability'.

If scales are not available, then you must <u>volume batch</u>.

It may be useful to know that one cubic metre of sand weights approximately 1450 kg and one cubic metre of stone approximately 2025 kg.

The materials can be measured in ordinary household buckets. The capacity of each bucket is likely to be about 10 litres, but this must be checked. Each bucket must be marked on the inside with a line to represent 10 litres.

Mix	Cement bag	Sand (m^3)	Stone (m^3)
1 : 2 : 4	1	0.07	0.14
1 : 3 : 6	1	0.10	0.20
1 : 4 : 8	1	0.14	0.28

Table 2. Proportion of concrete based on 1 bag of cement

The measurements in cubic metres can easily be converted into numbers of 10 litre buckets.

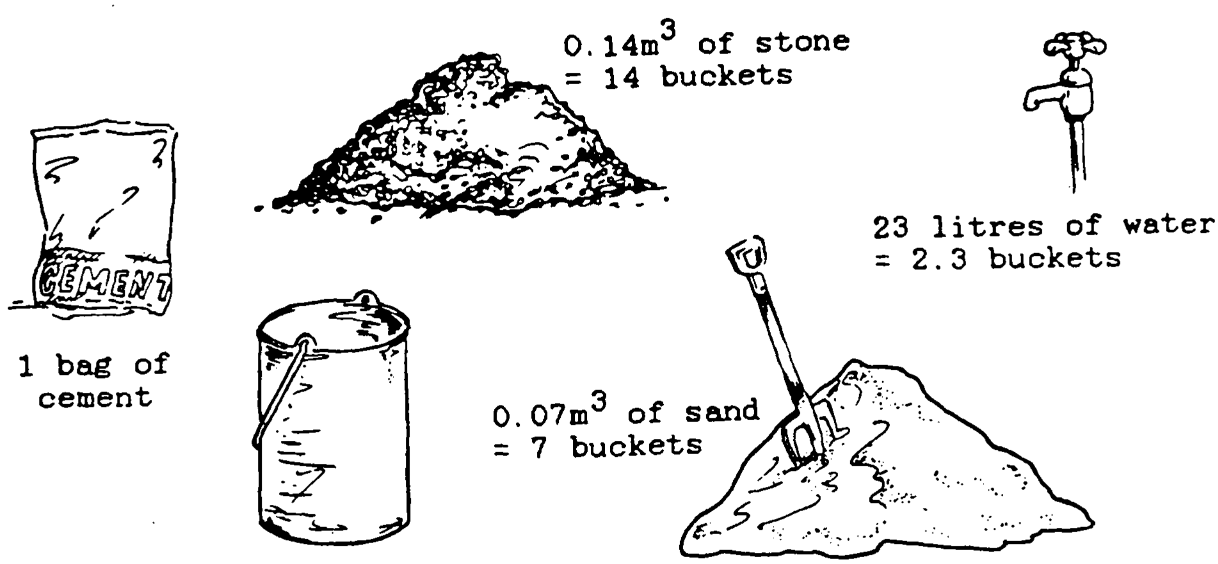

Figure 2. Sample measurements when volume batching by bucket

When cement is batched in buckets it is very important that the bucket is filled in the same manner each time. Do not bump the bucket or press down the cement. The amount of cement can vary a lot if it is packed or pressed down.

The amount of water required varies according to the type of aggregate and its moisture content. As a general rule, the water added should be between 1/2 and 3/4 the weight or the volume of cement.

If you want to mix the right amount of concrete for a specific job, then you need to know the volume of concrete required. The following table gives materials quantities required for 1 cubic metre of concrete.

Mix	Cement (kg)	Sand (m^3)	Stone (m^3)
1 : 2 : 4	326	0.45	0.90
1 : 3 : 6	228	0.47	0.94
1 : 4 : 8	175	0.48	0.96

Table 3. Materials in $1m^3$ of concrete

If a lot of concrete is required, the tedious routine of filling buckets can be changed by making wooden containers (batch boxes). These have lifting handles and a line drawn round the inside to show how much they can hold.

Figure 3 shows a batch box suitable for batching concrete, sand and stone.

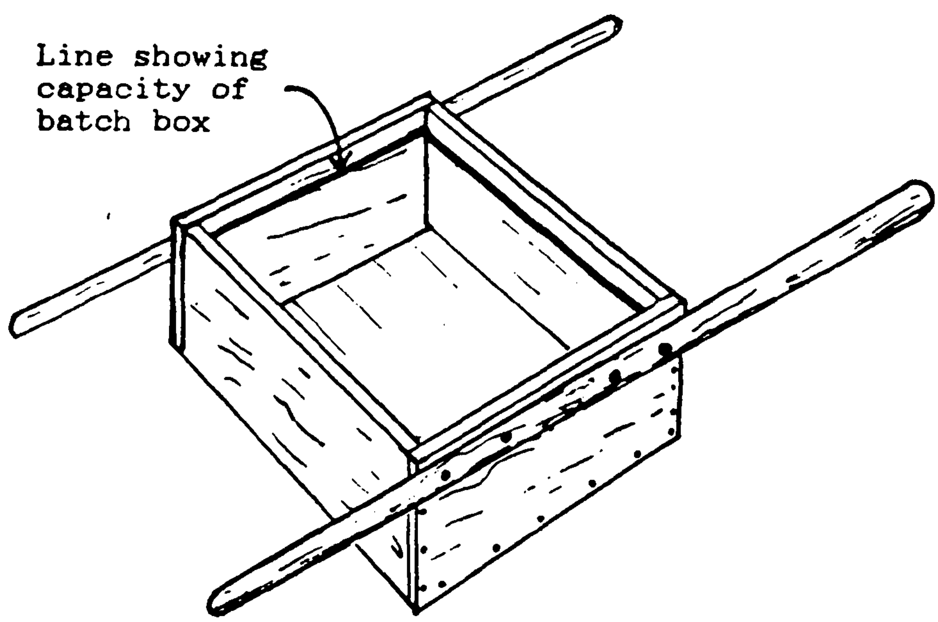

Figure 3. Typical batch box

4. MIXING

(i) By hand.

For small quantities, you can mix on a clean steel sheet using shovels. Research has shown that hand mixing, properly performed, gives a more consistent product than using some mechanical mixers. The cement and sand can be mixed together when they are dry and formed into a ring into which the stone is placed. The water is then gradually poured onto the stone and wet-mixing carried out until the mixture looks the same all over.

Figure 4. Mixing by hand

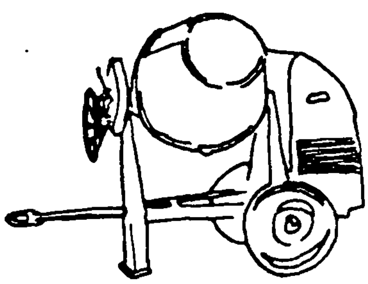

Figure 5.
Mechanical mixer

(ii) By mechanical mixer.

The type of mechanical mixer most suitable for small scale work and most likely to be available is the small tilting drum type. These have a discharge capacity of either 0.1 cubic metres (3.5 cubic feet) or 0.14 cubic metres (5 cubic feet). You should not dry mix the materials. The water should be added as the other materials are being loaded.

It is usual to mix concrete for 1 1/2 to 2 minutes. Stop mixing when all the mix is the same colour and consistency. It is very important that each batch should look the same as all previous batches.

When mixing is finished, empty all the concrete from the mixing drum at the same time. The mixing drum should be completely emptied before you load the next batch.

The more experience you have, the easier it will be to mix good quality concrete. With practice, you will be able to judge the quality of a concrete just by looking at it.

5. MORTAR

To make small repairs (ie. filling in cracks or small holes) a mix of cement, sand and water is used. This is known as mortar.

The mortar used for repairs should be of the same proportions as the cement and sand used for the concrete which requires repair. However, if the proportions of the original mix are not known, then a mortar of 1 part cement to 2 parts sand should be suitable for most repairs. Follow the same rules as for mixing concrete.

The mortar will shrink slightly as it dries and hardens. The amount of shrinkage depends on the amount of water in the mix - the more water, the more shrinkage. As little water as possible should be added to the mortar mix. It should be as dry as possible while still being workable enough to place.

6. DEFECTS IN CONCRETE

Defects in concrete usually occur because of mistakes made when mixing and placing the mixture.

Common Defects

1) If too much water has been added to the mix, the concrete will lose a lot of strength and the surface may break and flake. The concrete may shrink, causing cracking or separation at joints.

2) If the mix has been handled and dropped too much during mixing and placing, the mix may 'segregate' or separate. The lower layers of placed concrete will have too much aggregate, giving a 'honeycomb' effect, while the upper layers will have too much mortar, giving a 'fatty' effect.

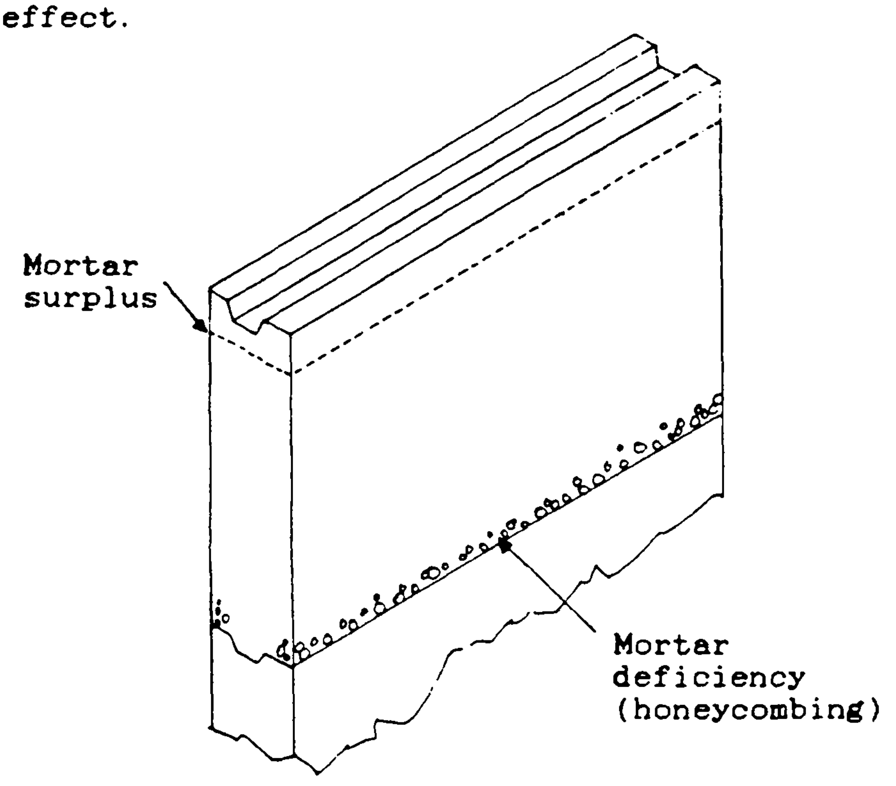

Figure 6. Honeycombing in a wall

3) Steel bars or wire mesh (reinforcement) are often placed inside concrete structures to make them stronger. If a bar is too close to the outside surface of the concrete it will start to corrode. The concrete will become stained and will begin to fall off. The reinforcement will eventually be exposed.

4. After concrete has been placed it must be allowed to dry slowly. This is essential to allow the cement to absorb all the water it needs to bond chemically with the aggregate. On a floor, water can be kept ponded by raising small clay barriers around the edge. For walls, continuous spraying is the best method. The concrete must be kept covered and wet for at least three days. This process is called curing. If concrete is not properly cured it will crack, allow water to pass through it, shrink a lot and lose strength.

5. Badly made formwork (the moulds into which fluid concrete is poured and in which it is left until it has hardened) can lead to bulges in the concrete surfaces and to honeycombing.

7. REPAIRS

When carrying out all repairs to concrete it is absolutely necessary to remove all defective concrete and cut back to the unaffected or good concrete below.

a. Slabs at ground level

1. When surface damage is only in a small area or areas.

   i) cut away damaged material;
   ii) clean exposed surface with a stiff wire brush;
   iii) saturate with water for 24 hours;
   iv) cover area with a thin film of neat cement paste, (ie. a smooth paste of cement and water)
   v) on top of this film place a thin layer of almost-dry mortar;
   vi) complete by adding a layer of stiff concrete which should be thoroughly packed into the cavity;
   vii) cover and wet-cure for three days.

2. Cracks in slabs must be cut back to the full depth of the crack and the cavity enlarged and treated as above.

3. When the surface damage is extensive, specialized techniques and machinery are needed to make the best repairs. If these are not available, then the surface should be cleaned off and covered with a new, bituminous wearing surface or the old slab removed completely and replaced with a new one.

b. Vertical surfaces

1. Honeycombing due to segregation or mortar leakage can be serious and extensive and cannot be remedied by plastering over with mortar. It should be repaired immediately the formwork has been removed, before the concrete is too hard to deal with. However, it is possible to repair after the concrete has hardened. The pourous material must be cut away until.

   i) solid concrete is reached;
   ii) any reinforcement is exposed and concrete is removed from behind it;
   iii) undercut edges are produced (see Figure 7)

   The cavity is thoroughly washed to remove dust, left wet and a thin coat of neat cement paste painted on. Finally, a mortar of almost-dry consistency is rammed into the cavity and the surface finished with a wood float.

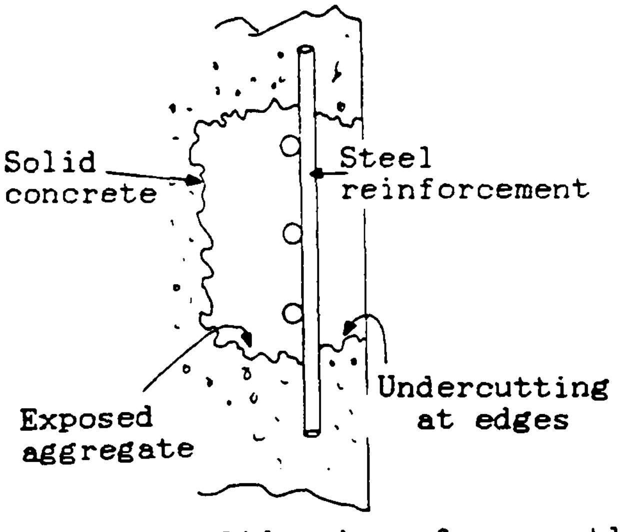

Figure 7. Side view of correctly prepared cavity

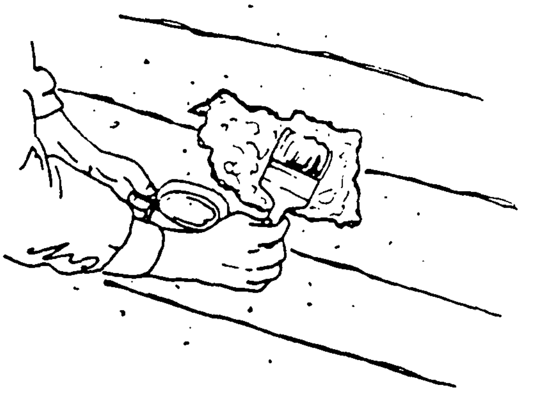

Figure 8. Applying cement paste

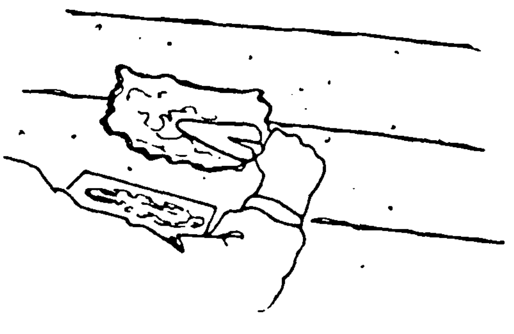

Figure 9. Filling hole with mortar

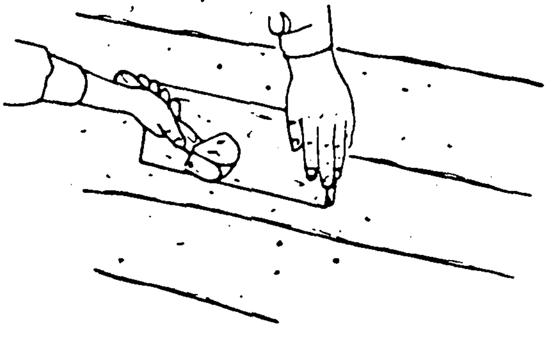

Figure 10. Compacting mortar with board and hammer

c. Exposure of reinforcement

i) Remove the concrete around the bar or wire tie using a hammer and chisel.
ii) Force the bar back into place or cut the wire at least a 1/2 inch from the face of the wall.
iii) Remove all loose pieces of concrete and wash off any dust or dirt.
iv) Thoroughly wet the surface of the cavity and apply a cement paste.
v) Ram or hammer almost-dry mortar well into the hole.
vi) Wipe the surface with a damp cloth so that it is level with the concrete surface.
vii) Cover and wet cure for three days.

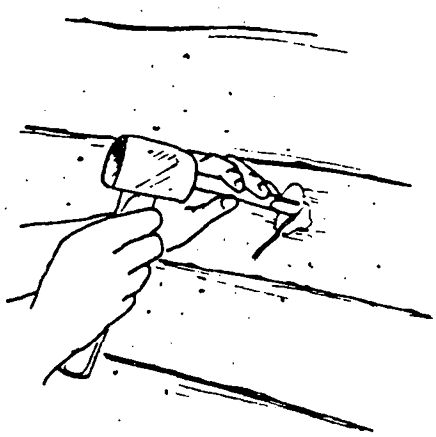

Figure 11. Removing protruding wire reinforcement

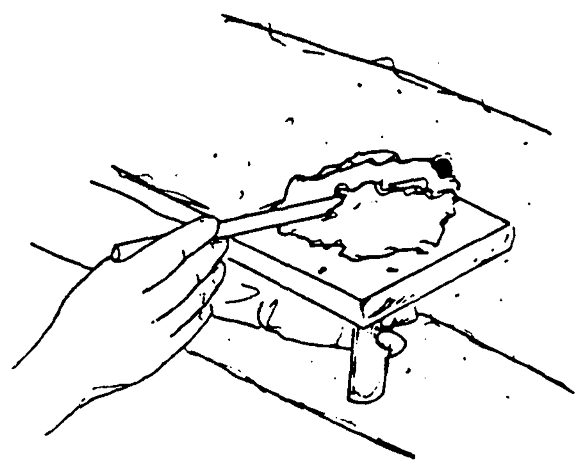

Figure 12. Filling hole using a rod

d. Leaks in water-retaining structures

It is not uncommon for some initial leakage of water to occur from concrete water tanks and in many cases this gradually reduces as the concrete matures. If the leakage is extensive and permanent, it may be necessary to line the structure with bitumen. Leakage which persists at a joint requires the whole joint to be exposed by cutting and the joint faces hacked away to expose the aggregate. These faces must be completely clean and free from dust. Then temporary shuttering is placed across the gap, the faces are wetted and the gap filled in the same way as for surface damage to a ground level slab.

e. Surface irregularities and air-holes

Rubbing the surface of the concrete with a carborundum stone will remove any projections and irregularities. It will also fill up most of the smaller air-holes if the concrete is no more than a day or so old.

If the concrete is older or if the air-holes are large, a mortar of 1 part cement and 11/2 parts sand should be rubbed into the surface. This can be done with a carborundum stone or with a wood float.

It is important to go over the whole surface of the concrete as otherwise a patchy appearance will result.

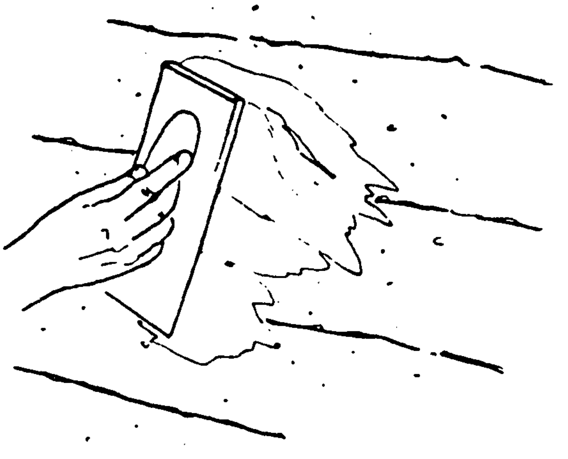

Figure 13. Rubbing cement/sand paste over the surface of the concrete

8. CONCLUSION

Repairs are time-consuming, costly and require patience and effort. Concealing defects by hastily applying mortar is never acceptable since, sooner or later, the mortar will fall away.

Some repairs are inevitable as concrete gets old and worn, but the best way to ensure that defects occur as little as possible is by employing good concrete practice in the initial building stage.

This module has not dealt with the making of formwork and the placing of concrete as these are specialized skills and are not normally part of operation and maintenance work. There are several publications which deal with these topics in detail.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE THIRTEEN - INSTRUCTOR'S NOTES

CONCRETE

1. INTRODUCTION

This module describes how to produce concrete for building small structures and for repairing existing concrete.

It discusses the materials needed to make concrete, how to proportion these materials both by weight and volume; how to mix concrete and mortar; the common defects in concrete and how to carry out repairs.

The module will be taught as a lecture with demonstrations.

After the lecture there should be a practical session where the students work in groups to mix concrete and carry out repairs. This practical experience will consolidate what has been taught in the classroom and is, therefore, very important.

2. TEACHING THE MODULE

a. PRE-DISCUSSION

Begin the session with a short discussion in which important points about concrete production are raised. This helps the instructor to assess the level of the students' knowledge.

Sample Questions

What do we use concrete for in water and sanitation work?

- for building latrines, wells, hand-pump surrounds repair work, etc.

What is concrete?

- a mixture of sand, stone, cement and water which binds together and becomes hard.

When concrete is wet it is soft. Why does it become hard when it dries, but does not become soft again even when it gets wet?

- Because the cement reactes chemically with the water. This changes it and it becomes very hard. But after it gets hard, the chemical action stops and it cannot become soft again.

Do you think it is very easy to mix concrete?

- It is not easy. You have to be careful to use the right amount of cement, sand, stone and water. And if you do not mix them correctly, you will make bad concrete.

Reassure the students that if they follow a few simple rules, they will be able to make good quality concrete.

Give a copy of the Students' Notes to each student.

b. MAIN TEACHING POINTS

Section 1

Make sure that the students understand the meaning of 'workable'.

Section 2a

Show examples of different kinds of aggregate.

Have sieves and examples of different sized aggregates in the classroom. Show the students how to measure the aggregate.

Section 2b

Draw a picture, or have a photograph or slide showing how concrete bags should be stored.

Section 2d

Show the students examples of commercial admixtures which are available.

Section 3

Explain fully the meaning of the mix proportions 1:2:4; 1:3:6 and 1:4:8 and the difference in the strength and uses of the different mixes.

Demonstrate how to volume batch the materials. Have buckets, a batch box and, if possible, samples of the materials in the class.

Ask the class to calculate how much of each material is needed to make different amounts of concrete. Ask the students to explain how they are going to work it out and write the calculations on the blackboard. Help them where necessary, but do not do the work for them. If the students cannot reach the right answers then this part of the lesson may have to be taught again.

After general class practice, and when the class are getting the answers right, set similar problems for the students to work out individually. After allowing sufficient time, ask a student to give the answer. Do not only ask volunteers to answer the questions - make a point of asking the quiet students questions too. Encourage the other students to correct their colleague is he or she is wrong. In this way the whole class is kept involved in the problem-solving exercise.

The instructor should prepare many problems before class, paying attention to what is appropriate for the students' needs (ie, what type of concrete repairs they will be carrying out and the equipment available).

Section 4

Don't waste too much time on this during class. Methods of mixing are best taught during the later practical session.

Section 5

Make clear the difference between concrete and mortar and when each is used.

Section 6

If possible, show slides or pictures illustrating defects in concrete, and methods of curing conrete.

Section 7

The necessity of removing all bad concrete before carrying out repairs should be emphasized.

c. POST DISCUSSION

Ask the students these questions after the lecture to review and consolidate what has been taught.

TOPICS FOR DISCUSSION

1. How would you decide whether a sample of stone was acceptable for concrete production? What points would you need to check?

2. What are the different methods used for batching materials for a concrete mix?

3. Which constituent of a concrete mix is the most important? Give reasons for your answer.

4. What are the three most important points to be observed in preparing a cavity in concrete before making it good?

3. PRACTICAL SESSION

The practical session should be carried out on site. The students will be expected to work in groups and receive the minimum amount of assistance from the instructor. They will be required to measure materials, make a concrete mix, prepare cavities in concrete and repair them satisfactorily.

4. FURTHER READING

Murdock L. J. and Blackledge G. F. - Concrete Materials and Practice (Arnold, 1968)

Reynolds C. E. - Concrete Construction (Concrete Publications, 1967)

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 14
MANAGEMENT

This module is designed to be a general introduction to the concepts of management, focussed on the needs of a water supply and sanitation organisation.

The module looks at "The manager's task", the role of "The Project Cycle" in planning, "Institutional considerations", "Human Resource Development", a Legislative framework and the planning of "Operation and Maintenance".

On completion of the Instructors introduction to Management, the participants should be able to begin discussing the strengths and weaknesses of their own organisation and personal performance under these headings.

More specific management information is dependent on the training needs assessment of the participants own organisation, and will be supplied by the course tutors.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE 14

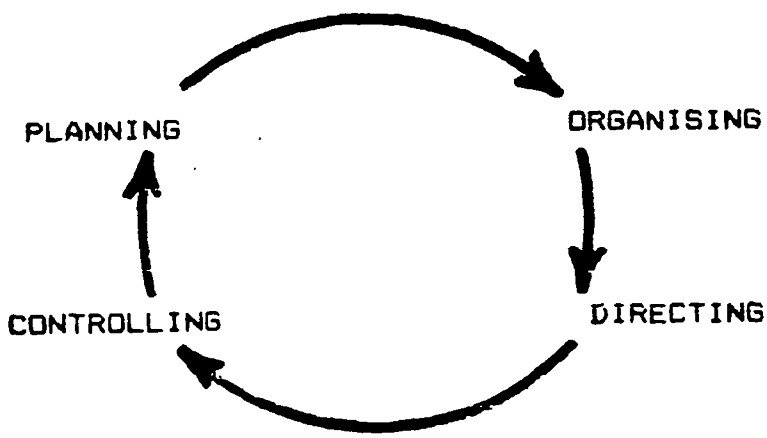
MANAGEMENT

Introduction

A manager is a person who guides the running of an organisation towards certain objectives. Managers work at different levels, some specialising in long-term planning, others involved in implementing work at site level.

In any organisation somebody has to decide the specific objectives of that group or section: that is, *what* they are trying to achieve. They then have to work out *how* to meet that objective, determining the people and resources required to help them. A manager has to encourage people in their work, showing them how to do things and leading them by example. A manager also has to have measurable goals that enables *checks* to be made to ensure progress towards the original objectives.

The tasks of a manager may be summarised as follows:



Planning: setting objectives, surveying resources, forming strategy; preparation of long term plans, annual budgets and work programmes, weekly or monthly plans and schedules.

Organising: grouping into a systematic whole, arranging, preparing, deciding who does what; making the group efficient; putting together all the components (equipment, finance, materials, people) in such a way that the overall plans succeed.

Directing: guiding the movements of, focussing and aiming the work of others, giving orders (but not ordering about); being a leader, teacher, advisor, helper as well as boss; it is better to encourage good performance rather than demand it.

Controlling: regulating, restraining, holding in check materials, finance and people; determining the difference between planned results and actual results at all stages of the work; making sure things happen the way they are planned. Work control keeps activities headed in the right direction.

2 THE PROJECT CYCLE

All the work in a water and sanitation organisation can be understood in terms of the Project Cycle. This approach has been devised to encourage a more methodical approach to project development and implementation.

Project Identification and the Sector Plan
This determines the need for a project, describes objectives and policies. It defines the target population giving economic and health indicators, present service coverage and standards, outline costs of work and additional staffing requirements. It also defines steps required to complete project.

Pre-Feasibility Study
Having determined the objective, various alternative means of achieving these goals must be considered, bearing in mind Technical, Social, Environmental, Financial, Health, Institutional and Economic criteria. This results in a single preferred option for meeting the objectives.

Feasibility Study
This considers a detailed design and analysis of the preferred alternative along with cost estimates, cost recovery schedule and implementation programme.

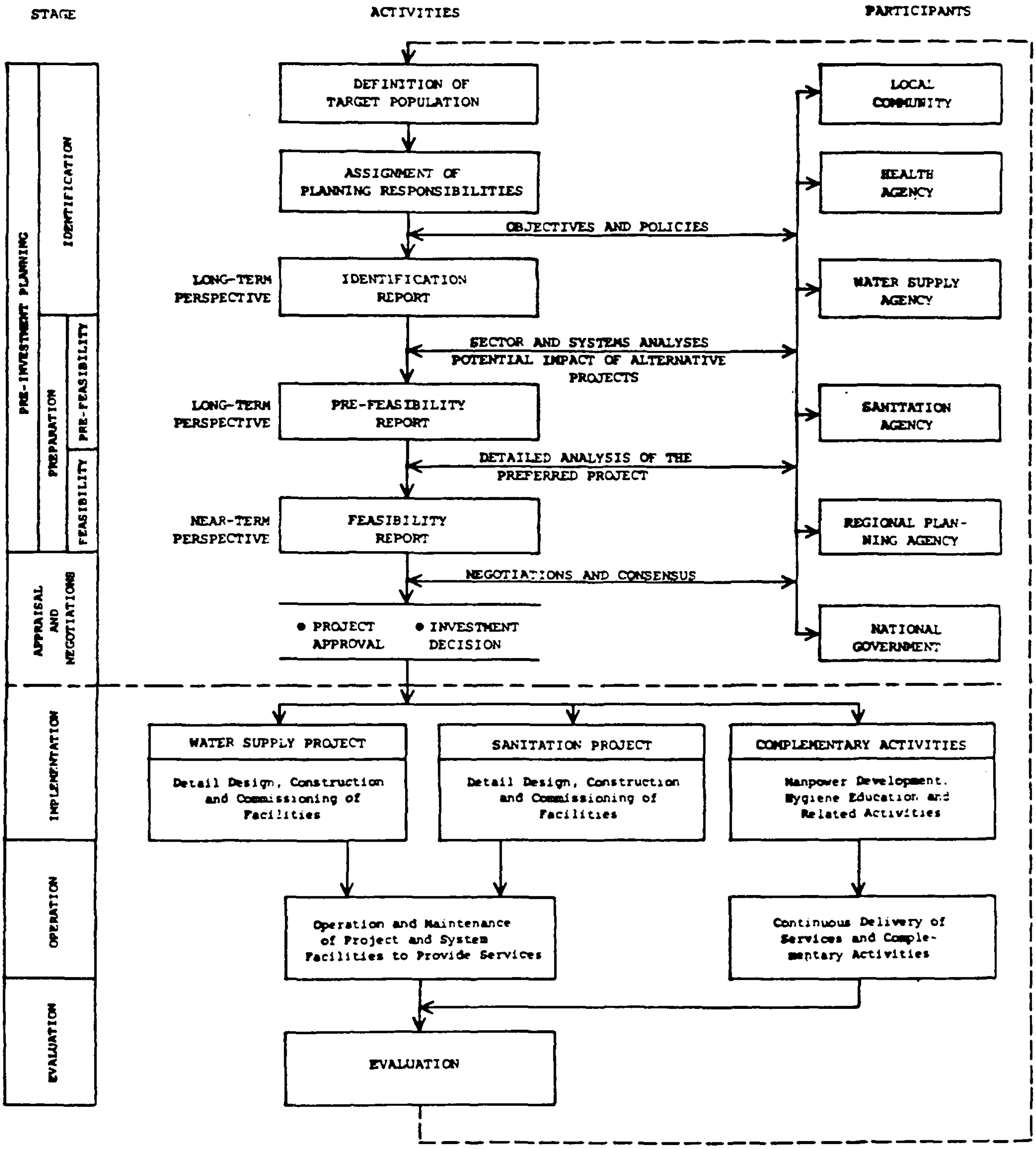
Appraisal and approval
An independent check is made upon the suitability of the proposed work looking at technical and non-technical factors; this may then be followed by approval of funding.

Implementation
Following approval and funding, the chosen facilities are constructed, either by contractors, government personnel or the community.

Operation and Maintenance
Perhaps the most vital part of the cycle is the operation and maintenance programme where the original objective of providing clean water and/or effective sanitation is realised. The people benefit only as long as the system can be kept working at the required standard.

THE PROJECT CYCLE

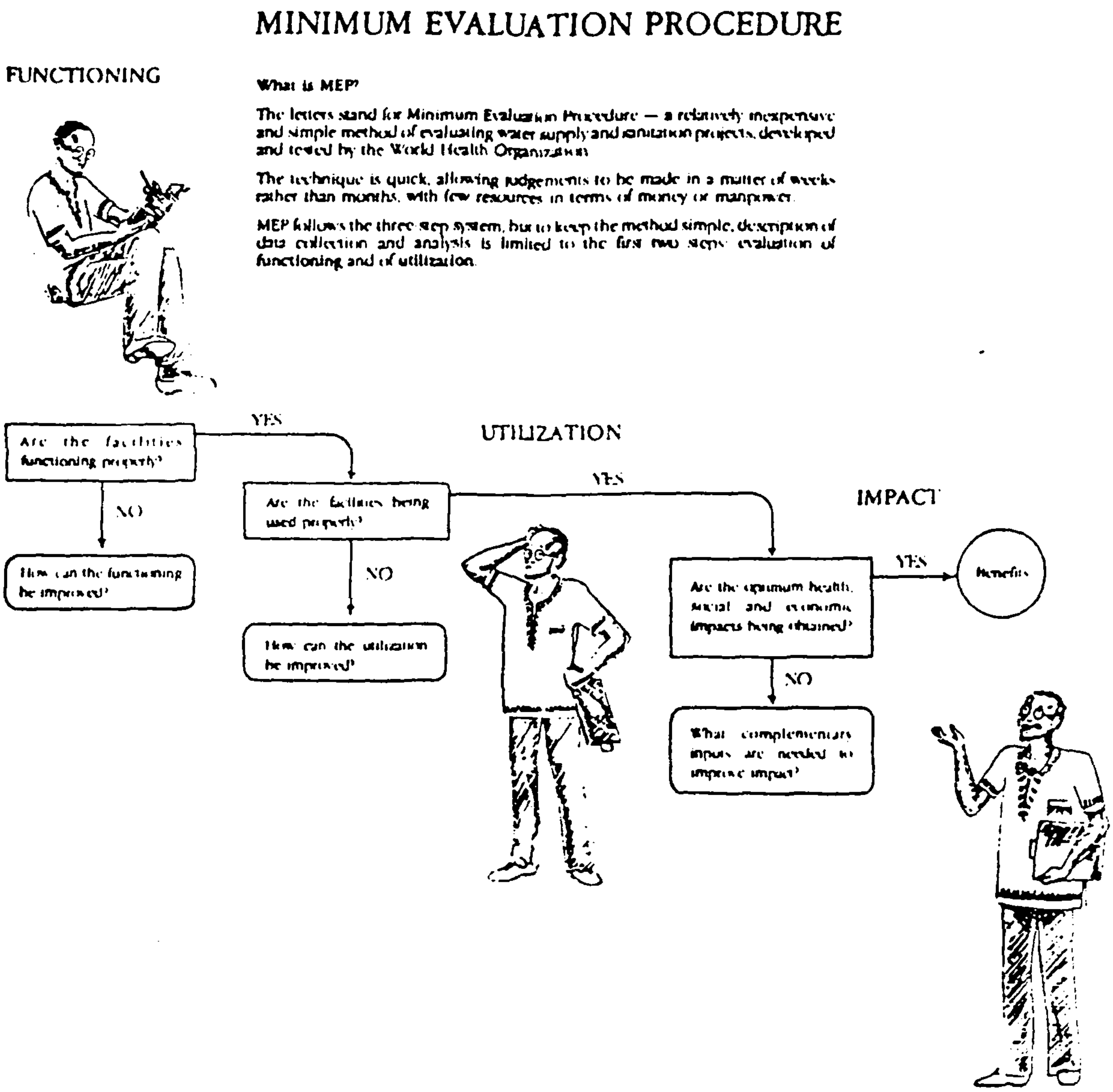
DEVELOPMENT STAGES FOR WATER SUPPLY AND SANITATION PROJECTS



Based upon The Project Cycle, World Bank.

Evaluation
Finally a check on all the preceeding work is carried out to ensure that the facility is functioning correctly, that it is being used by the people it was intended for and that they are benefiting as a result.

The project cycle description of the steps of a project is called a cycle because the evaluation of one stage of a project provides the information required for successful identification of the next stage of a programme.



3 INSTITUTIONAL CONSIDERATIONS

One of the major areas to consider for effective management of a water supply and sanitation programme is the institutional capabilities of the responsible organisation. This refers to the style and appropriateness of the organisation as well as to the particular needs of the staff within it.

Organisations and structure

To be effective, management has to have a sound organisation structure which acts as a framework within which people can work and which is geared to achieving the overall objectives of the authority.

Ten rules of sound organisation:

1. The responsibilities of each person are clearly defined.
2. The people who are responsible also have the authority to carry out decisions.
3. No manager or worker is subjected to definite orders from more than one source above him.
4. Orders are not given to subordinates bypassing an intermediate manager.
5. Criticism of subordinates is always made in private.
6. All disputes or differences between workers and managers are quickly and carefully resolved.
7. Promotions, wage changes, disciplinary actions are always approved of by the manager directly above the affected person.
8. No manager or employee is ever required by the organisation to criticise the person above him.
9. Any manager whose work is subject to regular inspection is given assistance to enable him to maintain an independent check upon the quality of his work.
10. Efficiency in an organisation springs from the voluntary cooperation of the people who work for it.

4 HUMAN RESOURCE DEVELOPMENT

Limitations in preparation, implementation, operation and maintenance of schemes are often blamed on poor performance of programme staff and the ignorance of the people using the system. A normal response is to plan a training programme to educate all involved in how to carry out their tasks correctly.

However, teaching personnel skills and knowledge may not in itself solve difficulties of performance. Motivation theory shows that there are many factors to be considered in enabling people to perform to their full potential. It is the role of the manager of the programme to consider all aspects of human resources development.

It is suggested that deficiencies in human performance can generally be traced to one or more of the following causes: lack of skill or knowledge; environmental and/or management difficulties; motivational, incentive or attitudinal causes. If lack of skills or knowledge is the primary cause of a performance problem, training is the likely solution. However, if problems stem from environmental and/or management causes, or from motivational causes, they will probably not be solved by training alone. In a number of surveys, managers involved with water and sanitation programmes have estimated that only 10-30 per cent of performance difficulties are due to lack of skills or knowledge which can be rectified through training.

Motivation Theory

Physical needs must be satisfied first- but when they have been satisfied they are no longer motivators and higher needs in the ladder became significant

Self-realization needs	Job-related satisfiers
Reaching your potential Independence Creativity Self-expression	Involvement in planning your work Freedom to make decisions affecting work Creative work to perform Opportunities for growth and development

Esteem needs	Job-related satisfiers
Responsibility Self-respect Recognition Sense of accomplishment	Status symbols Merit awards Challenging work Sharing in decisions Opportunity for advancement

Social needs	Job-related satisfiers
Companionship Acceptance Love and affection Group membership	Opportunities for interaction with others Team spirit Friendly coworkers

Safety needs	Job-related satisfiers
Security for self and possessions Avoidance of risks Avoidance of harm Avoidance of pain	Safe working conditions Seniority Fringe benefits Proper supervision Sound company policies, programs, and practices

Physical needs	Job-related satisfiers
Food Clothing Shelter Comfort Self-preservation	Pleasant working conditions Adequate wage or salary Rest periods Labor-saving devices Efficient work methods

It is therefore recommended that personal skill development must be complemented by the strengthening of the organisational environment, whether formal or informal, in which the person works.

To train people effectively it is desirable to enhance their breadth and depth of knowledge about their particular responsibility. It is also necessary to improve their ability to carry out any particular tasks. In order to do this a process known as the training cycle is followed. This same cycle may be followed for householders involved in community programmes, technicians, sanitarians and managers as well as for professional engineers.

The training cycle

Preparation of any training programme begins with an assessment of training needs. This requires an organisation chart describing the different jobs to be carried out in order to complete the objective. The objective should not be limited to completion of initial construction but should include operation and maintenance also. Each of the jobs listed then requires a job description, that is a detailed list of the tasks to be carried out by a person in that position (whether or not employed by the programme). Comparing the job description with the knowledge and skills of people likely to be available to do a task leads to a list of training needs. A training plan is prepared from the list of training needs having determined the main priorities. The plan should specify the people to be trained with target dates for completion and objectives for what might be accomplished as a result of the training.

Implementation of training depends upon whether the needs are for:

knowledge - lectures and books are particularly useful for imparting knowledge;

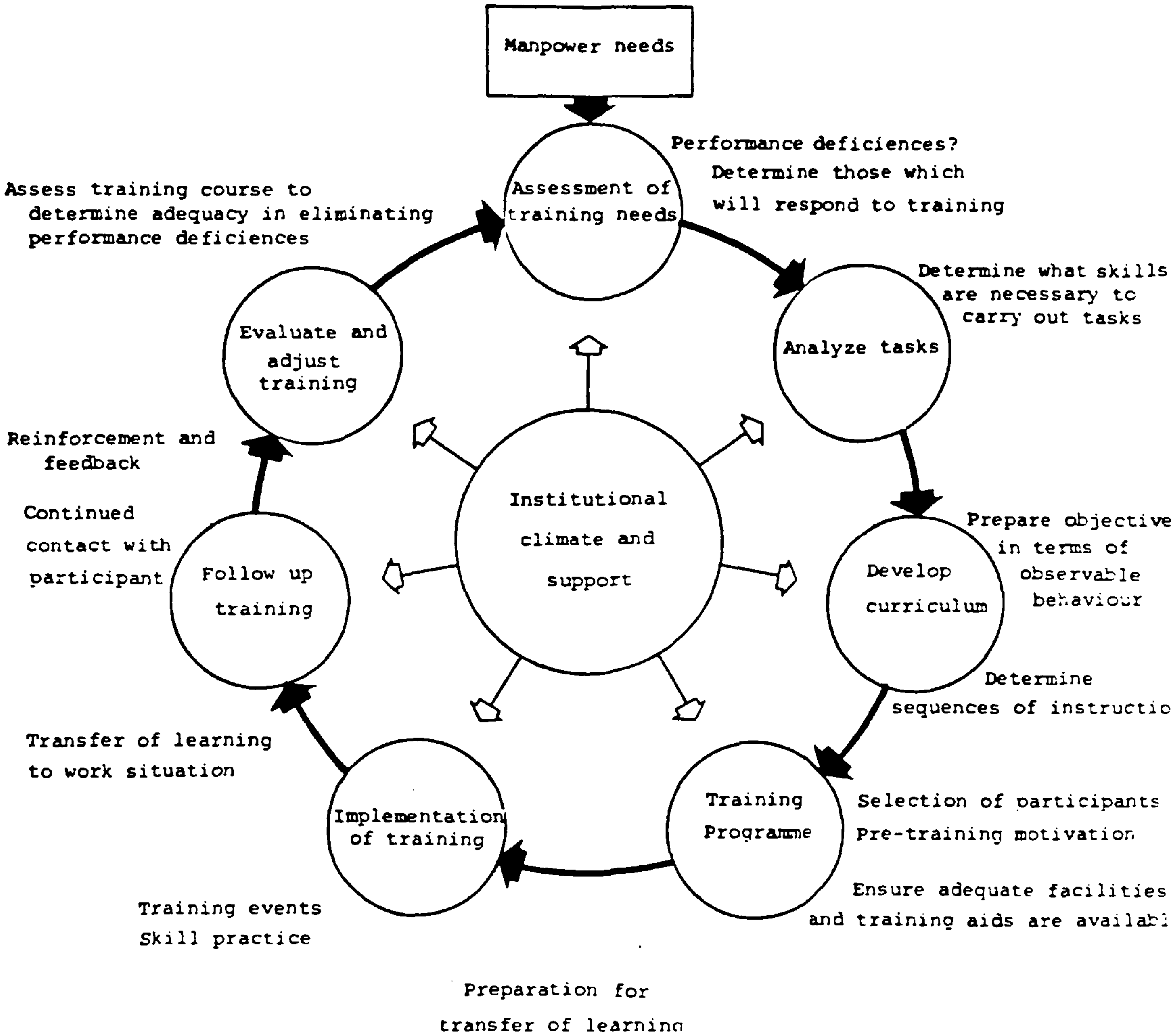
manual skills - can be developed by step by step development through demonstration, participant practice and correction of faults, concentrating on key areas;

social skills - can be developed by the use of role-playing, case studies, discussion and practice under supervision;

attitude - can be improved by group discussion, personal interview, case studies and feedback;

systems - for example, clerical procedures and stock control can be improved by the provision of check-lists and by demonstration and practice with correction.

The Training Cycle



Motivational requirements

Adequate motivation of staff is a necessary prerequisite for successful training. Where incentives (not only money) provided for staff are inadequate, the recommended approach to human resources development requires that such matters are corrected before straightforward training can be effective.

Of particular importance to project staff is that they can see future career development beyond the present project. It is also necessary to ensure that status, conditions of service and salary scales compare favourably with those for other available employment. This is particularly relevant for senior posts where the holders have to work away from home.

5 LEGISLATION

Workers, supervisors and managers have to be aware of governmental legislation which affects their work.

Basic legislation is necessary to enable a public health agency to initiate and develop activities in the field of water supply and sanitation. Legislation can contribute towards effective management by giving a clear definition of duties and responsibilities and clear allocation of responsibilities between different institutions. Legislation also may specify physical and financial objectives along with providing for external monitoring and enforcement. However, legislation will be most effective where it acts as an enabling framework rather than as a rigid straitjacket. It is worth remembering that laws cannot be enforced without the cooperation of most of the persons concerned.

On the basis of such legislation, the public health agency concerned is in a position to formulate and issue more detailed rules, regulations and standards.

A water code has four major categories:

Rights on natural water - to establish the power, rights and duties of individual users and the government over natural water in its various forms, including arrangements for safe disposal of waste water.

Rights relating to land - to give powers over privately owned land in relation to proper management of surface and groundwater.

Registration and licensing of rights to use water - to allocate water between competing consumers based on national development priorities, protecting users of resources and giving security to users in the form of guaranteed supply at a certain standard.

Administrative structures - which define the objectives of the authority, its constitution and financial powers.

6 OPERATION AND MAINTENANCE

Operations have to be linked with a well planned maintenance programme if the project is to yield its intended benefits. There are two types of maintenance, corrective and preventive.

> Corrective maintenance is undertaken to repair plant or equipment which has broken down.
>
> Preventive maintenance describes work or measures taken to prevent facilities going wrong in the first place.

Often preventive maintenance is overlooked because of the pressures involved in trying to operate and repair equipment. However, this leads to reduced benefits and higher costs.

There are four parts of a preventive maintenance programme:

Plan	Personnel	Parts	Records

Planning
In any plan for preventive maintenance, the location of the works must be considered - remote areas require greater planning. Similarly the age and condition of the equipment has to be considered. The degree of abuse of equipment by untrained personnel is important as well as the availability of funding. The plan is made up of a list of individual maintenance activities, that is what is to be done with details of who is to do the work and information on how this is to be achieved and how often it is to be carried out.

Personnel
Staff require not only knowledge of how a job is to be done but understanding of why it is necessary. This requires appropriate training and motivation of staff members. On-the-job training on a regular basis is necessary, particularly for those who have had limited formal education.

Parts
The correct availability of spare parts and tools has to be ensured by management whether for corrective or preventive maintenance. Materials management as described below is vitally necessary.

Records
Accurate information on how often items are required must be maintained for efficient use of stocks. A good record system should include the name of the equipment, its serial number, type and class, the date of installation,the cost of purchase, the name and address of the manufacturer, the name and address of any service organisation, the availability and location of service manuals, the name of the facility which the unit serves and the location of the particular unit. The records should also indicate the date and nature of any problems and overhauls with details of parts fitted and the time taken to fit them.

MECHANICAL PLANT

AREA

WORKS

Location	No. of Identical Units

Local No.					
Maker's Serial No.					
Plant No.					
Local No.					
Maker's Serial No.					
Plant No.					

Description	Supplier	Date Supplied
	Make	
Capacity		

Size	Output	H.P.
Head ft.	Impellor Size	Press. p.s.i.
Speed r.p.m.	Fig. No.	Drg. No.
Suction Dia.	Stop Valves Make	
Delivery Dia.	Safety Valve Make	
Drive Shaft Size	Reflux Valve Make	
Bearings		

Drive Detail V. Belt No. Belts Ref.	Seal Type Serial No.
Coupling Flexible Solid	Bushes No. " Size
	Filter Make Type
Pulley Sizes Driver Driven	Gearbox Make Size Type Ratio Input R.P.M. H.P. Output R.P.M.
Sprocket Sizes Driver Driven	
Chain Type Size No. of Links	

Other Associated Equipment

PLANT AND MACHINERY RECORD

Description .... Location ....

Maker's Reference .... Depreciation Method ....

Type .... Power .... Serviceable Life ....

Installed ....

Date	Ref	Costs £	Depreciation		Balance	Maintenance Record		
			Year	Amount		Year	Amount	Remarks

ELECTRICAL PLANT				
AREA				
WORKS				
Location			No. of Identical Units	
Local No.				
Makers serial No.				
Plant No.				
Local No.				
Makers Serial No.				
Plant No.				

Description of Enclosure	Drip Proof	Hose Proof	Totally Enclosed	Supplier	Date Supplied
Rotor Type	Squirrel Cage	Wound	Tristot	Make	
H.P.	Frame size			R.P.M.	Rating
Volts	Mounting			Makers Connection Diagram	
Amps	Starting		Ins. Class	Rotor Amps	
	Running		B.S.	Rotor Volts	
Bearings	D.E.		Brushes No. of	Size	
	N. D. E.			Grade	

STARTER				
Local No.				
Makers Serial No.				
Local No.				
Makers Serial No.				

Type	DOL	Location	Integral	Panel Ref. Details Make Serial No. Date Dra. Rating
	Star/Delta		Panel	
	Auto Slip Ring		Individual	

Overload relays	Type	Serial No.
Main Fuse	Ref.	Amp.
Control Fuse	Ref	Amps
Indication Bulb	Volts	Watts
Associated equipment.		

Initially, preventive maintenance usually requires a greater input of management time because of the greater degree of planning and organisation required. Because of this and other factors it should be recognised that in some situations it may be more cost effective to carry out corrective rather than preventive maintenance. With some machinery it is cheaper to allow continued long term operation without interference as in certain cases the preventive maintenance can cause more problems than it solves.

Annual cost of machinery maintenance is normally in the region of 7%- 15% of original capital cost and annual building maintenance up to 3% of investment cost.

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE FOURTEEN - INSTRUCTOR'S NOTES

MANAGEMENT

1. INTRODUCTION

This module will be taught as a lecture, with the main points highlighted on flip charts or Overhead Projection Sheets. The lecture should be followed by group discussion.

The topics covered in this module are varied and wide ranging. At the technician level it is probable that the instructor will only be able to begin to introduce the vocabulary used by managers and consultants. With more experienced staff it will be possible to show how all the different components have to be equally efficiently managed and integrated in order to form a cohesive and effective organisation.

2. MAIN TEACHING POINTS

Whatever management systems and terminology are used it is most important to communicate the idea that an effective organisation primarily depends upon the willing co-operation of the people who work within it. Where all levels of staff are made to feel important as they work towards accepted objectives, then there is effective management.

3. VISUAL RESOURCES

The diagrams used in the Student Notes should be copied onto Flip Charts or Overhead Projection Sheets to complement the lecture.

4. DISCUSSION QUESTIONS FOR USE WITH PARTICIPANTS

This subject is well suited to the use of discussion groups. The class should be divided into small groups of about three to five people. The groups have to discuss certain topics (such as those given below) and try to reach group decisions on each point. Enough time should be allowed for all the groups to cover all the points, but the discussions should be stopped before the participants get bored. The instructor then asks each group to report to the class on the results of their discussion. For example, for some questions the instructor could list on the blackboard the points which each group has thought of and the lists can be compared. Do the same things occur in many lists? Why? Are the lists quite different? Why?

The Instructor should prepare his or her own questions to suit each particular audience. To be effective, the questions should relate directly to the participants' own work situations and include provocative ideas such as:

List FOUR things that the manager above you does effectively.

Describe FOUR things that your superior has to waste his time on.

What percentage of your working day is wasted because of poor management?

List THREE improvements in your conditions of service that would make you work harder.

If you were promoted to be chief of your section, what changes in the organisation would you make?

Take TWO forms or other items of paperwork in your organisation and discuss how they could be improved.

List FIVE items in your stores which are not used regularly.

List ONE extra item you wish to see in stock.

5. FURTHER READING

With such a wide topic, it is vital that the instructor has access to background material such as is listed below, or other similar texts. The Student Notes are not designed to be sufficient.

Austin - Rural Project Management (Batsford)

Baum W. C. - The Project Cycle (The World Bank)

Carefoot N. & Gibson H. - Human Resource Development, WHO/CWS/ETS/84.3 (WHO)

Clifton R. H. - Principles of Planned Maintenance (Arnold)

Gupta D. R. & Rajput R. K. - Purchasing and Storekeeping (Tata McGraw Hill)

Oldcorn R. - Management (Pan)

WHO - Minimum Evaluation Procedure, ETS/83.1 (unpublished)

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 15
MANAGEMENT AND FINANCE

This module is designed to be a general introduction to the concepts of financial management, focussed on the needs of a water supply and sanitation organisation.

The module looks at "Accountancy and Control", "Budgeting" and "Materials Management".

On completion of the Instructors introduction to Management and Finance the participants should be able to begin analysing the financial and materials management system of their own personal performance under these headings.

More specific financial management training is dependent upon the training needs of the participants own organisation, and will be supplied by the course tutors.

FINANCE and MANAGEMENT

The coordination and control of money, personnel and resources is a vital part of the management process. By means of book-keeping and accountancy the good manager not only provides financial information for his organisation but also has a tool to control the activities of his section.

Accounting is the reporting, analysis and interpretation of recorded information on all transactions. An accountant prepares reports from the book-keeper's records, analyses them and interprets them for interested parties. Book-keeping is the methodical and systematic recording of transactions in monetary terms.

Source documents are the pieces of paper which contain information to be recorded in the books of account. They relate to transactions like the buying and selling of goods, settling of debts and payments to workers. These source documents are stored to support the records of whatever transactions took place. Order forms, advice notes, delivery notes, goods received records, stock control cards, invoices, debit notes, credit notes, bank statements, receipts, paying in slips, cheques, petty cash vouchers, payroll registers, time sheets are all used as source documents or as validating records which are used to back-up source documents.

PURCHASE ORDER

__________ 19____

Ship to: __________

Via __________ On: __________

Please furnish us the following items.

Quantity	Unit	Description of Articles	Unit Price	Amount

Terms of Payment	Prepared by	Approved by:	PO Number
		System Superintendent	

MATERIALS AND SUPPLIES RECEIVING REPORT

Received from ____________________ Date Received ________

Address ____________________

Dr. No. ________________ No. ________

PARTICULARS	Quantity Received	Unit Price	Amount
		Total	

I hereby certify that all articles listed above have been duly inspected and are found in good order.

____
Received by

____
Designation

Remarks: ______________________________

PETTY CASH VOUCHER

Payee: ______________________________ 19 ______

PARTICULARS	Account Charged	Amount
Amount in words:		

Please attach all available receipts to support this payment	Approved by: ________ System Superintendent	Received by: ________	PCV No. ________

EMPLOYEES EARNING RECORD

Name and Address:					Department/Section			Date Employed			Employee No.
Pay Period Ending	Regular	Overtime	Allowance	Gross	Whitholding Tax	SSS Premiums	Medicare	Advances	Others	Total	NET PAY

(FRONT)

SALARY RATE						INCOME TAX EXEMPTION			
Date	Designation	Reference	Regular Base	Allowance	Hourly Rate	Date	Units	Date	Units

VACATION LEAVE RECORD						SICK LEAVE RECORD					
Date	No. of Days	Balance	Date	No. of Days	Balance	Date	No. of Days	Balance	Date	No. of Days	Balance

DAILY TIME RECORD

Name ____________________

Position ____________________

Employee No ____________ Month ________

Day	A.M. Arrival	A.M. Departure	P.M. Arrival	P.M. Departure	Hours	Minutes
1						
2						
3						
4						
5						
6						
7						
25						
26						
27						
28						
29						
30						
31						
TOTAL						

I certify on my honor that the above is a true and correct report of the hours of work performed of which was made daily at the time of arrival and at departure from office.

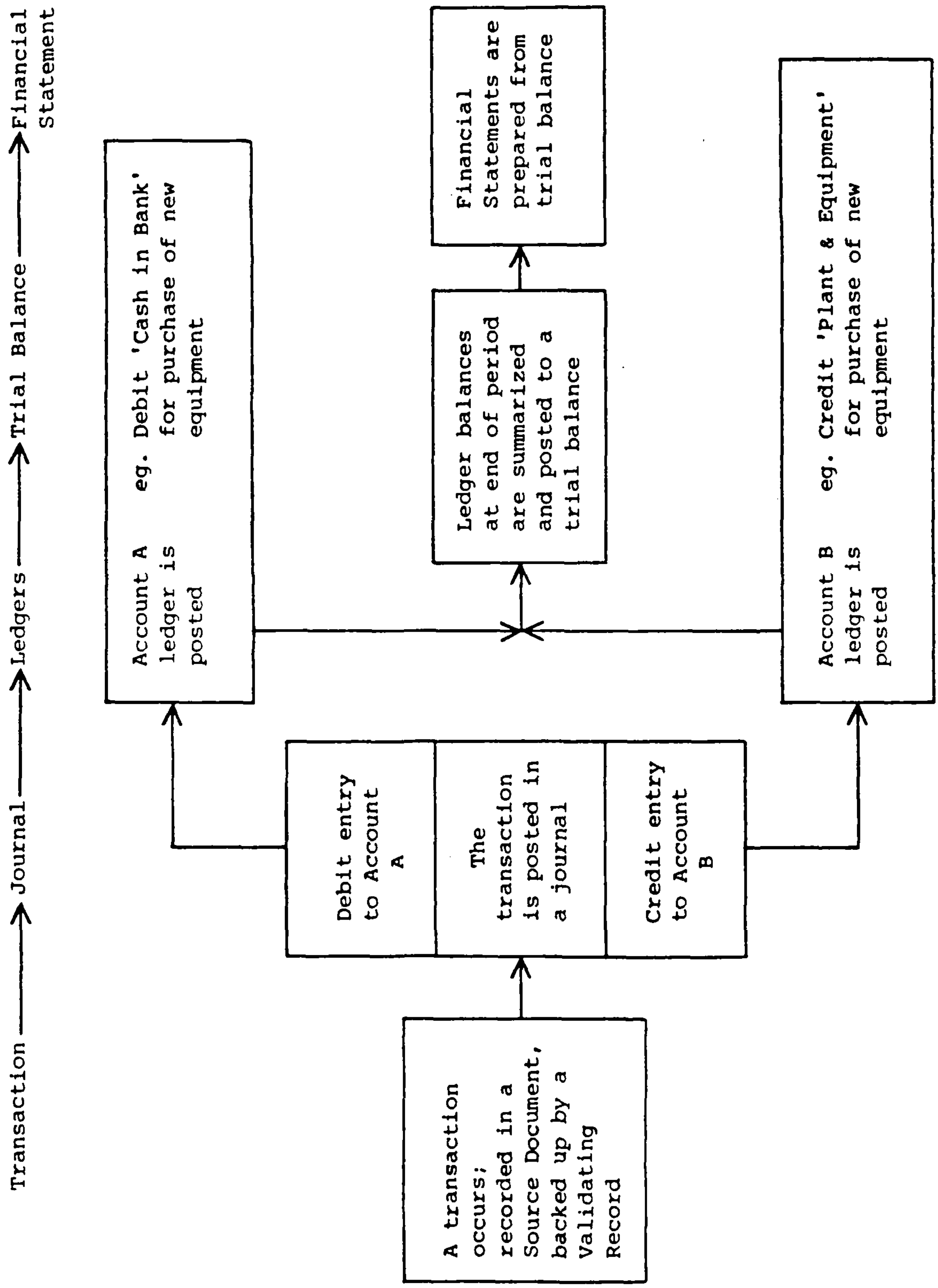
____
Signature

Verified as to the prescribed office hours:

____
Supervisor

Information from the source documents is recorded in books of original entry or journals with an appropriate account code number. There is normally a cash receipts book, a cash disbursements book, an expense journal, a sales journal and a journal ledger. This information is then transferred at monthly or quarterly intervals to a general ledger which contains all the relevant information under account headings.

Double entry book-keeping Whenever a transaction takes place two things occur: a receiving of value and a giving of value. A cash purchase involves a giving away of money and a receiving of the money's worth of goods. It is helpful therefore to record both of these events to give a true picture of what has occurred. Double entry means that every



Flow of Entries

debit entry made in a ledger must be accompanied by a credit entry and vice versa. The account receiving value is debited and the account giving value is credited. This system gives a complete picture of each and every transaction, it makes it logically easy to follow the movement of funds, it gives a double check on each transaction recorded in the books which makes it easy to prove the accuracy of the book-keeping as, at any time debits should equal credits.

BUDGETS

Managers not only have to control what is presently happening with regard to monetary transactions but they also have to plan ahead. A budget is a statement which expresses in money terms a plan for the future. It is 'a plan turned into numbers'.

Before looking at different types of budget it is helpful to understand the nature of costs:

Direct costs or prime costs are incurred in actually carrying out particular tasks, while indirect or overhead costs represent the supporting activities.

Variable costs change relative to output of a certain activity whilst fixed costs are constant irrespective of production.

Controllable costs can be influenced and changed by the manager to suit his own purposes, while uncontrollable costs are beyond immediate influence.

These different types of costs are analysed to prepare three main types of budgets:

Operating budget - which forecasts income and expenditure during the budget period which is usually one year. The previous years budget and the actual income and expenses may be taken as the starting point. However, it may be more efficient to consider a zero based budgeting system where every item has to be justified in relation to objectives or outputs and nothing is allowed to carry over from one year to the next.

Cash Budget - which is prepared for each month to determine the amount of cash an organisation or a manager's section is likely to receive and spend in a given period to predict cash flow. Timing of transactions within a year may influence what can be achieved

Capital Expenditure Budget - which is a plan for future expenditure on plant and equipment. It is necessary because funds are often limited and it may take a long time to pay back loans on expensive items.

MATERIALS MANAGEMENT AND STOREKEEPING

Materials management is the activity of procuring, receiving, safe-keeping and distributing materials, stores and supplies.

The essentials of good storekeeping include:

- Assigning a proper place to everything
- Keeping every item in its assigned place
- Maintaining adequate but simple records of every item
- Providing quick and willing receipt and issue of items
- Providing protection against pilfering and damage
- Issuing oldest items first
- Using proper methods of identifying and coding
- Providing adequate space and storage equipment
- Keeping records up to date with regular inspection and verification

Storekeeping tasks

The role of a storekeeper is to foresee the needs of the organisation for materials or products in such a way that neither too much nor too little quantity is available in store.

Because it is not economic to care for all items in a store in the same manner, there need to be different control methods for different goods. An item should only be stocked if there is a definite need for it as indicated by the frequency of use or the difficulty or time lag involved in obtain ing the item when it is needed.

In most stores the items may be grouped into three major categories:

Major items (A) - which have to be strictly controlled, representing the top 70% of turnover value but only 15% of the number of items; requires a constant review of usage and purchase price;

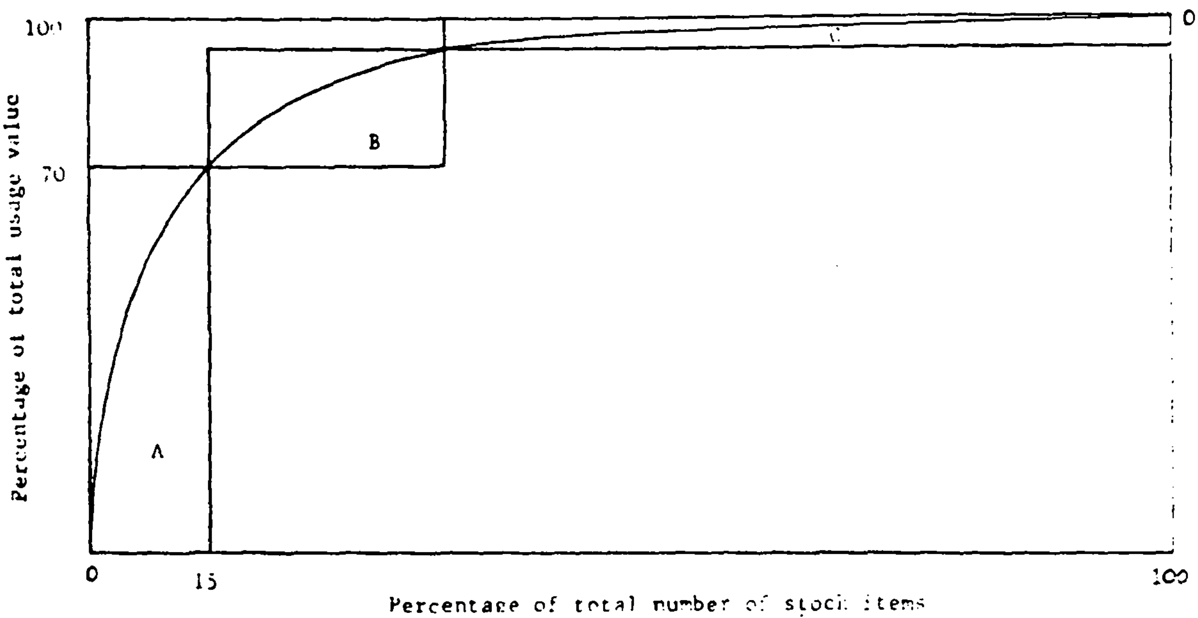
General items (B) - needing moderate control; to be reviewed periodically, every 3 - 6 months; represent 10% to 20% of the number of items and 15% to 20% of the expenditure;

Minor items (C) - which represent 70% of the number of items but only 15% of the total value; require only annual review and may be ordered for long periods;

Stocking levels

In determining the amount of stores to hold at any one time consideration must be taken of:

Overstocking	- where there are excessive costs of insurance, stores facilities, maintnenance and the costs of unusable capital;



Maximum stock level - based upon normal consumtion, ordering time, storage facilities, risk of deterioration, anticipated price changes;

Re-order level - the point where it is most economic to re-order stocks;

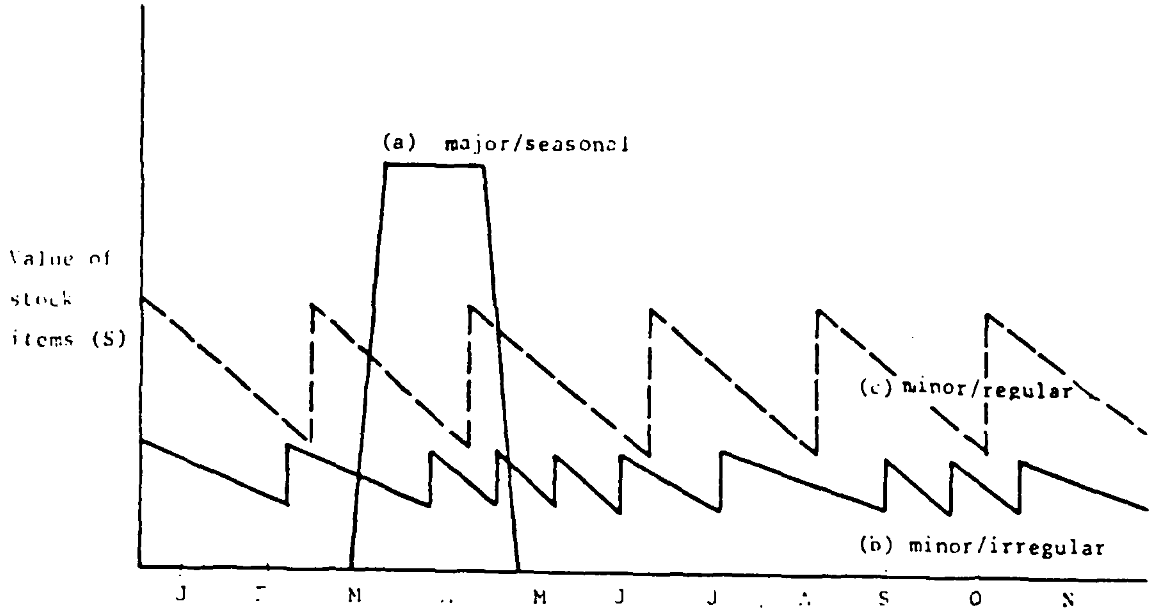
Minimum stock level - ideally, the level reached as the new order is received into store, below which one would be understocked;

Understocked - where there are likely to be delays in output of water or construction of new works or in repairing of faults due to shortage of materials;

Three types of stock fluctuation may be recognised:

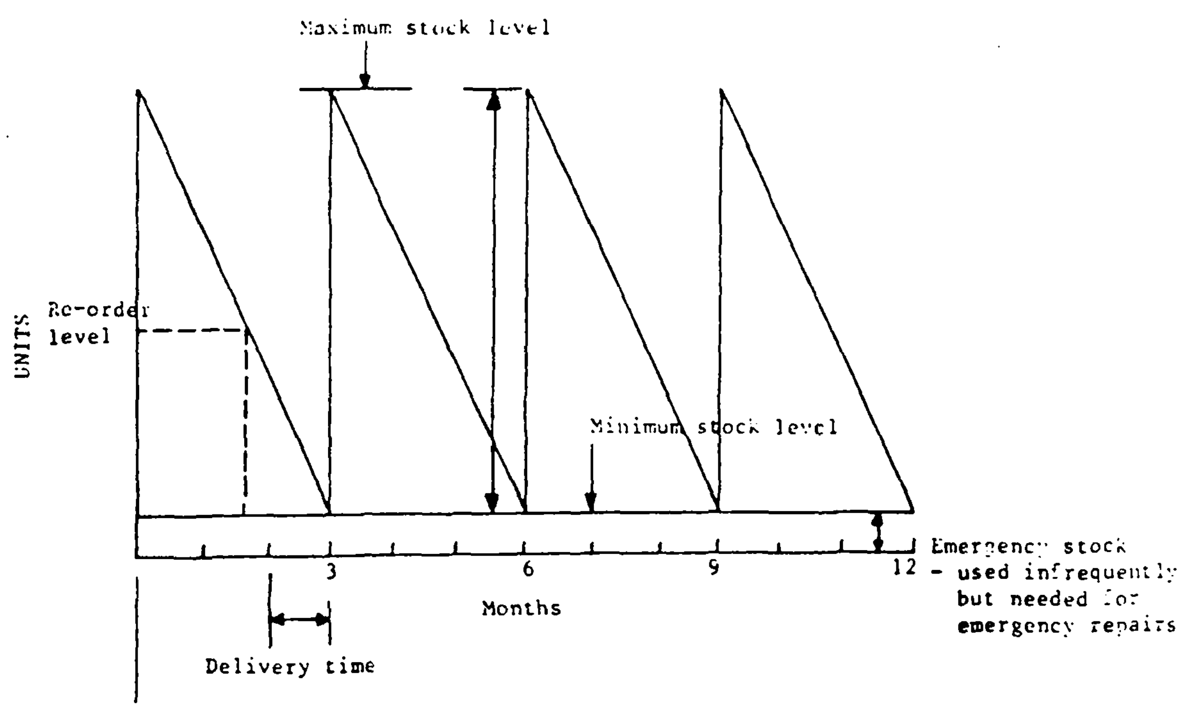
Major seasonal demands - which can only be predicted from past experience or accurate future plans with purchasing organised according to order times;

Minor irregular fluctuations - which are managed by having a reserve stock stored seperately as in a two bin system, or where the records are specially marked as with highlighting cards to ensure that reasonable demand can be catered for during re-ordering.



Three types of stock fluctuations

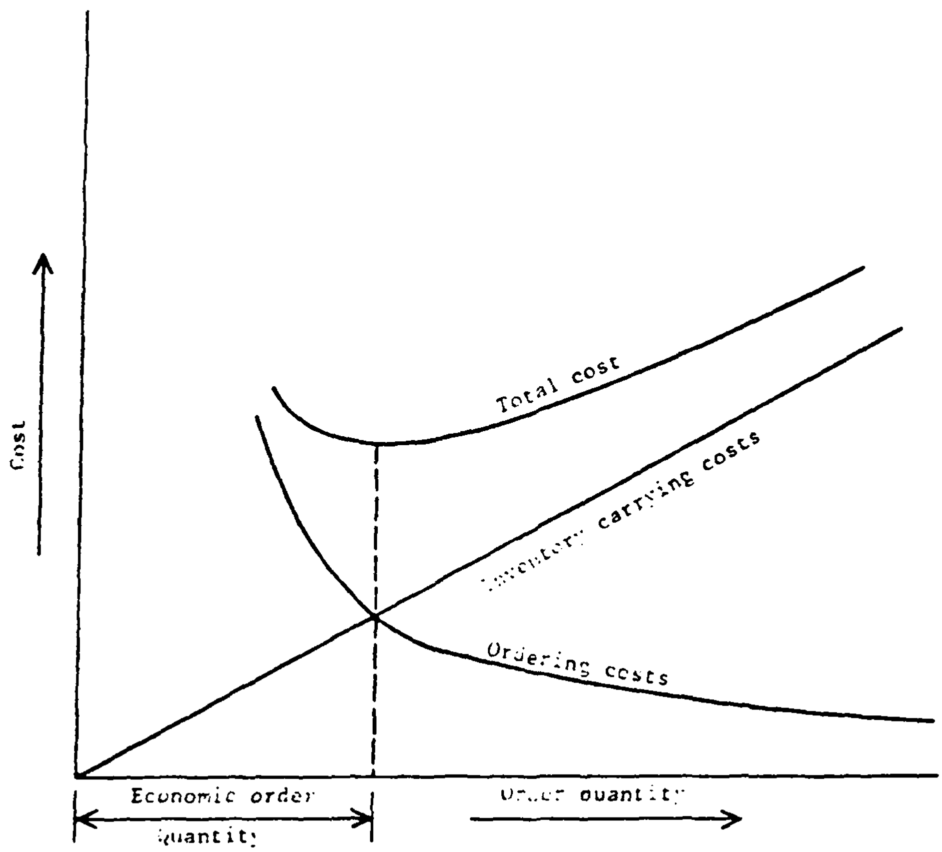
Minor regular fluctuations - with demand stock items that have a history of frequent usage and can be re-ordered regularly according to the 'Economic order quantity';



Order points and quantities for stock with minor/regular fluctuations

The Economic Order Quantity = $\sqrt{2AC/IH}$

where
H= Holding cost per unit expressed as a percentage,
C= Cost of placing order
I= Item cost
A= Number used where unit cost is constant regardless of order quantity



Economic order quantity

It may also be advisable to have a *Safety stock* , the amount of which is influenced by an estimate of the demand and lead time; a formula has been devised such that:

$$\text{Safety stock} = K \sqrt{\text{Average demand during lead time}}$$

where K is a figure between 2.6 and 0 based upon the acceptable average number of years between running out of stock and the order quantity in months supply. For rural projects it is advisable to use a K value of 2.

Purchasing

The storekeeper should request the purchasing/procurement officer to order the economical amount at the right time with clearly defined specification.

It is possible to use systems for comparing different items to be purchased under a 'Lowest evaluated cost' which does not necessarily lead to the cheapest item being selected. The LEC is the weighted average of delivery price, time of delivery, subsequent operating costs, servicing arrangements, compatibility of equipment, and the reliability of the technology.

Inspection

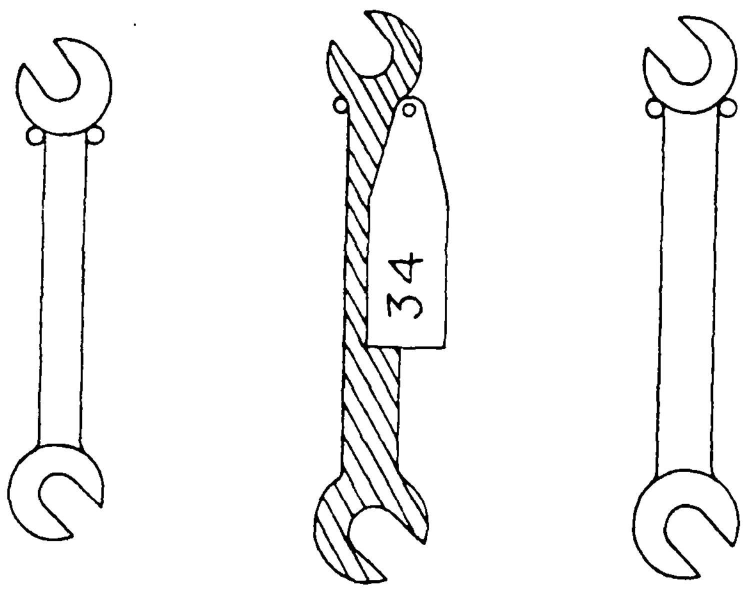
All materials received must be checked both for quantity and quality and for overall agreement with specifications.

Storage

The storekeeper is presponsible for keeping all materials and equipment in a safe manner where they can easily be located. Storage methods include:

- Racks
- Shelves (fixed or adjustable)
- Bins
- Pallets, to minimise handling

Large, weather resistant materials should be stored outdoors in a fenced yard. Flammable materials must be kept in a separate shed. Perishable materials require particular attention. Tools, other than those routinely carried in tool boxes, may be stored on a shadow board or wall board. All vehicles, plant and equipment may be registered on wooden sign boards with slots for details of current location and driver/user.



Tag recording the identity of borrower of a returnable spanner

Issue

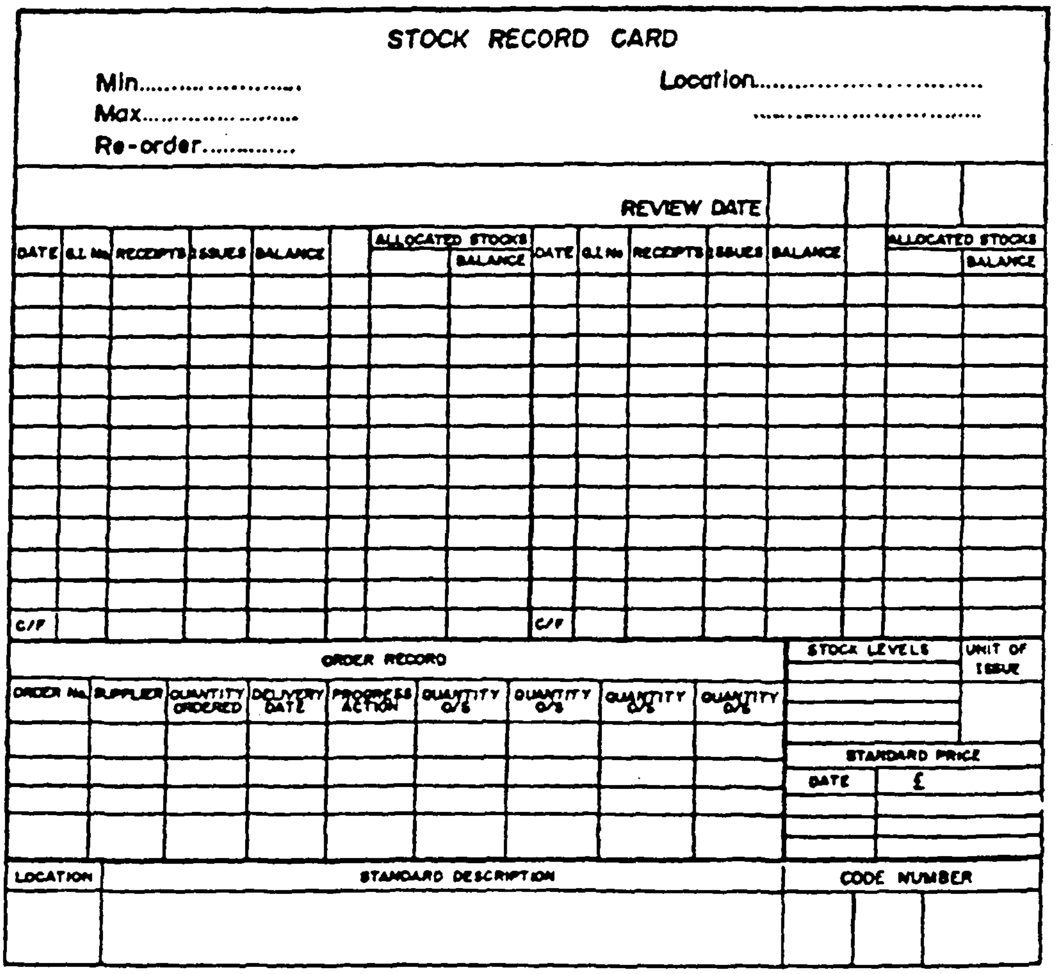
It should be the aim of any stores organisation to be able to issue stores promptly, when properly authorised, to responsible persons with the minimum of delay and the minimum of paperwork.

Frequently used items should be stored close to the issue point to minimise the time taken to get them.

Stores records

It is the storekepers duty to maintain correct and accurate records of everything received and issued. All items should be identifiable with code numbers for material, type, finish, and location by area/bay/row/stack.

Stock record cards, as illustrated, ensure accountability, determine stock demand, enable stock control, and record purchasing information. These cards should define the cost of the particular item whether by 'first in, first out' basis, 'last in, first out', average or current cost basis.



Stock-checking is required at regular intervals to physically verify the quantity and condition of all goods in the store. This checking may be undertaken annually when the stores are closed for all receipts and issues for a number of days whilst everything is counted. Alternatively, to minimise disruption, stock-checking may be carried out quarterly when 25% of the items are checked each quarter which still results in each item being checked annually. Smilarly, continuous checking may be used where 1% of items are checked daily in order to even out the process.

The storekeeper should also coordinate with other departments in order to determine any new or revised estimates of demands for materials and to provide necessary information for stores accounting.

MATERIAL DESCRIPTION	COUNT	[illegible]	CODE
	LOCATION	ORDER OF MATERIAL RETURNED No.	
	[illegible]		
	[illegible]		
	[illegible]		
	[illegible]		

DATE OF STOCKTAKING	STOCK-TAKER	CONDITION G-GOOD F-FAIR B-BAD	STOCK ACTUAL	STOCK MATERIAL CONTROL CARD	AVERAGE RATE	EXCESS QUANTITY	EXCESS £	SHORTAGE QUANTITY	SHORTAGE £	CALCULATIONS CHECKED BY	ENTERED MATERIAL CONTROL CARD BY	[illegible] APPROVED

STOCKCHECKING CARD

Issued to PURCHASING MANAGER, STORES CONTROLLER	STOCK TURNOVER REPORT	Period Date

Code	Description	Main Classn	Stock on Hand at Period End: Actual (1)	Target (2)	Variance (3)	Stock Turnover (Weeks' Usage): Current Period Actual (4)	Year to Date: Actual (5)	Target (6)	Last Year (7)	Comments on Variances (8)
			£	£	%					
		A B C								
	Total									
		A B C								
	Total									
		A B C								
	Total									
	Total									

Water, Engineering
and Development Centre
WEDC

World Health Organisation
Eastern Mediterranean Regional Office
Centre for Environmental Health Activities

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 16
COMMUNITY PARTICIPATION

This module is designed to be a general introduction to the concepts of community participation, focussed on the needs of a water supply and sanitation organisation.

The module looks at the overall reasons for considering the crucial need for involvement of communities, how communities may be enabled to help themselves, a planning structure to coordinate the needs of the community with requirements of the water agency, the role of the group meetings and the types of questions to consider in social surveys.

On completion of the Instructors introduction to Community Participation the participants should be able to analyse their own approach to participation, whether it is directive or participative and begin to consider areas of improvement within their own organisation's approach to involving people in the provision of clean water supply and sanitation.

More specific information is dependent upon the training needs assessment of the participants own organisation, and will be supplied by the course tutors.

Water, Engineering
and Development Centre
WEDC

World Health Organisation
Eastern Mediterranean Regional Office
Centre for Environmental Health Activities

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE I6

COMMUNITY PARTICIPATION

1. INTRODUCTION

It has been estimated that between 30% and 50% of water supply and sanitation facilities in the less developed countries are out of action at any one time. Investigations into this problem suggest that the two main reasons for failure are the use of inappropriate technology and the lack of user participation.

Ensuring that the people who ultimately use any system are involved in it's preparation, construction and maintenance is believed to produce four main results:

1. Community involvement can assist in promoting hygiene practices that lead to the measurable health benefits that are the aim of any water and sanitation scheme.

2. Community participation helps to ensure regular maintenance of the facilities where the users feel that the system belongs to them.

3. Community participation can reduce the costs of constructing and operating the system where the users give their labour to help with the construction and maintenance. In improving the design, participation may also reduce costs and remove the risk of investment being wasted.

4. Involvement in a water or sanitation scheme can give people the confidence to undertake further development projects on their own.

There are two main approaches to community participation. These have been described as 'Directive' and 'Participative'. In the first 'directive' approach, all the power remains with the sponsoring agency. It is assumed that the end users have some knowledge which may be of use, but the survey and design is done by the agency staff. The community is called upon to give their labour free of charge and it is assumed by the agency that the people will look after the maintenance. However, the people still perceive the scheme as 'belonging' to the agency and feel no incentive to be involved in maintenance.

The ideal 'participative' approach assumes that local people have the management skills and will quickly learn the necessary technical skills. (If the people cannot understand the technology it suggests that the chosen technology is inappropriate). The community realises its own need and asks for help from the agency. The outsiders advise and suggest but the community makes its own decisions about the design. The agency may provide a technician but he teaches the necessary skills rather than doing the job himself. Maintenance can then be organised by the people as they now have the required skills to make the repairs.

The major problem with this ideal approach is that it can take a long time for a community to make the necessary commitment and decisions. This does not usually tie in with the budgeting and planning constraints of the agency. However, it appears that the more closely projects follow the participative approach, the more successful they are in the long term. It has to be remembered that you cannot develop people . You can only assist or enable them to develop themselves .

This means that it is only when the members of the community perceive the project as being theirs , as belonging to them , that it will stand any chance of surviving as a real development in that area.

This does not mean that there is no place for outside help or ideas or initiative - all these can be given in varying amounts in different situations. But there are ways of giving that build up the donors and ways of giving that build up the recipients, and the task is to find out how to give in such a way that the people can improve their quality of living without becoming dependent upon outside assistance.

2. HOW TO HELP COMMUNITIES TO HELP THEMSELVES

a) Identifying needs

Through consultations, informants, questionnaires and surveys, an overall picture of a community's wants and needs can be established. These will often be in general terms and it is part of the task of the outsider to help the people see how the completion of a specific job can help to meet their general desires.

In the extreme case where people seem totally uninterested in any aspect of development, or see 'development' solely as a way to acquire a pair of shoes or a radio, then there is no common ground and no basis for a project.

More usually though there are several aspects of water, housing and environmental conditions where the people want improvements that are of significance for development.

'The people must want the problem to be solved'

In most situations in rural areas, it may be that a Health Education campaign is required before people understand the need for clean water and sanitation - be prepared to wait until the people want the problem solved, otherwise there are unlikely to be any health benefits as a result.

b) <u>Identifying solutions</u>

1. The community should be encouraged to search out their own ways of meeting their needs. Having identified their own solutions they should be encouraged to find and use their own methods and materials to carry out those solutions.

2. When new ideas and techniques have to be brought in from outside, ensure that the technology chosen is suited to the needs and resources of the community.

3. If technical solutions are required, explain them in ways that the community can see and understand, so that they can ultimately find their own solutions.

4. Consider visits to prototypes which have worked in other areas. Learn from what's happening in adjoining districts.

5. Allow time for new ideas to be 'seeded' and then to germinate and grow before pushing communities into using them.

6. Total involvement of community leaders at the planning stage should ensure that the local culture and tradition is respected.

7. Try to encourage a positive use in the project of traditional customs.

c) <u>Identifying Personnel</u>

1. As Project Engineer or Technician (or the representative of the Agency/Authority/Council) you have to be committed to the idea of Community Participation if you are to expect the people to trust your guidance.

2. Expect to learn from the people as well as sharing your ideas with them.

3. Communicate enthusiasm, determination, drive, commitment, inspiration, love of one's work - and don't be afraid to get your own hands dirty.

4. The community must be able to have confidence in the Project Personnel.

5. Try to find a community 'insider' who has moved out. That is someone from the area who has received an education and is now in Government service (or Business, etc) away from home. If he is respected by the people he will be able to give powerful back-up and agreement to new ideas.

6. Try to identify some person or group who will be the 'prime motivator' (animateur) in the community (eg, Chief, Religous Leader, Teacher, Village Development Committee, etc). Ensure that this person or group is responsible for the organisation and management of the work in such a way that you can't bypass them in order to get early completion.

   You can't expect everyone in the community to understand what's going on and that doesn't matter if there is a core group who have grasped the idea.

7. Consider a training scheme to teach people the skills they will need to construct, operate and maintain the system.

8. Don't forget to involve the women of the community in the project - they may not be too well represented at discussions and meetings but they could well be the prime beneficiaries and users of the project.

9. Remember that people are vital to community projects: lack of economic resources is often given as a reason for not having implemented ideas for improvement, though lack of leadership and lack of technical knowledge are often more crucial.

10. Involve women project personnel wherever possible.

d) <u>Identifying responsibilities</u>

1. Be prepared to give precise details of the way in which the 'authority' can help the community. Written agreements (as long as you can keep your side of the bargain) help to build up trust and mutual confidence.

2. Give sketches, plans and design figures where it will help the people to understand the project and make it more their own.

3. Formalise the agreement not only with the leaders or the development committee but with the majority of the community, either through an open meeting or by a fixed percentage of the population 'signing' the agreement.

4. Even with written guidelines, be prepared to be flexible and fair as work progresses and situations change. The written agreement is there to serve the project, not to bind it.

5. Remember that the aim of 'self-help' is not to get people to work for no wages. It is simply one means among many of ensuring that the work does not proceed unless the people themselves want it and are committed to making it happen.

6. Structure the work so that the task is simple at first and that early success can be seen as a result of participation - and yet devise ways of allowing the work to become increasingly complex so that the people can grow in their ability to deal with the problem and feel an <u>increasing</u> sense of accomplishment.

7. Aim to move towards increasing participation and community responsibility - so that a follow-on project might be able to happen without outside assistance.

8. Help the people to understand the need for continuing input to a project in terms of maintenance and operating. There should be no problems of 'handing over' if the project already belongs to the people, but they might need advice as to what will be required in the long run.

3. PLANNING

a. Demonstration

From the planner's point of view, implementation of a successful water supply or sanitation project normally follows a recognisable pattern. After the initial surveys described below, a demonstration or experimentation phase is required. This is to experiment with techniques and materials which are effective at minimum cost; to demonstrate the resulting techniques to government and community leaders; and to begin to stimulate demand for these services from individuals and groups within the community. However, if an affordable design already exists which is well recognised and accepted by the prospective users, this pilot phase may be reduced or omitted.

b. Consolidation

At the community level the distinction between the demonstration phase and the consolidation phase may appear blurred. However, there comes a point where the basic technology has been proved to be feasible and the project approach is generally acceptable. Before widespread implementation can begin, a period of consolidation is required, primarily to organise the institutional aspects of the project.

Testing the details of the technology continues so that the community can see that the demonstration systems are still important and cared for. However, the primary thrust is to determine the support (technical, financial, material and administrative) that the agency has to provide in order to enable householders and the community to build their own public health systems. Training of community personnel and technicians, identification of community leaders, involvement of health, educational and other sectoral staff, confirmation of sanitary codes and regulations, testing of promotional materials and general administrative support all have to be considered.

c. <u>Expansion</u>

The expansion or mobilisation phase aims to encourage every *household* and *community* in the target area to achieve a satisfactory level of public health provision within a certain period of time. With the preparatory work completed, the preferred options can be promoted with confidence, in the knowledge that they are technically feasible, socially acceptable and financially affordable. This period of expansion may also be considered in terms of promotion, construction, operation and maintenance. Promotion consists of selling the idea to communities and householders, to help them to see that there is a need to improve their public health provision and that they have the capability to help themselves.

Implementation continues with full community involvement along the lines described above. This approach to participation is illustrated by Figure 1 where it is suggested that direct agency managed projects may initially have a much larger apparent impact. However, as soon as the agency input is completed the effectiveness of the schemes rapidly diminishes. With the community based approach, although it may take a lot longer to gain momentum, the long-term result is more satisfactory.

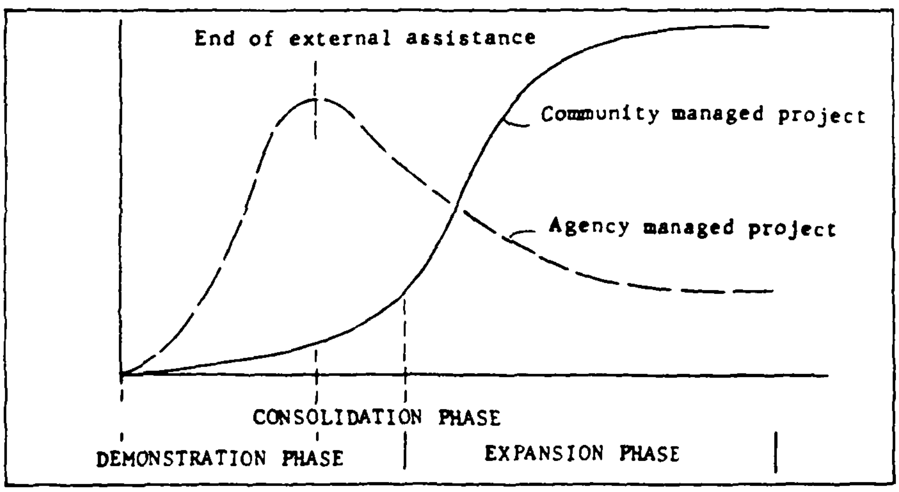


Figure 1.

4. GROUP MEETINGS

One of the aspects of community participation that requires particular attention is the use of group or community meetings. In order to be effective they need to be understood and managed by the agency representatives in order to achieve the best results.

There are different types of meetings:

- Pre-Feasibility Study Meeting (First Public Meeting);
- Information Meeting (Post Survey Meeting);
- Detailed Design and Survey Meeting;
- Pre-Organisational Teach-in (Participation Meeting);

as well as regular Water Supply and Sanitation Committee Meetings.

It is necessary to beware of 'Meeting Overkill' - too many meetings for too small a project. Use sub-group meetings if necessary but don't shortcut the discussions.

a. Venue and time

Community Centres, Schools, Church/Mosque/Temple, trees, are all places that may be recognised as proper places for meetings and which can be considered neutral, where no particular faction within the community has control.

The timing of meetings must be convenient for the community, rather than suitable for officials because of their working hours.

b. Approach

The following points should be considered:

- Establishing credentials, use of introductory letters;
- Use of Vernacular/Regional/National Languages;
- Style and extent of translation (if necessary);
- Use of clear explanations;
- Communications techniques.

c. Participants

The participants should represent the entire community and are likely to include:

Elders, Chiefs, Paramount Chiefs, Linking Chiefs, Chairman and Village Councillors, Women (special Women Only Meeting?), Youth, Family Heads, Religious Leaders, Representatives of Political Party/Parties, Local Government Officials, Doctors/Health Workers, Traditional Healers, Assistants/Teachers/Health Officers/Building Inspectors, etc.

Remember that 'every voice counts'. If there is a large target population, consider breaking up into smaller sub-groups to ensure participation.

d. Chairperson

A Chairperson is required to conduct and organise the meeting, to welcome guests and visitors and to make introductions. The chairperson may be elected from group members to organise the debate and to ensure that there is only one speaker at a time. All questions should be allowed, interactions amongst members are to be encouraged, but all issues have to be clarified before moving on. The chairperson can also act as a 'tension reliever' by injecting some humour and light relief when the meeting gets too heavy. He/she will also need to give a summary of the proceedings so that at the end of the meeting everybody knows where they've got to.

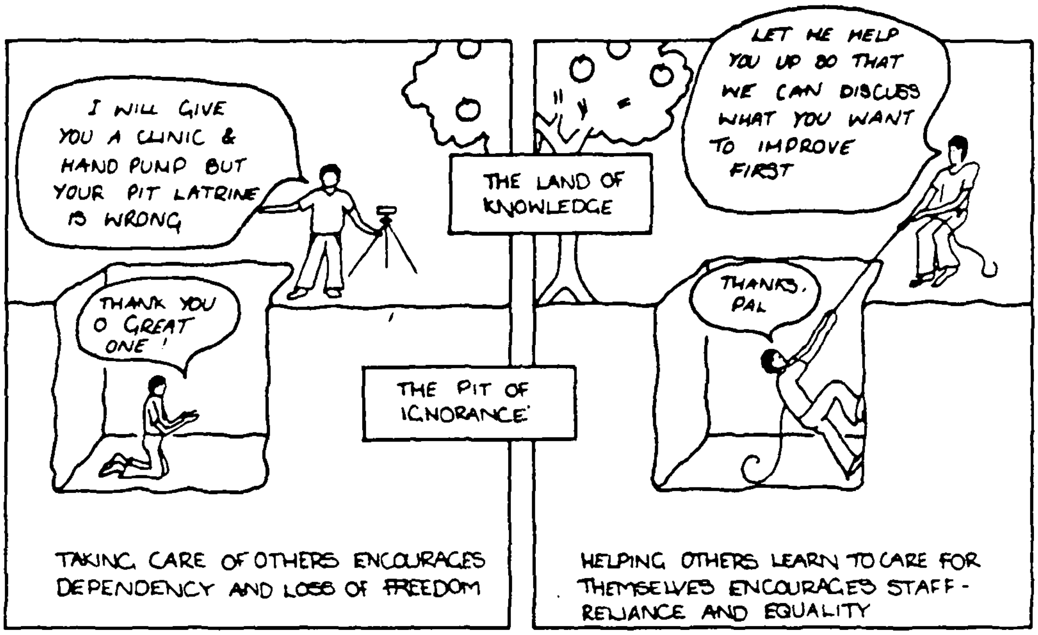
e. Secretary

A secretary is required to take minutes, that is the notes of the meeting. They will record discussions, note resolutions for record purposes, record attendance, organise future meetings. The secretary must be accepted by the community.

f. Expert

The outsider or expert from the sponsoring agency must be respectful, follow customs, accept food and hospitality, and be prepared to be quiet! They have to get people on their side, request the meeting from the 'right' people, find a respected member of the community and gain their acceptance of the idea before the meeting. They must be CLEAR and patient; it can be helpful to refer to local situations and nearby village improvements. However, it is often said that what is important is not what you say but how you say it. The 'expert' should respond to questions but keep to the point, be considerate of 'hostile' comments, channel discussion, especially of technical points arrange everything to suit the community's social and econonmic profile and most importantly, should expect to learn from the people.

TWO APPROACHES TO PUBLIC HEALTH ENGINEERING



adapted from 'Where there is no doctor', David Werner, TALC, Macmillan, 1977.

Figure 2.

It is also necessary for the promoter to know the people's background, the names and locations of leaders, the customs of addressing people and the acceptable dress of the people. They should seek ideas from other local officials who have held meetings in the village or area, invite fellow officers from other departments and allow plenty of time for questions so as to elicit confidence. They should know the organisational structure of the community, be prepared to give important aspects of policy and activity in written form, detail what is being given and what is being requested, and be open, flexible and reliable. They will have to prepare in advance of the meeting, see the purpose of the meeting as educative and not simply as a means of getting the project accepted, recognise the objectives of the project and be able to share them, ensure that the people understand the nature of the project, and recognise the objectives of the meeting - is it to inform? to initiate action? to motivate participation? to stimulate enthusiasm?

Finally the experts should avoid telling people things they don't need to know and, most importantly, should avoid raising false hopes.

5. SURVEYS - COMMUNITY CONSULTATIONS

Part of the process of involving communities in the provision of their own public health facilities is to find out what their existing situation is and what they might need to do to improve it.

An extensive Baseline Survey is a scientific study of an area to determine the existing conditions. As well as acting as a guide as to what work is needed, it also gives a starting point to see whether any improvement takes place as a result of the development programme.

For a water project this would require sampling and laboratory analysis of all water sources, plus detailed questionnaires completed by a significant proportion of the community and accompanied by examinations, including blood tests and stool tests.

However, it has been shown that such expensively gained information is of limited use and can at times be misleading - of far more value is the result of informal interviewing and information gathering which can give a better picture of the situation and can be a useful first stop in encouraging community participation.

There follows a list of questions which need not be answered by everybody in a village, but a Community Development Worker needs to have some idea of the consensus answer to if any development project is to be effective.

Questions:-

What are the existing water sources? In the wet season? In the dry season? (Ask the Community Health Worker for a sketch map of the area with population centres and water sources marked on it) How much water is there at each source? How far from people's homes is it? (ie, How far do the women have to walk?) How many people use each source? How clean is the water at source? (Ask permission to take some samples for checking) How clean is the water when stored at home? (Ask permission to take some samples for checking))

Do the people think of the water as clean or dirty?
Do they perceive a problem of health connected with it?
Do the people want more water?
nearer water?
cleaner water?

(It is not adviseable to ask questions in such a way that the only answer can be 'yes')

Is there any understanding of the health problems connected with water? Is there any understanding of the Health problems connected with excreta disposal? Is there any desire to improve health? Is water being carried or stored in dirty/contaminated containers? Are the children taught to use water wisely? Where do the cattle drink? Where do the goats drink

Is any care taken over safe places to defecate, particularly for the children? What are the main health problems in the community? Are they water related?

Are the women being consulted ?

What are the main social or developmental difficulties in the community?

Should improved water supply be seen as a priority or do other things need to come first? Are there any means in the community to pay for improvements? Is there a will to maintain any improvements?

How committed are the Chief, Elders, Medical Assistant, Community Health Worker, Village Development Officer, Village Health Committee, Area Secretary Political Party, Local Government Inspector, Agricultural Extension Worker, Religious Leader, School Teachers, District Planning Committee, Member of Parliament/Assembly and other local leaders to supporting any improvements?

This appears to be a very long list of questions to help decide on what may be one small water supply scheme. However, if the answers to these and other questions are not understood then any improvement is more likely to fail - and news of that failure will spread far faster in the area than news of any success.

Water, Engineering
and Development Centre
WEDC

World Health Organisation
Eastern Mediterranean Regional Office
Centre for Environmental Health Activities

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE I6 - INSTRUCTOR'S NOTES

COMMUNITY PARTICIPATION

1. INTRODUCTION

This module will be taught as a lecture. The students will also be asked to participate in role plays.

Every country, every district, every community has to be approached differently in order to involve the users successfully in the improvement of their own public health facilities.

The instructor must therefore seek to communicate the concept that community participation is vital for long term sustainable water supply and sanitation schemes. The actual mechanisms and details will differ, but the belief that previously inexperienced users can play a significant role in the preparation, planning and implementation is the most important idea to communicate.

The role plays sketched out below may be used to reinforce the ideas in the Student's Notes.

2. ROLE PLAYS

Role play 1

You are the responsible water engineer for a large district in your country. Much of your time seems to be taken up with water supply schemes in the growing rural towns. However, a local politician has persuaded your superior in the Ministry of Water Supply that an area of five villages using traditional methods must have an improved supply. You have therefore been instructed to draw up proposals and implement a water supply scheme in these villages.

All the reports you've heard about this area suggest that the people are not community minded and that maintenance will be a problem - especially as the Ministry have already told you privately that there will be no funds available after the capital works are completed.

The technical solutions to the problem are fairly straightforward, but as you put together the proposals you realise that the scheme will only work if the community becomes fully involved. You therefore draw up some unofficial proposals for consultation with the people and for their participation in the construction and maintenance of the scheme.

* * *

Divide the participants into small groups to consider the approach they would use to involve the people in this project, from project preparation through to operation and maintenance of the facilities.

Bring the groups together. Explain that the participants will be taking the parts in a role play in order to get a better idea of what it actually feels like to be in the situation under discussion. The participants assign the main characters in the role play to volunteers, with unassigned participants making up the 'subsistence farmers'. The participants who are assigned the main roles can each be given a card which briefly outlines the attitudes and opinions of the character they are playing. This helps the participants identify with the role they are playing, provides a starting point for the discussion and, hopefully, means that the sorts of questions and problems which occur in real life will have to be dealt with by the participants.

Suggested characters:

- Water Engineer
- Assistant Engineer
- Subsistence Farmers (men and women)
- A slightly richer farmer
- Chief
- Headman
- Medical Assistant
- Agricultural Extension Officer
- Rural Council Official
- Local Teacher

In order to make the role play interesting and amusing for all concerned it may be necessary for the instructor to play a provocative role by asking awkward questions of the water engineer or the chief. This reminds the participants of what happens in real life and encourages them to be more realistic in their own roles.

The role play should be closed before the participants begin to tire of the activity. It is then most important to have a time of de-briefing, to allow the participants to step back from the roles they have created for themselves and to give everybody a chance to discuss the results. Who said what, why and how helpful was it? are the the sorts of questions to consider. Should the Engineer have been more helpful, open, patient, brief, explanatory, etc.? How should the Chairman have reacted to the awkward questioner? From drawing out the answers to these points, the Instructor can illustrate many of the points made in the Student's Notes.

Role Play 2

As responsible engineer for water supply in an area comprising one third of your capital city you are well trained and experienced in conventional techniques.

One day the City Engineer calls you into his office to explain that a visiting foreign aid delegation has officially promised to pay for a water supply scheme for a squatter area which you had always previously ignored. You are instructed to draw up specifications and proposals for the work, but are also warned that the capital budget is limited and that any funds for maintenance of the new work will have to come out of your existing budget, which seemed tight even for the existing programme.

Your protests are over-ruled: the work must be done for political reasons......

Therefore, you try to plan for the work to be done using simple techniques and involving the people in the construction and management of their own facilities. This will require community participation and, as a first step, you arrange a community meeting.

Suggested characters:

- Water Engineer
- Assistant Engineer
- Squatters (men and women)
- Slightly richer squatters
- Medical Assistant
- Public Health Inspector
- Council Housing Official
- Resident's Leader from nearby middle-income housing estate
- Local teacher

* * *

The role play may be further complicated by introducing the idea that there is a long-term plan by the Council to have a new housing scheme in the squatter area and that there is a strong rumour that the area is to be bull-dozed to make way for the new development.

3. FURTHER READING

Oakley and Marsden - Approaches to participation in rural development, ILO, 1984

SEARO - Achieving success in community water supply and sanitation projects, Paper No. 9, WHO, 1985

White A. - Community Participation in water and sanitation, IRC 17, 1981

Whyte A. - Guidelines for planning community participation in water supply and sanitation projects, WHO, 1983

Water, Engineering and Development Centre

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World Health Organisation
Eastern Mediterranean Regional Office
Centre for Environmental Health Activities

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Module 17

NATIONAL AND INTERNATIONAL AGENCIES

Objectives:

To provide a background to the provision, operation and maintenance of rural water supply and sanitation systems by providing information about:

a. the International Drinking Water Supply and Sanitation Decade, the Decade approach at the national level and the Alma-Ata Declaration of WHO with its target of health for all by the year 2000;

b. national agencies and organisations, with a list of the UNDP Resident Representatives of countries in The Eastern Mediterranean Region;

c. United Nations Organisations, with addresses - specifically FAO, ILO, UNCHS, UNICEF, UNDP, and UNESCO;

d. the World Bank and regional banks; and

e. bilateral agencies and non-governmental organisations.

Water, Engineering
and Development Centre

WEDC

World Health Organisation
Eastern Mediterranean Regional Office
Centre for Environmental Health Activities

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE I7

NATIONAL AND INTERNATIONAL AGENCIES

1. THE INTERNATIONAL DRINKING WATER SUPPLY AND SANITATION DECADE

In November 1980 the General Assembly of the United Nations formally declared 1981 - 1990 to be the International Drinking Water Supply and Sanitation Decade. Its official target is 'clean water and adequate sanitation for all by 1990.' Member countries are committed to bring about a substantial improvement in the standards and levels of services in drinking-water supply and sanitation by the year 1990.

The Decade approach at the national level, comprises:

1) complementary sanitation and water-supply development;

2) priority given to underserved populations, both rural and urban;

3) self-reliant and self-sustaining programmes;

4) use of appropriate technology that people can afford;

5) participation of communities in all stages of projects

6) co-ordination of water-supply and sanitation programmes with programmes in other sectors; and

7) association of water-supply and sanitation with other health improvements.

At the international level, emphasis is laid on:

1) promoting and supporting national programmes for the Decade through technical co-operation;

2) concentrating technical co-operation on building up national capacities and generating dynamic, self-sustaining programmes;

3) promoting technical co-operation among developing countries; and

4) encouraging the external financing of the national Decade activities.

The approach outlined here is closely linked to that of primary health care. The Decade is part of the wide range of community and rural development activities with which primary health care is inextricably linked.

Eighty per cent of the world's disease is linked to unsafe water and poor sanitation. And illness can often drive a poor family into starvation.

"The number of water taps per 1000 persons will become a better indicator of health than the number of hospital beds," prophesied Dr. Halfdan Mahler, WHO Director-General, at the United Nations General Assembly in November 1980.

The World Health Assembly has decided on the target of health for all by the year 2000, and the Declaration of Alma-Ata adopted by the International Conference on Primary Health Care stated that primary health care was the key to the attainment of the target.

The Declaration of Alma-Ata defines primary health care as 'essential health care based on practical, scientifically sound and socially acceptable methods and technology made universally accessible to individuals and families in the community through full participation and at a cost that the community and country can afford to maintain at every stage of their development in the spirit of self-reliance and self-determination';

WHO regards the International Drinking Water Supply and Sanitation Decade as a major contribution to its objective of achieving health for all. It is a principal part of, as well as a leading step towards, primary health care. Many of the activities of the Decade strengthen the general health infrastructure. WHO policy and programmes at all levels are committed to making water supply and sanitation a priority, with particular emphasis on rural and underserved populations. The environmental health programme is committed to combining the limited resources at the international level with co-operation at the country level.

Although we are now drawing near to the end of the Decade, its aims have not yet been achieved and if health for all is to be achieved by the year 2000, new approaches both in national strategies and in international support are required.

2. NATIONAL POLICY

In many countries it has been found that priority in water-supply and sanitation has been given to urban areas and to the better off. It has also been found that often there is too much reliance on central management; that lower-level technicians and workers are not used enough or given enough responsibility; and that the standards and technology are of too high a level, resulting in operating problems and expense which have made it possible only to provide some of the people with improved water supply and sanitation.

3. NATIONAL AGENCIES AND ORGANIZATIONS

Governments in different countries have established different mechanisms for co-ordination of the Decade. In many cases a National Action Committee (NAC) has been established. Ministries and national bodies concerned with the development of drinking water supplies and sanitation are members of the NAC.

The NAC (or similar) can request assistance from the international staff assigned to the country by United Nation's (UN) Agencies, who are members of the Co-operative Action (CA) for the Decade. In some countries Technical Support Teams (TST) have been set up. The focal point for international support to countries is the UNDP Resident Representative (UNDP ResRep)

NAC
National Action Committee

Bilateral Development
Co-operation Agencies

Financing Agencies

UNDP
Res Rep

Non Governmental Organizations (NGOs)

Members of the TST - WHO, UNICEC, UNESCO, ILO, FAO, etc

UNDP Resident Representatives in countries of the WHO Eastern Mediterranean Region

Afganistan	UNDP ResRep	PO Box 5, Kabul
Bahrain	''	PO Box 26814, Manama
Democratic Yemen	''	PO Box 1188 Tawahi, Aden
Djibouti	''	Boite Postal 2001, Djibouti
Egypt	''	PO Box 982, Cairo
Iran	''	PO Box 11365-4558, Teheran
Iraq	''	PO Box 2048 (Alwiyah), Baghdad
Jordan	''	PO Box 35286, Amman
Kuwait	''	PO Box 2993, Safat
Lebanon	''	PO Box 11-3216, Beiruit
Libya	''	PO Box 358, Tripoli

Morocco	''	Casier ONU, Rabat-Chellah
Oman	''	PO Box 5287, Ruwi, Greater Muscat
Pakistan	''	PO Box 1051, Islamabad
Qatar	''	Box 3223, Doha
Saudi Arabia	''	PO Box 558, Riyadh 11421
Somalia	''	PO Box 24, Mogadiscio
Sudan	''	PO Box 913, Khartoum
Syria	''	PO Box 2317, Damascus
Tunisia	''	Boite Postale 863, Tunis
United Arab Emirates	''	PO Box 3490, Abu Dhabi
Yemen Arab Republic	''	PO Box 551, Sana'a

In addition to the NAC and TST, there are other ministries and organizations involved in water supply and sanitation present in each country. These may also be approached for information, advice, assistance and encouragement.

4. INTERNATIONAL ORGANIZATIONS

The aim of the international organizations is to co-operate with governments in identifying, reducing and eliminating problems which affect the development of the water supply and sanitation programme. They help to select and then develop particular projects.

a. UNITED NATIONS ORGANIZATIONS

FOOD AND AGRICULTURE ORGANIZATION (FAO)

The FAO aims to improve rural water supply and sanitation and to improve rural environmental health. It also assists member states in the improvement and expansion of agriculture.

Address: Senior Officer,
Water Resources,
Development and Management Service,
Land and Water Development Division,
Food and Agricultural Organization of the United Nations,
Via delle terme di Caracalla,
I - 00100 ROME,
Italy.

INTERNATIONAL LABOUR ORGANIZATION (ILO)

The ILO undertakes technical training and management development. It also assists governments to procure funds and provides technical assistance to implement development projects which employ labour-intensive technologies.

Address: Focal Point for Water-related Activities,
International Labour Office,
CH-1211 GENEVA 22,
Switzerland.

UNITED NATIONS CENTRE FOR HUMAN SETTLEMENTS (UNCHS)

UNCHS gives information and produces training material on appropriate infrastructure for low-income communities. The provision of water supply and sanitation is closely related to other infrastructure components, settlements planning, shelter and community services.

Address: Research and Development Branch,
United Nations Centre for Human Settlements,
PO Box 30080,
NAIROBI,
Kenya.

UNITED NATIONS CHILDREN'S FUND (UNICEF)
Young children are particularly vulnerable to diarrhoea and other diseases caused by unsafe water and inadequate sanitation. UNICEF co-operates in the provision of safe and sufficient water supply for drinking and household use in rural and some peri-urban areas.

Address: United Nations Children's Fund (UNICEF),
United Nations,
NEW YORK, N.Y. 10017,
United States of America

UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP)

UNDP mobilizes voluntary financial support from governments world-wide and uses it to fund effective development services. At national and regional levels, UNDP supports the efforts of developing countries to educate and train their people, to assess national resources and mobilize the money needed to exploit them, to develop technological capabilities, and to plan the most effective use of resources for progress.

UNDP has approximately 10,000 technical experts in the field at any given time.

Addresses:
for programme matters - UNDP/WHO Co-ordinator,
EHE Unit,
World Health Organization,
1211 GENEVA 27,
Switzerland.

For public information matters:

UNDP Division of Information,
International Drinking and
Sanitation Decade,
1, UN Plaza,
NEW YORK, N.Y. 10017,
U.S.A.

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION (UNESCO)

UNESCO focusses on the improvement of the capacity of member states to assess, plan and manage their water resources through the improvement of scientific knowledge concerning water resources, by training specialized manpower and educating the general public.

Address: The Director,
Division of Water Sciences,
UNESCO,
7, Place de Fontenoy,
F-75700 PARIS,
France.

b. THE WORLD BANK AND OTHER REGIONAL BANKS

THE WORLD BANK

The World Bank provides loans for productive purposes which must stimulate economic growth in the recipient countries. Each loan or credit is made to the government or must be guaranteed by the government concerned.

General Information can be obtained from:

The Advisor Rural Water and Sanitation,
Water and Urban Development Department,
World Bank,
1818 H Street, N.W.
WASHINGTON D.C. 20433

ARAB FUND FOR ECONOMIC AND SOCIAL DEVELOPMENT

The Fund finances economic and social development projects in the Arab countries. It places special emphasis on infrastructural projects.

Address: The Sanitary Engineer,
Projects Department,
Arab Fund for Economic and Social Development,
KIC Building - Safat,
PO Box 21923,
KUWAIT.

ARAB FUND FOR TECHNICAL ASSISTANCE TO AFRICAN AND ARAB COUNTRIES (AFTA)

The aim of the fund is to co-ordinate and finance technical assistance programmes arranged by the League and other Arab countries; provide consultancy services and experts; organize their exchange between Arab and African countries; co-ordinate scientific and technological development and the development of the means and modes of production. The Administrative Council of the Fund gives priority to Arab experts and provides scholarships and training.

Address: Arab Fund for Technical Assistance to African and Arab Countries,
c/o League of Arab States,
37, Khairaldin Basha Street,
TUNIS,
Tunisia.

EUROPEAN ECONOMIC COMMUNITY (EEC)

The financial and technical assistance granted by the EEC supports programmes and projects which will contribute towards correcting economic imbalances in the beneficiary country and also contributes to its economic and social development.

Address: Head of the Division.
Commission of the European Community,
Direction Generale du Developpement,
Division Infrastructural II,
200, Rue de la Loi,
B - 1049, BRUSSELS,
BELGIQUE.

ISLAMIC DEVELOPMENT BANK (IDB)

The purpose of the IDB is to foster social progress and economic development of the member countries and Muslim communities in accordance with Islamic Shariah.

Address: The Director,
Operations and Projects Department,
PO Box 5925,
JEDDAH,
Saudi Arabia.

KUWAIT FUND FOR ARAB ECONOMIC DEVELOPMENT

The Fund provides and administers financial and technical assistance to developing countries. It does not usually give any recipient country assistance with more than one project at a time and when considering further assistance, takes into consideration the progress made on previous projects.

Address: Kuwait Fund for Arab Economic Development,
PO Box 2921,
KUWAIT.

OPEC FUND FOR INTERNATIONAL DEVELOPMENT

All developing countries, except for member countries of OPEC, are eligible for assistance from the OPEC Fund.

Address: Director (Africa/Asia* Region)
OPEC Fund for International Development,
VIENNA,
Austria.

*as appropriate

5. BILATERAL AGENCIES

Many countries have their own organizations which offer assistance to developing countries in the field of water supply and sanitation.

CANADIAN INTERNATIONAL DEVELOPMENT AGENCY (CIDA)

CIDA provides a wide range of assistance, including financial and technical assistance, food aid, industrial commodities and raw materials, capital equipment, and the services of experts.

Address: Director-General,
U.N. Programmes Division,
Multilateral Programmes Branch,
Canadian International Development Agency (CIDA),
200, Promenade du Portage,
Hull,
QUEBEC KIA OG4,
Canada.

DANISH INTERNATINAL DEVELOPMENT AGENCY (DANIDA)

DANIDA will provide loans and grants for projects which aim at providing equal access to safe and reliable sources of drinking water of adequate quality, pay special attention to underserved populations, involve local participation, use simple and affordable technology, and have established arrangements for operation, maintenance and repair.

Address: DANIDA,
Ministry of Foreign Affairs,
Asiatisk Plads 2,
1448, COPENHAGEN K,
Denmark.

DEPARTMENT FOR INTERNATIONAL DEVELOPMENT CO-OPERATION (FINNIDA)

Provides funding for water supply and sanitation projects.

Address: Department for International Development
Co-operation,
Mannerheimintie 15 C,
00260 HELSINKI 26,
Finland.

CAISSE CENTRALE DE CO-OPERATION ECONOMIQUE

Provides technical assistance and funding.

Address: Caisse Centrale de Co-operation Economique
Direction Generale,
233, Bld. Saint-Germain,
75007 PARIS,
France.

BUNDESMINISTERIUM FUR WIRTSCHAFTLICHE ZUSAMMENARBEIT (BMZ)

BMZ provides technical co-operation, advisory services, equipment and financial aid.

Addresses:

(Financial Co-operation) German Agency for Technical Co-operation,
Dag-Hammarskjold-Weg 1,
PO Box 5180,
D - 6236 ESCHBORN 1,
West Germany.

(Financial Co-operation) Kreditanstalt fur Wiederaufbau
Palmengartenstr. 5 - 9,
D - 6000 FRANKFURT / MAIN,
West Germany.

NETHERLANDS MINISTRY FOR DEVELOPMENT CO-OPERATION

Provides financial aid, technical assistance, emergency aid, and training.

Address: Sector Management,
Drinking Water Supply and Sanitation Sector,
Ministry for Development Co-operation,
THE NETHERLANDS.

NORWEGIAN AGENCY FOR INTERNATIONAL DEVELOPMENT (NORAD)

Provides funding, personnel assistance and equipment.

Address: Norwegian Agency for International Development,
PO Box 8142,
Oslo Dep,
OSLO 1,
Norway.

SWEDISH INTERNATIONAL DEVELOPMENT AUTHORITY (SIDA)

Provides funding, personnel and equipment. 97% of aid is given as grants and supports programmes and sectors within countries rather than individual projects. Most assistance goes to countries which the United Nations has defined as least developed.

Address: Swedish International Development Authority,
S - 105 25 STOCKHOLM,
Sweden.

SWISS DEVELOPMENT CO-OPERATION

Provides grants, donations and loans.

Address: Directorate of Development Co-operation and
Humanitarian Aid,
Federal Department of Foreign Affairs,
3003 BERNE,
Switzerland.

OVERSEAS DEVELOPMENT ADMINISTRATION (ODA)

Provides financial aid, technical co-operation on a project basis, emergency aid, and training.

Address: The Principal Engineering Adviser,
Overseas Development Administration,
Eland House,
Stag Place,
LONDON SW1E 5DH,
United Kingdom.

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT (USAID)

Provides loans, grants and equipment.

Address: The Chief,
Community Water Supply and Sanitation Division,
Office of Health,
Development Support Bureau,
U.S. Agency for International Development,
International Development Co-operation Agency,
WASHINGTON D.C. 20523,
U.S.A.

NON-GOVERNMENTAL ORGANIZATIONS

There are many non-governmental organizations which contribute to the water supply and sanitation programme either by funding alone, or by providing funding, technical assistance and advice. These include:

MISEROR

Address: Miseror,
Postfach 1450,
Mozartstrasse 9,
5100 AACHEN,
Federal Republic of Germany.

CARITAS INTERNATIONALIS

Secretary General,
Caritas Internalionalis,
Palazzo San Calisto 16,
00153 ROME,
Italy,

NOVIB - NETHERLANDS ORGANIZATION FOR INTERNATIONAL DEVELOPMENT CO-OPERATION,

Secretary General,
NOVIB,
7, Amaliastraat,
2514 JC,
THE HAGUE,
The Netherlands.

LEAGUE OF RED CROSS SOCIETIES

International Federation of National Red Cross and Red Crescent Societies,
17, Chemin des Cretes,
Petit-Saconnex,
GENEVE,
Switzerland.

CHRISTIAN AID

Christian Aid,
PO BOX 100,
LONDON SE1 7RT
United Kingdom.

OXFAM

Oxfam,
274, Banbury Road,
OXFORD,
Oxon,
United Kingdom

CATHOLIC FUND FOR OVERSEAS DEVELOPMENT (CAFOD)

CAFOD,
2, Garden Close,
Stockwell Road,
LONDON SW9 9TY,
United Kingdom,

CATHOLIC RELIEF SERVICES (CRS)

Director of Operations,
CRS,
1011, 1st Avenue,
NEW YORK,
N.Y. 10022, U.S.A.

CO-OPERATIVE FOR AMERICAN RELIEF EVERYWHERE (CARE)

Regional Program Officer (Africa/Asia*)
CARE,
660, 1st Avenue,
NEW YORK,
N.Y. 10016, U.S.A.

*as appropriate

CHURCH WORLD SERVICE (CWS)

Assistant for Development,
CWS,
475, Riverside Drive,
NEW YORK,
N.Y. 10115, U.S.A.

SAVE THE CHILDREN
54, Wilton Road,
WESTPORT,
Connecticut 06880,
U.S.A.

SAVE THE CHILDREN
Mary Datchelor House,
17, Grove Lane,
LONDON SW5 8RO
United Kingdom

VOLUNTEERS IN TECHNICAL ASSISTANCE (VITA)
1815 N. Lynn Street.
ARLINGTON,
Virginia 2229,
U.S.A.

THE EVANGELICAL ALLIANCE RELIEF FUND (TEAR FUND)
11, Station Road,
TEDDINGTON,
Middlesex TW11 9AA
United Kingdom

WATER AID
1, Queen Anne's Gate,
LONDON SW1H 9BT,
United Kingdom.

VOLUNTEER ORGANISATIONS

The following organizations provide trained personnel to work in developing countries. One of the primary objectives of the volunteers is to train counterparts to continue the work after the volunteers have completed their term.

THE U.S. PEACE CORPS

How to obtain Peace Corps assistance -

1) In countries where the Peace Corps presently operates, contact the Peace Corps Director, c/o The American Embassy.
2) In countries where there is no Peace Corps programme, contact the American Embassy or write to the address given below.

Address: Water/Sanitation Sector Specialist,
Office of Programm Development,
U.S. Peace Corps,
806, Connecticut Avenue, N.W.,
WASHINGTON, D.C. 20526,
U.S.A.

UNITED NATIONS VOLUNTEERS

Requests for U.N. Volunteers must originate from or be approved by the host government.

Address: The Co-ordinator,
U.N. Volunteers,
Palais des Nations,
CH - 1211 GENEVE 10,
Switzerland.

VOLUNTARY SERVICE OVERSEAS (V.S.O.)

Applications for volunteers are normally made through the host government.

Address: Voluntary Service Overseas
9, Belgrave Square,
LONDON SW1X 8PW,
United Kingdom.

The information in this module is taken from the following sources, in which further details are available.

The International Drinking Water Supply and Sanitation Decade Directory (March 1984)

The International Drinking Water Supply and Sanitation Decade - Project and Programme Information System (April 1983)

Drinking-Water and Sanitation, 1981-1990 - A Way to Health (World Health Organization, Geneva)

British Aid for Water and Sanitation Projects (Isabel Blackett, Loughborough University, November 1984)

Water, Engineering and Development Centre

WEDC

World Health Organisation
Eastern Mediterranean Regional Office
Centre for Environmental Health Activities

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

MODULE 17 INSTRUCTOR'S NOTES

NATIONAL AND INTERNATIONAL AGENCIES

1. INTRODUCTION

The Student's Notes are intended as an information leaflet. They can be used to generate discussion about the role of national and international agencies in water and sanitation projects.

Before teaching the module, the Instructor should discover which agencies are active in the country where the course is taking place, what kind of projects they support, what form that support takes and what is the best method of approaching individual agencies.

The Instructor also needs to do some further reading on the aims of the International Drinking Water Supply and Sanitation Decade.

2. TEACHING THE MODULE

Using the Student's Notes as a starting point, the Instructor should discuss with the class the various points which describe the Decade approach at national level. The participants should be asked what they think each point means and any misunderstandings should be cleared up. The difficulties of implementing any of the points should be discussed. The Instructor should have considered possible problems before teaching the class in order that he or she can direct the discussion to ensure that areas which need consideration are dealt with.

Participants who have had experience of dealing with national and international agencies should be encouraged to relate their experiences to the rest of the class.

Using the list of banks and agencies listed in the Student's Notes, the instructor should indicate which agencies are active in the country in which the participants live and what types of projects they support.

Methods of applying to banks and agencies should be discussed. The usual approach is to contact a local organisation such as a Church, a women's group, national or local government department, village committee or other NGO working in the area.

After the initial contact, some agencies may ask for their standard application form to be filled in. Others will ask applicants to write up their own proposals. The instructor should have samples of application forms and use these to tell the participants what type of information the agencies are looking for. The importance of writing clearly and concisely should be emphasized. Forms should be typed if possible.

It is important to give as much information as possible on the organisation that is requesting the work, its background, activities, organisation, etc. References may be required and evidence of the technical ability to design and implement the work may be needed, when appropriate.

The more detailed, accurate, concise and clear the initial proposal, the quicker the agency can decide whether to support it or not. The importance of the quality of the written proposal should be emphasized to the participants.

A useful exercise at this stage is to divide the participants into small groups and ask each group to write a brief proposal for an imaginary project. At least half-an-hour should be allowed for this. Then the papers should be exchanged and the proposals assessed by other groups. Any omissions, faults or queries about a proposal should be noted by the reviewing groups and the proposal should then be passed back to the originating group for consideration and discussion.

3. FURTHER READING

These books are also listed in the Student's Notes.

The International Drinking Water Supply and Sanitation Decade (March 1984)

The International Drinking Water Supply and Sanitation Decade - Project and Programme Information System (April 1983)

Drinking-Water and Sanitation, 1981-1990 - A Way to Health (World Health Organization, Geneva)

Blackett I. - British Aid for Water and Sanitation Projects (Loughborough University, November 1984)

Water, Engineering
and Development Centre

WEDC

World Health Organisation
Eastern Mediterranean Regional Office
Centre for Environmental Health Activities

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

Additional Notes

Water, Engineering and Development Centre
WEDC

World Health Organisation
Eastern Mediterranean Regional Office
Centre for Environmental Health Activities

MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

ADDITIONAL NOTES - 1

KEYNOTE ADDRESS

The Opening Ceremony of a course should be carefully prepared to set the scene for what follows. It should not be so long that students become bored. On the other hand it should be as impressive as possible so that the students become aware of the importance of the task they are undertaking.

The Ceremony should start promptly at the time given on the programme. Staff and students should be in their places a few minutes beforehand. The form of the ceremony depends on local conditions.

If possible a short speech of welcome should be given by an eminent person such as a government minister, a senior civil servant or the resident representative of the World Health Organization.

A Keynote Address should also be given. It is important that this is presented by a good speaker who is able to inspire the audience. The chief instructor of the course may be an appropriate person. Sometimes the keynote address is given by someone not directly associated with the course, such as a senior medical officer.

The Address might emphasize the importance of -
- health for all by the year 2000;
- providing water supply and sanitation in order to improve health, well-being and socio-economic status;
- ensuring that operation and maintenance are properly carried out in order to ensure sustainability; and
- the role of communities as well as full-time workers in ensuring good operation and maintenance.

Students might be encouraged to -
- learn all they can from the instructors and the notes provided;
- ask questions about anything they do not understand;
- learn from other students; and
- apply what have learned when they return to their stations.

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

ADDITIONAL NOTES - 2

PARTICIPANT FAMILIARIZATION

Often the students do not know each other before joining a training course. Since the programme is of short duration it is important that they should quickly become familiar with other students so that they can work together.

At the start there may be *introductions*, when all the students and instructors give brief accounts of their education, background and present employment. Personal matters, such as number of wives and children, should be mentioned. It is usually best for one of the instructors to be the first to speak, to give an example of the type of information that should be mentioned and an example of how long the introduction should be.

It is helpful if everyone has a duplicated list of participants so that all can see the correct names of others and check the introductions against the list.

If the group is large it may take longer for the students to get to know each other, and there may be too many to carry out the introductions all together. One way of overcoming this is to prepare name badges that are affixed to clothing with safety pins. These may be in several different colours. All students (and instructors) with the same colour then have to get together and carry out the introduction process in the smaller groups.

The next step might be to get the students to discuss some controversial topic. A local problem, perhaps relating to conditions of service or levels of pay, is likely to be particularly suitable for discussion. A general topic would be "should more use be made of women to ensure good community participation in water supply and sanitation programmes?"

One way to encourage discussion is to divide the students into pairs. Each pair then talks together for three minutes, during which they try to decide a common opinion. The pairs are then paired again, forming groups of four. They have to decide a common viewpoint, or decide what they can agree and what cannot be agreed. The groups might then be joined again until everyone is together for final discussion.

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ADDITIONAL NOTES - 3

COURSE METHODOLOGY

The Instructor's Notes given for the various sessions in the programme are intended as suggestions. The methods to be followed for each course should be decided well in advance, bearing in mind the answers to the following questions.

a. What is the *Objective* of the course?
This needs to be clearly defined.

b. Who are the *participants*?
How familiar are they likely to be with the material covered?
Are they likely to have had practical experience of some or all of the topics covered?
Are all likely to be fluent in the language used, whether Arabic, English or French?
Are they accustomed to learning? [Field workers may find it strange to be back in a learning situation, whereas students in a college or University find the course to be an extension of the type of activity they are doing all the time.]

c. Who are the *instructors*?
Are they experienced teachers, or practical workers who may be unfamiliar with instructional techniques?

d. What *facilities* are available in the premises to be used for the course?
In particular, is there an electricity supply?

Instruction should be progressive and varied.

PROGRESSION
Start from what the students already know (or what they have learned in previous sessions) and move on to new information and ideas.

In a practical subject the progression might be:
- *explanation* - telling the students what is to be done, and why;
- *demonstration* - the instructor showing what has to be done;
- *execution* - the students carrying out the task; and
- *practice* - repeated execution until the task can be done well

VARIETY

Make sure the students do not become bored.

In the course as a whole, and in each individual session, you can use a variety of methods, such as:

lecture - the instructor does all the talking - but a lecture should always be followed by "any questions?"; [note that a "lecture" need not take the whole of a session - the method can be used for a few minutes and then there can be a change of method];

"any questions?" - an opportunity for students to ask the instructor to repeat what is not understood or to give more details;

discussion - the instructor prompts the students to give their own opinions about the subject, and the students do most of the talking;

"buzz groups" - discussion of a particular problem in groups of three or four students for a short time (say three minutes) and then the groups are asked in turn to report back;

questions-and-answers - the instructor asks individual students questions about the subject and calls for their replies;

films and tape-slide presentations - neither instructor nor students has an active part to play - but the presentation should always be followed by question and answer or discussion to draw out important matters covered;

case studies - detailed examination of real situations, preferably with duplicated notes;

role play - using small groups of students, ask each one to adopt the role or viewpoint of a particular individual affected by a project and then play out the interaction between the individuals;

demonstration - showing how certain activities should be performed, or showing a particular piece of equipment; and

calculations - the students do some simple computation, such as working out the amount of water needed for a village or the size of pit needed for a latrine for a family.

Whenever individual students are required to talk (for example in discussion or questions-and-answers) make sure that *all* students are involved.

SOME ADDITIONAL POINTS

Make sure all students can see and hear you.

At the end of a session give a summary of the main points covered and make sure all students understand them.

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APPENDIX FOUR (PART 1)

WATER SAMPLING

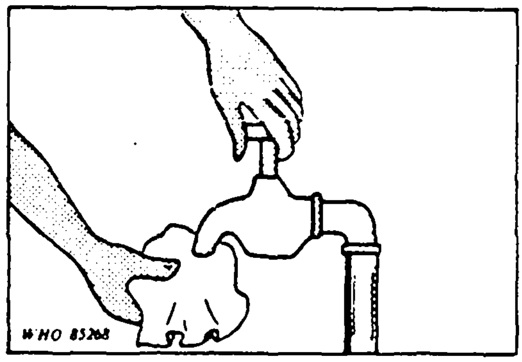
1. SAMPLING FROM A TAP OR PUMP OUTLET

The steps to be followed in sampling from a tap or pump outlet are described in sequence below.

A. Clean the tap

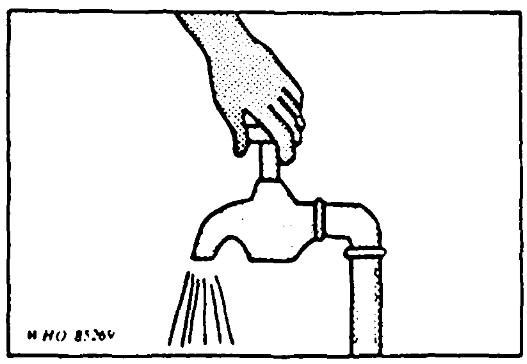
Remove any attachments from the tap that may cause splashing and, using a clean cloth, wipe the outlet in order to remove any dirt. Wash your hands.

If the tap leaks it must be repaired before sampling.



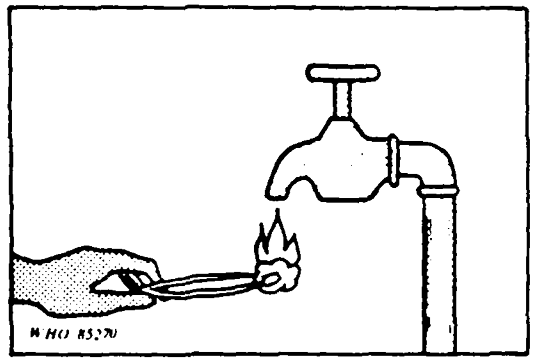
B. Open the tap

Turn on the tap at maximum flow rate and let the water flow for 1-2 minutes to clear the service line.



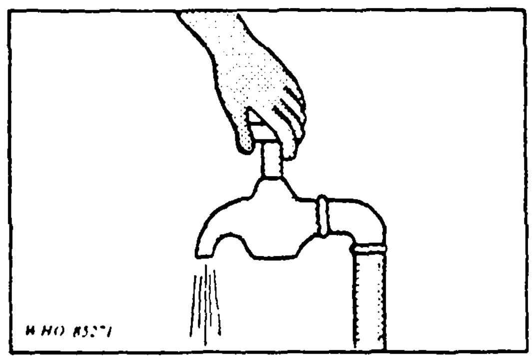
C. Sterilize the tap

Sterilize the tap for a minute with the flame from an ignited cotton-wool swab soaked in alcohol: alternatively, a gas burner or cigarette lighter may be used.



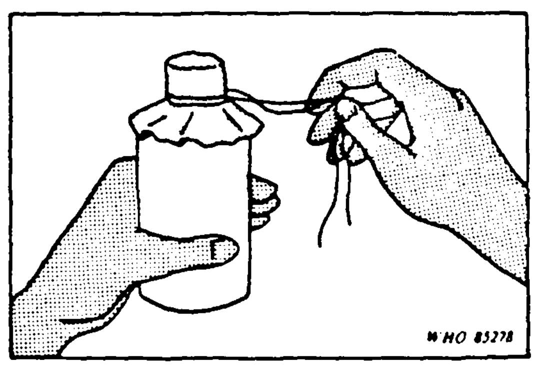
If the tap is plastic do not use a flame: a solution of hypocholorite will suffice. In some books tap sterilization is not considered important. However, if in doubt, sterilize the tap.

D. Open the tap prior to sampling



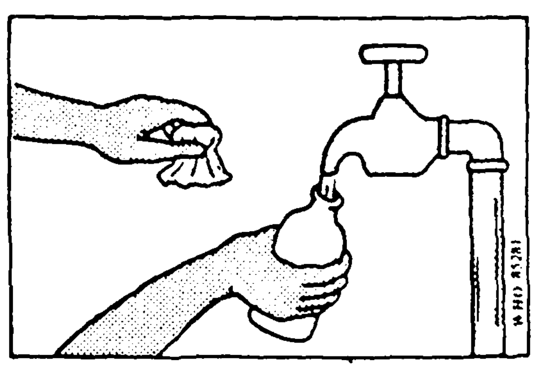
Carefully turn on the tap and allow the water to flow for 1-2 minutes at normal flow rate.

E. Open a sterilized bottle



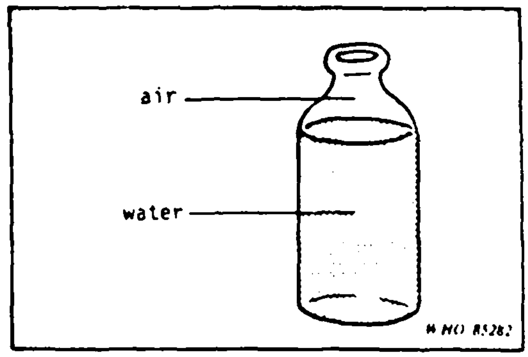
Untie the string fixing the protective paper cover and pull out or unscrew the stopper, keeping your fingers on the paper.

F. Fill the bottle



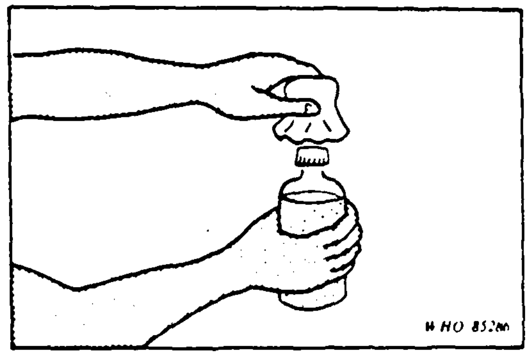
While holding the cap and protective cover face down-wards (so as to prevent entry of dust that might carry micro-organisms), immediately hold the bottle under the water jet, and fill.

A small air space should be left to facilitate shaking at the time of inoculation prior to analysis. Bacteria prefer to attach themselves to surfaces or particles. In order to spread the bacteria evenly, shake the bottle vigorously to detach them from the sides.



G. Stopper or cap the bottle

Place the stopper in the bottle or screw on the cap and fix the brown paper protective cap in place with the string.



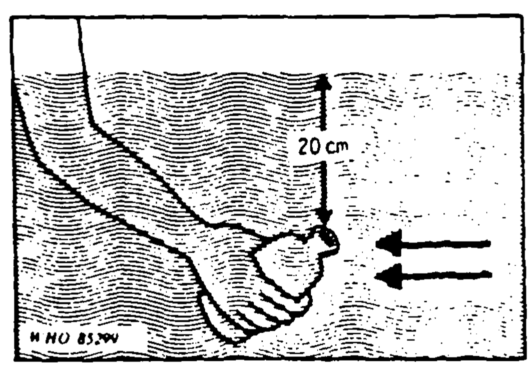
Place a label on the bottle, place it in a transport box and return to the laboratory within 6 hours.

2. SAMPLING FROM A WATERCOURSE OR RESERVOIR

Open the sterilized bottle by the techniques described above.

A. Fill the bottle

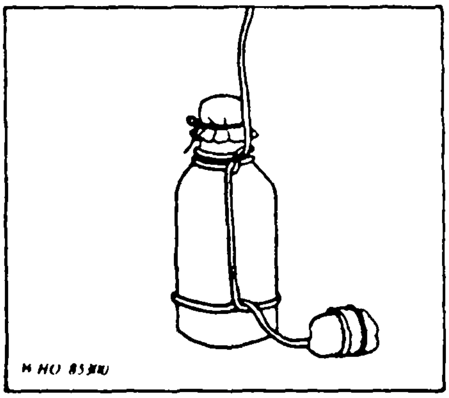
Holding the bottle by the lower part, submerge it to a depth of about 20cm, with the mouth facing slightly upwards. If there is a current, the bottle mouth should face towards the current. If there is no current, scoop the bottle away from your body. The bottle should then be stoppered as described previously.

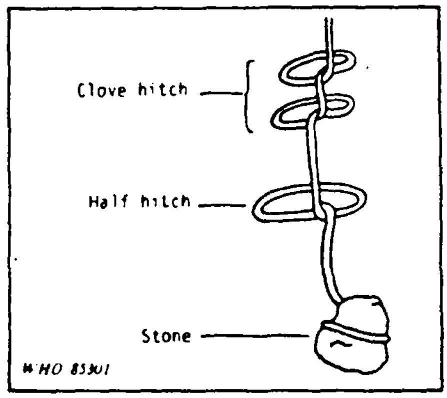


3. SAMPLING FROM DUG WELLS AND SIMILAR SOURCES

A. Prepare the bottle

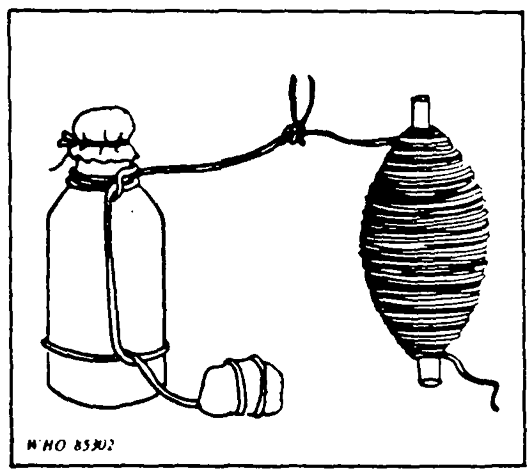
With a piece of string, attach a stone of suitable size to the sampling bottle





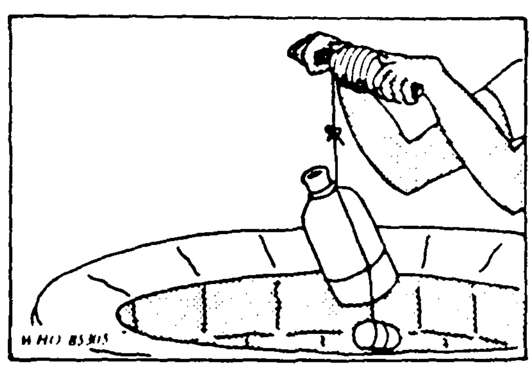
B. Attach bottle to string

Take a 20 metre length of clean string rolled around a stick and tie on to the bottle string. Open the bottle as described in Section One.



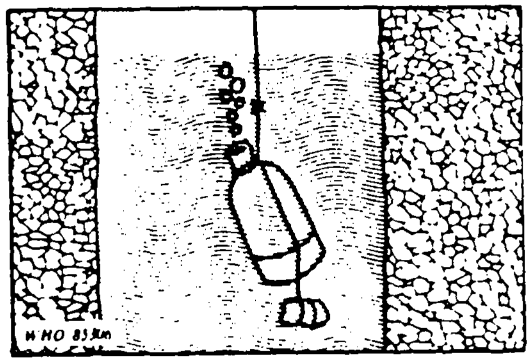
C. Lower the bottle

Lower the bottle, weighted down by the stone, into the well, unwinding the string slowly. Do not allow the bottle to touch the sides of the well.



D. Fill the bottle

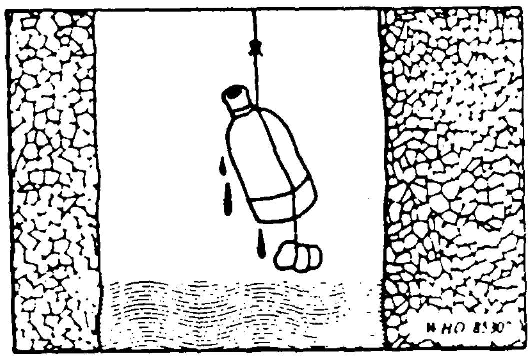
Immerse the bottle completely in the water and lower it down to the bottom of the well.



E. Raise the bottle

Once the bottle is judged to be filled, rewind the string round the stick to bring up the bottle. If the bottle is completely full, discard some water to provide an air space.

Stopper the bottle as described previously.



These techniques are best demonstrated and then tried out by the course participants under field conditions.

APPENDIX FOUR (PART 2)

FREE RESIDUAL CHLORINE TESTING

1. INTRODUCTION

Two procedures can be used to determine residual free chlorine: one is based on a commercial comparator and the other involves visual inspection and comparison of the colour developed in test tubes. Two different reagents are available for use - N,N-diethyl-para-phenylene diamine (DPD) and ortho-tolidine (OT). The latter has the disadvatage of being a carcinogen and, if used at all, must be handled with extreme caution.

Brief details are also given here of a method based on the use of starch and potassium iodide. This method, however, is not specific for residual free chlorine and may therefore give false positive results. Despite this limitation, it has been included because of its widespread use in many countries.

2. COMMERCIAL VISUAL COMPARATOR TECHNIQUE

a. Equipment

Commercial comparators are of two basic types:

(i) the disc type, containing a wheel of small coloured glasses;
(ii) the slide type containing liquid standards in glass ampoules.

However, both consist of the same components: a box with an eye-piece in front and two cells, the whole arranged so that both cells are in the field of vision of the eye-piece.

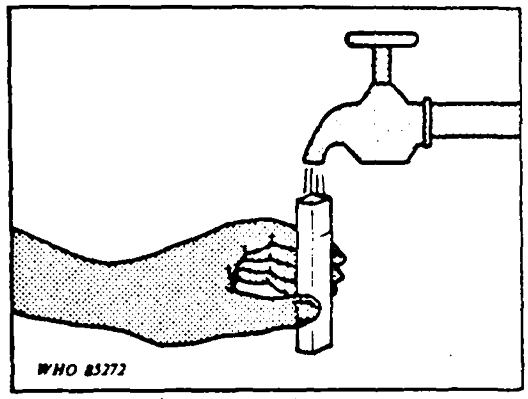
One cell, containing a water sample without the reagents, is placed in line with the rotating coloured glasses or the ampoules containing the standards. The water sample containing the reagent is placed in another cell. If free chlorine is present, a colour will develop. The concentration of chlorine is estimated by matching the colours in both cells, as seen through the eye-piece. Each colour of the disc or ampoule corresponds to a certain quantity of chlorine in the water. Different calibration discs or ampoules are needed for each of the reagents specified.

b. Reagents

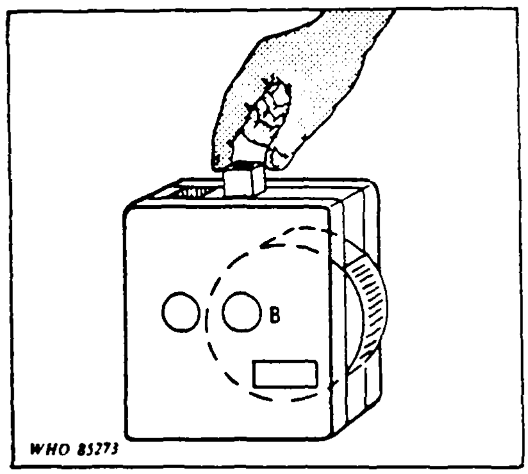
As most comparators are intended for use with the manufacturer's reagents, care must be taken to keep a good stock of them. This is a disadvantage, since it involves dependence on the local supplier, and occasionally importation problems can arise. On the other hand, an advantage of the technique is that it is not necessary to prepare solutions of standards, which makes it very easy to carry out.

c. <u>Determination of free chlorine</u>

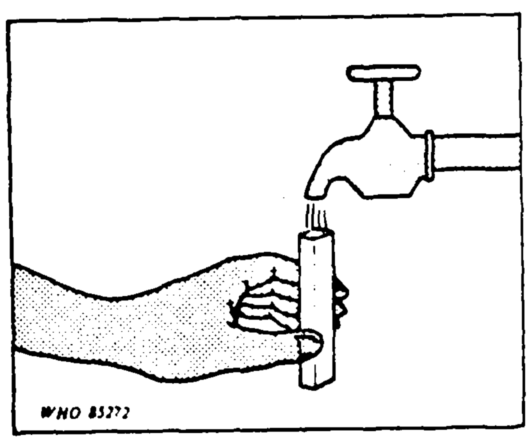
A. Rinse a comparator cell two or three times, and then fill it with the water sample up to the mark on the cell.



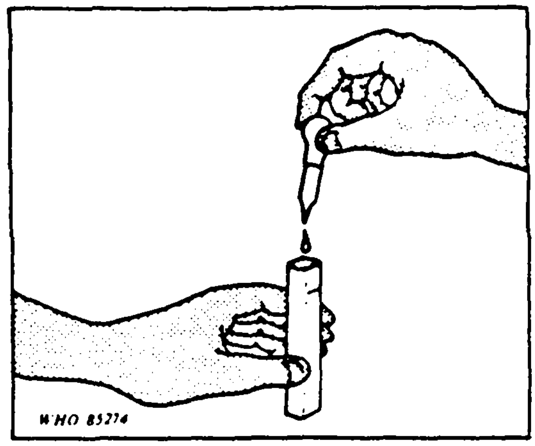
B. Place the cell in the cell carrier of the comparator, which is in line with the coloured standards (B).



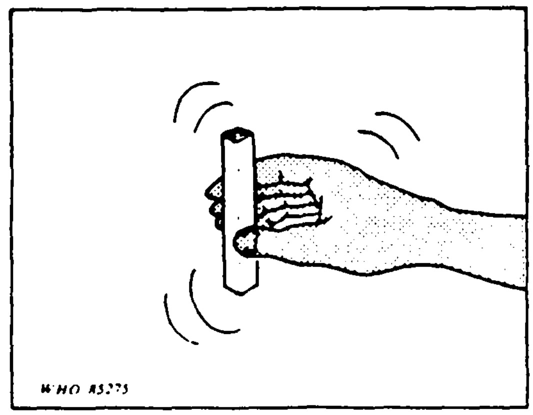
C. Rinse the second cell and fill it with the same water.



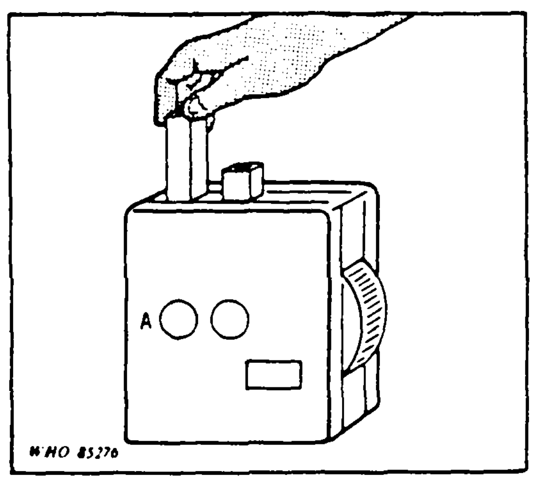
D. Add reagent in the second cell, in accordance with the manufacturer's instructions.



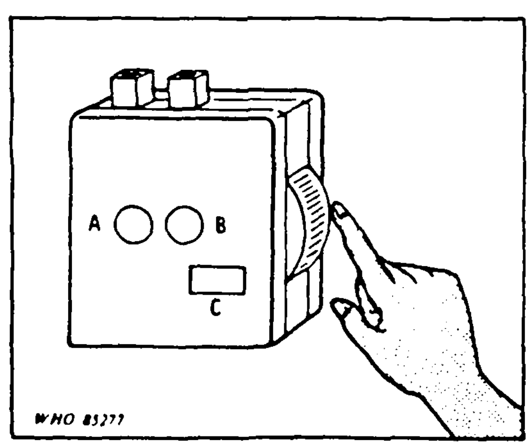
E. Shake the cell (for not more than 3-5 seconds) so as to mix the reagent.



F. Place the cell in the comparator (A).



G. While facing good natural light, hold the comparator and rotate the disc until the colour of a standard (B) is the same as that developed by the reagent (A). Immediately (ie, in less than 20 seconds) read at C the value of free chlorine in mg/litre. Cooling the sample to about 1oC is also advantageous.



3. TEST-TUBE TECHNIQUE

The standard test-tube technique involves the use of Nessler tubes. For field use, however, ordinary test-tubes can be employed. The method is based on visual comparison between the colour developed in a tube to which the reagent has been added and the colour of pre-prepared standard solutions contained in sealed test tubes.

Since most drinking-waters are chlorinated to give a final residual chlorine concentration of less than 1 mg/litre. As with the commercial comparator technique, the rapidity of determination (less than 20 seconds) will help to prevent the reagent acting on any combined chlorine present and thus reduce the risk of falsely high free chlorine values. Cooling the sample to about 1oC also minimizes the error from any combined chlorine present.

Application of the test-tube technique requires that a local or regional laboratory prepare the colour standards and reagents. The necessary equipment, reagents and procedures are described in the relevant literature on analytical methods.

4. STARCH-POTASSIUM-IODIDE METHODS

a. Equipment

The following are required:

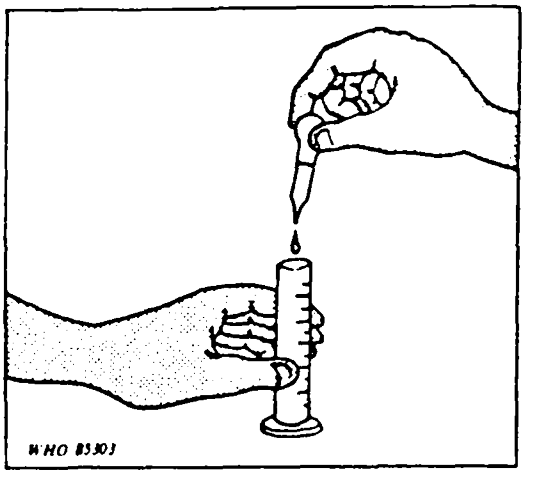
- 100 ml measuring cylinder;
- dropper pipette.

b. Reagent

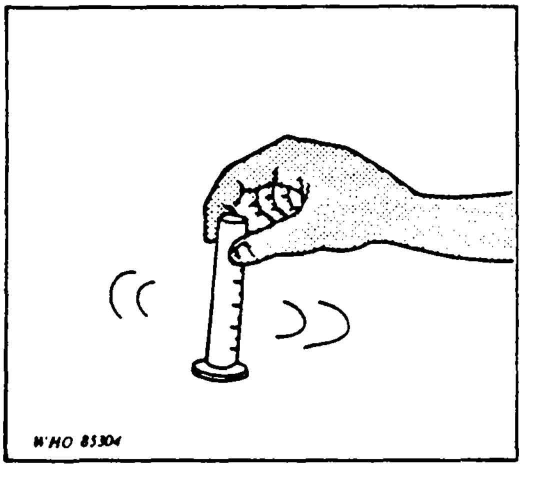
Dissolve 2 g of soluble starch in 100 ml of distilled water. Boil the solution and allow it to cool to room temperature. Add 8 g of potassium iodide and agitate the mixture until it is completely dissolved. Store the solution in a brown glass bottle. If 2 or 3 drops of chloroform (or formaldehyde) are added, the solution will remain stable for 2-3 weeks.

c. Determination of residual chlorine

A. Add 5-6 drops of the starch-iodide solution to 100 ml of water sample in a measuring cylinder.



B. Mix thoroughly.



The residual chlorine content of the water sample is found from the colour produced, as follows:

Colour	Residual Chlorine (mg/litre)
No colour	0.0
Light blue	0.1 - 0.3
Dark blue	>0.3

(From 'Guidelines for Drinking-Water Quality', Volume 3, WHO, Geneva, 1985)

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MAINTENANCE AND OPERATION OF RURAL WATER SUPPLY AND SANITATION SYSTEMS

ADDITIONAL NOTES - 7

CASE STUDIES

Case studies may be prepared from a variety of material, including the following:

a. *the instructor's personal experience*

b. *the personal experience of individual students*

c. *published case studies*

d. *information obtained from published material* and edited to make studies

e. *imaginary situations.*

The objective of a case study is to relate subjects covered during the course to a particular situation.

For example, methods used to manage the operation and maintenance of handpumps in a particular district could be discussed in a case study. Students would be given sufficient details of the district, the water resources, the population, the community leadership patterns and so on to enable them to understand the problems faced in setting up a management system. They might then be asked to suggest and discuss appropriate systems. Alternatively the management system actually adopted could be described and the students would be required to criticize it by identifying the good and bad features.

The advantages of using situations that are personally known to the instructor or one of the students are that further details can be given during discussion and the conditions are real and true to life. Students can be made to realize that the lessons learned in other sessions do in fact exist in practice.

On the other hand, a hypothetical situation could be devised using an imaginary district. It then becomes possible to so arrange the information given to students that several options are suitable and can be compared.

Case studies of greatest value are those which lead to real discussion - where some students argue in favour of one possible solution and others support different ideas.

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