WHO/DANIDA Course

on

Surveillance & Control of Drinking Water Quality

Centre for Developing Countries
Technical University of Denmark

Division of Environmental Health
World Health Organization

Robens Institute
University of Surrey

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Preface

This Course Manual is prepared in the **Centre for Developing Countries, Technical University of Denmark**, for use in the **WHO/DANIDA Course on Surveillance & Control of Drinking Water Quality** in Arusha, Tanzania, November 1990. The Course is the sixth of its kind.

The Course is organized by **Division of Environmental Health, World Health Organization**, Geneva, with Dr. **Richard Helmer** as International Course Coordinator, in collaboration with **Water Quality Laboratory, Ministry of Water Minerals and Energy**, Tanzania, with Mr. **Francis Gumbo** as National Course Coordinator. Valuable contribution to the course set up and the course material is given by **David Wheeler, Barry Lloyd & Jamie Bartram** from the **Robens Institute, University of Surrey**, Guildford, United Kingdom. This course and the yearly training programme are sponsored by The Danish International Development Agency, **DANIDA**.

The main objective of the training programme is to promote greater concern among public heath and public water supply authorities for the need to carry out more efficient drinking water quality surveillance, particularly in the rural areas of the developing countries. Water quality problems of small community water supplies deserve special attention, since the prevalence of contaminated supplies is high, primarily due to poor sanitation and hygienic conditions.

The philosophy of the course is reflected in this manual. The idea is to train public health officers in using the water quality guidelines, in preparing national standards, planning for surveillance programmes and conducting sanitary inspections. Through sanitary inspections the public health officers are enabled to select and to protect the water sources, to introduce preventive and corrective measures and ensure proper operation and maintenance .

Eli Dahi, Course Director.

1 Water Quality & Health

1.1 Introduction

The prime objective of the International Drinking Water Supply and Sanitation Decade (1981-1990) is to provide an adequate and safe supply of drinking-water to the underserved population of the world. The word safe cannot be overemphasized since the impact of drinking-water quality on health has been well documented and range from massive outbreaks of communicable diseases to subtle chronic toxicological effects.

The quality of drinking water has been implicated, directly or indirectly, in the spread of major infectious and parasitic diseases such as cholera, typhoid, dysentery, hepatitis, giardiasis, guinea-worm infection and schistosomiasis. Symptomatic manifestations of some of these diseases are acute diarrhoea, one of the leading causes of infant morbidity and mortality in the developing world. In some countries as much as 40 % of mortality in children under five years of age is related to diarrhoeal diseases.

Chemical substances in drinking-water may lead to toxic effects in humans: crippling fluorosis occurs in areas where the drinking-water contains excessive concentrations of fluoride; the toxic effects of pesticides, lead and other metals, nitrate and nitrite have at times led to clinical manifestations of various physiological disorders.

There are in addition two important potential chronic disease problems related to drinking-water quality: cancer and an increase in genetic defects. Although there are gaps in our knowledge, although we are less quantitatively certain about such health effects there are enough qualitative indications of hazard to persuade several national government to take rapid steps to minimize the occurrence of carcinogenic chemicals - such as chloroform, benzo(a)pyrene, carbon tetrachloride - in drinking-water.

1.2 Microbiological/Biological Quality

The toll of human suffering from the microbiological and biological contamination of drinking-water is heavy. In our concern about drinking-water quality, we must always keep in mind that priority consideration should be given to improving the microbiological and biological[1] quality of water for human consumption. The most common and widespread danger associated with drinking-water is contamination by faecal material. Such faecal pollution introduces a variety of intestinal pathogens - bacterial, viral, and protozoan pathogens - and helminth parasites which cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal diseases of epidemic proportions.

Protection of drinking-water sources from contamination by faecal material is of paramount importance and much can be done using simple protective interventions to provide drinking-water of acceptable quality.

Microbiological/biological contamination of drinking-water can also occur in subsequent handling, during storage and dispensing: water storage jars are left directly on the floor, uncovered, and a short-handled cup is used as the dipper. Such practices results in the contamination of water by the user. many people are not aware of the health hazards caused by using alternative water sources of questionable microbiological/biological quality. Thus the provision of a safe potable supply by itself will not necessarily prevent infections. A health education programme is essential.

1.2.1 Bacterial Pathogens

Bacterial pathogens are transmitted to human host by ingestion of contaminated water and food, person-to-person contact and exposure to aerosols. The water route plays a major role in the spread of intestinal bacterial infections such as cholera or typhoid.

The minimum infectious dose levels necessary to cause human infection varies according to the nature of the bacterial pathogen. With *Salmonella typhi*, few organisms can cause diseases while with *V.cholera* and enteropathogenic *E. coli* as many as 10^8 organisms may be necessary to cause illness. The dose-effect relationship however varies with age, nutritional status and general health at the time of exposure; those at highest risk are infants

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[1] For the purpose of this discussion, microbiological quality deals with bacteria and virus in drinking-water while biological contaminants refer to protozoa and helminths.

and young children who have not yet developed a natural immunity, the sick and the aged. For these people, infective doses are often significantly lower than for the general adult population.

For these reasons, assessment of risk associated with variations in bacteriological quality is difficult and controversial because of insufficient epidemiological evidence, the number of environmental factors involved, and their changing interrelationships. Thus, for the protection of the public health, drinking-water should not contain any bacterial pathogens. To ensure the absence of such pathogens, drinking-water should be free from faecal coliforms organisms which are indicative of contamination with faecal material.

This water quality goal has been expressed in the Guidelines for Drinking-Water Quality in the form of a recommended Guideline value of zero faecal coliform per 100 ml at all times, in any type of water supply, piped or unpiped, treated or untreated.

Because of varying national priorities and economic factors, such a goal might not be attainable and water of less than satisfactory quality must at times be available to consumers. However, a responsible national health agency will act for the elimination or reduction of adverse health effects from bacteriologically contaminated drinking-water as soon as their existence is recognized.

1.2.2 Virological Quality

When drinking-water is contaminated with enteric viruses, two diseases may occur in epidemic proportions - gastroenteritis and infectious hepatitis.
Gastroenteritis of viral origin may be associated with a variety of agents and manu of these have been identified only recently. Viral gastroenteritis, usually of 24-72 hours duration with nausea, vomiting and diarrhoea, occurs in individuals of all ages. It is most serious in the very young or very old where dehydration and electrolyte imbalance can occur rapidly and threaten life if nor corrected without delay.

Hepatitis, if mild, may require only rest and restricted activities for a week or two, but when severe it may cause death from liver failure, or may result in chronic diseases of the liver. Severe hepatitis is tolerated less well with increasing age and the fatality rate increases sharply beyond middle age.

Viruses do not multiply outside the living host, however they may remain viable in the aquatic environment for days or months and are more resistant to environmental factors than indicator bacteria. Moreover, one viral particle is capable of initiating the infectious process. To ensure that the drinking-water is free from viral particles, the Guidelines recommend the use of a water supply source which is free from faecal contamination.

In the event a water source is subject to faecal pollution, treatment requirements are specified which will insure the inactivation of viruses: turbidity $\leq$ 1 NTU, a minimum of 0.5 mg/liter free residual chlorine, contact time $\geq$ 30 minutes, Ph $\leq$ 8.0.

1.2.3 Protozoa

Species of protozoa known to have been transmitted by the ingestion of contaminated drinking-water include *Entamoeba histolytica* and *Giardia* the causative agents of amoebic dysentery and giardiasis respectively. Waterborne transmission of these diseases is specially high in developing countries where the carrier rate is high. Symptoms of amoebic dysentery range from mild diarrhoea to fulminating bloody dysentery. Liver abscess debilitating diarrhoea. One viable cyst of *Giardia* and *E. histolytica* may establish infection in a susceptible host. Drinking-water should therefore not contain nay such pathogenic intestinal protozoa.

The pathogenic intestinal protozoa and their cyst are extremely resistant to environmental conditions and to chlorination. Protection of sources and/or adequate treatment (filtration) are the most effective ways of preventing infection.

1.2.4 Helminths

Guinea-worm infections, or dracontiasis is a major disabling disease. In countries of the sub-Sahara, north-east Africa, the Arabian peninsula, Iran, Pakistan and India, an estimated 20 million people - all rural - are victims of Guinea-worm infection. This is the only human disease that can be eradicated solely by provision of safe drinking-water.

Dracunculus, the Guinea-worm, is transmitted by freshwater copepods which represent an obligatory intermediate stage. One infected copepod containing a single larva is sufficient to infect man and therefore such larvae should be absent from drinking-water. Well protection and installation of piped water systems in villages are the best approach to preventing guinea-worm infection. Simple filtration or addition of temephos will also control the copepod host.

The human *schistosomes* are a cause of severe morbidity and sometimes death in a number of the 200 million people infected worldwide. Schistosomiasis has severe consequences an liver, intestine and bladder functions and may lead to bladder cancer and liver fibrosis. Schistosome infections are acquired when water containing cercariae is used for domestic activities, bathing or washing. A single cercaria may infect man.

Provision of safe drinking-water for bathing and washing will reduce human contact with infected sources previously used; and has resulted in drastic reduction in the incidence of new infections and overall prevalence of the disease.

1.3 Chemical Quality

Chemical contaminants are nor 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 waterborne infectious and parasitic diseases are rampant in a society.

Chemical contamination of drinking-water may be due to natural geological sources (e.g. fluoride, selenium, total dissolved solids), use of chemicals in agriculture (pesticides and nitrates), treatment and distribution of water (chloroform, vinylchloride, lead, copper) and industrial waste such as those form paper and textile mills, tanneries, petroleum industry (e.g. chromium, phenols, trichloroethylene).

Figure 1 depicts the effects on health of chemical substances as a function of concentration (Vettorazzi, personal communication, 1980). Ideally, for essential elements, the concentration should be below the no-effect level or zero for substance which are believed to have no-threshold limits. Many scientists believe that carcinogens belong to this category. For certain substances exerting aesthetic effects, a curve somewhat similar to that of essential elements may be applicable: distilled water is unpalatable, while above a certain concentration of total dissolved solids, water acquires objectionable taste.

In arriving at the guideline values for various substances in water, the total intake from air, food and water for each substances is taken into consideration, as far as approach for arriving at national limits for a toxic substance such as lead in drinking-water.

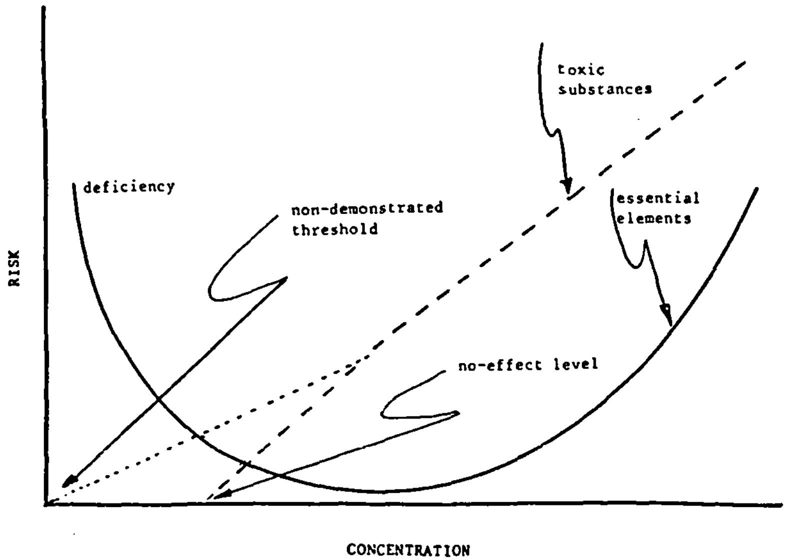


FIG. 1.1 Health effects of toxic substances and essential elements. After G. Vettorazzi 1980.

Such limits are variable, as it should be depending on exposure to lead from food and air. In making the computations for figure 2 (applicable to adults only), the following assumptions have been made:

Maximum "not observed adverse health effect"	:60 μg of absorbed lead/day, from all sources /air, water, food).
Daily volume of inspired air:	20 m^3
Daily volume of water consumed:	2 liter
Lead absorption from food:	10 %
Lead absorption from water:	10 %
Lead absorption from air:	40 %

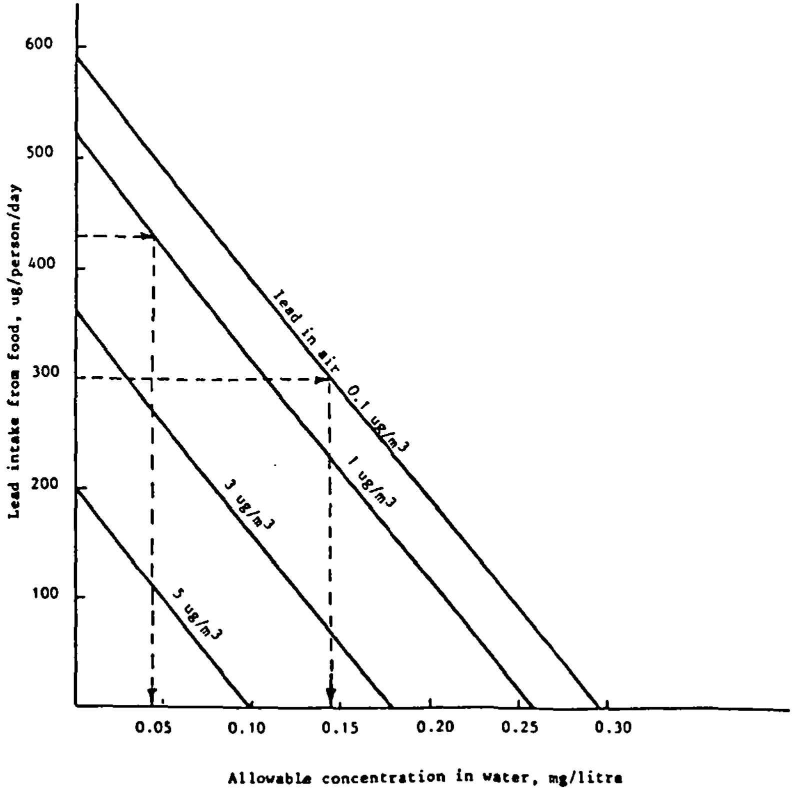


FIG. 1.2 Setting limits for lead in drinking-water. After H. Galal Gorchev 1979.

It can be seen from figure 2 that in urban areas (for example air lead 1 $\mu g/m^3$), and with a daily intake from food of 430 μg (FAO/WHO maximum tolerable daily intake), the allowable concentration of lead in drinking-water should not exceed 0.05 mg/liter. However, in rural areas (air lead 0.1 $\mu g/m^3$), at an average intake of lead from food of 300 μg/day, a level of lead in drinking-water of 0.15 mg/liter could be tolerated.

Such graphs could be constructed for a variety of contaminants provided certain metabolic and toxicological factors are known. They would serve to make "allocations" for the various routes of exposure as well as adopt standards that are appropriate to national situations; such standards could differ appreciably from the WHO Guideline Values.

Constituents discussed here have been selected on the basis of their potential significance in countries of the Eastern Mediterranean Region.

1.3.1 Fluoride

The role of fluoride in reducing the incidence of dental caries is well known. Once fluoride is incorporated into teeth, it reduces the solubility of the enamel under acidic conditions and thereby provides protection against dental caries. Frequent or continuous exposure of teeth to fluoride ions, such as in drinking-water, is considered beneficial in enhancing this protection, possibly by direct absorption of fluoride ions into the enamel structure.

Fluoride levels of about 1 mg/liter provide substantial protection against dental caries. However, for fluoride the margin between beneficial and toxic effects is rather small (see figure 1), Higher concentrations and increase in water consumption may lead to excessive exposure and adverse health effects varying from mottling of teeth to crippling fluorosis.

The Guidelines recommend a Guideline value of 1.5 mg/liter on the assumption that the daily per capita consumption of drinking-water is about 2 liter. In hot climates, an average water consumption of 5 liter/day is not unusual and in such cases, fluoride levels in drinking-water should be decreased accordingly.

1.3.2 Total Dissolved Solids

Total dissolved solids (TDS) in drinking-water consist of chlorine, sulphate, carbonates, sodium, magnesium and calcium. Excessive dissolved solids in drinking water are aesthetically unacceptable and in addition may lead to corrosion or incrustation in water distribution system. At concentrations greater than approximately 1200 mg/liter the taste of water becomes increasingly unpalatable.

As far as health aspects are concerned, there is no evidence of adverse physiological reactions at TDS levels greater than 1000 mg/liter. on the contrary, the results of epidemiological studies suggest that high levels of certain salts (calcium and magnesium) may have beneficial health effects.

1.3.3 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 resulting nutritional health impact of such incidents may be significant.

The toxicity of widely used pesticides is regularly evaluated by the FAO/WHO Joint Meetings on Pesticide Residual (JMPR). On the basis of toxicological and epidemiological studies the experts develop Acceptable Daily Intake (ADI), expressed in mg per kilogram body weight, for pesticides under consideration.

Guideline values have been recommended for several of the persistent chlorinated pesticides known to occur frequently in drinking water: aldrin and dieldrin, chlordane, 2,4-D, DDT, heptachlor, gamma-HCH (Lindane) and methoxychlor. These guidelines values were derived from ADIs with the assumption that not more than 1 % of the ADI would be derived from drinking-water for a 70 kg person drinking 2 liters of water per day. The ADI is based on lifetime exposure, therefore short-term concentrations above the guideline value, e.g. those resulting from vector or aquatic weed control operations, may be acceptable but require carefully surveillance. it should be kept in mind that the guideline values recommended are set at a level to protect human health and may not be suitable for the protection of fish and other aquatic life.

ADIs have been developed for some one hundred pesticides. Using these ADIs, guideline values may be easily derived for those pesticides which are known to be widely used in a country and which have not been dealt with in the Guideline for Drinking-Water Quality.

As new toxicological information becomes available, the ADI values may be revised.
In 1984, JMPR allocated an ADI for DDT of 0.01 mg/kg body weight, replacing the previous Conditional ADI of 0.005 mg/kg bodyweight. As a result, the new Guideline value for DDT may be calculated to be approximately 5 μg/liter instead of 1 μg/liter. The Odor Threshold Concentration of DDT is 350 μg/liter and therefore a Guideline value of 5 μg/liter may be appropriate based on health as well as aesthetic considerations.

The above illustrates the dynamic aspect of the Guideline and new information on the effects of chemicals on human health will influence the numerical values of some of the recommendations made in the Guidelines.

1.3.4 Nitrate and Nitrite

Excessive levels of nitrate and specially nitrite in drinking-water may cause methemoglobinemia in infants. The problem is one for bottle-fed infants and thus is not of any concern where infants are breast-fed.

Limited epidemiological evidence indicate that at levels of nitrates less than 10 mg/liter (as nitrogen), there does not seem to be any problem with methemoglobinemia. There are considerable uncertainties as to the level of nitrite which may cause such clinical effects, nevertheless it must be appreciably lower than that for nitrate.

1.3.5 Turbidity

Particles in drinking-water are aesthetically objectionable and can serve as shields for pathogenic microorganisms. Moreover, many toxic chemical such as pesticides and heavy metals are selectively absorbed on suspended matter. The efficiency of disinfection is drastically reduced in presence of turbidity: the disinfectant is unable to reach the target organism because of a physical barrier, or chemical reactions with turbidity particles may occur thus decreasing the available disinfectant concentration. Consumption of turbid water may thus be a dangerous health risk.

1.3.6 Petroleum Products

Industrial waste from the petroleum industry are at times discharged directly into the rivers or may receive inadequate treatment with consequent, contamination of water supplies. As a results of spills and dumping of chemical waste, concentrations of petroleum hydrocarbons in groundwater up to levels of several mg per liter have recently been found.

Of the petroleum hydrocarbons, benzene is frequently identified as contaminant of drinking-water, albeit at general low concentrations. Because of its toxic properties, a guideline value of 10 μg/liter has been recommended for benzene. This value is based on a lifetime risk of leukemia of 1 in 100,00 and consumption of 2 liter drinking-water by a person of 70 kg body weight.

1.4 Conclusion

The microbiological, biological, chemical and physical quality of drinking-water have great *impact on human health. provision of a safe and adequate supply of drinking-water is an* essential component in the primary health care approach to the goal of Health for All by the Year 2000. To quote a resent Regional Committee, member States are urged:

1) To update their national drinking-water standards, taking into consideration the Guidelines for Drinking-Water Quality,

2) to develop and implement monitoring, surveillance and control programmes to ensure the safety of drinking-water and
3) to initiate a community-level information and education programme that will foster awareness of the people's right to safe drinking-water.

1.5 References

This chapter is based on a paper given by H. Galal-Gorchev 1986.

2 Water Quality Guidelines

2.1 Introduction

The last edition for the WHO International Standards for Drinking Water /1/ was issued in 1971 and that of the European Standards /2/ in 1970. These Standards have now been reviewed, revised and combined and will be issued in 1982/83 under the title of the Guidelines for Drinking Water Quality.

The old Standards have been widely used and applied by Member States. The WHO International Standards for Drinking Water have been among one of the most widely recognized and utilized WHO publications. The recommendations contained therein have been adopted in their entirety in a number of Member States while in others they have been used as the basis for establishing national standards.

There is a substantial difference between the old Standards and the new Guidelines. The new Guidelines cover more substances, primarily chemicals, than the old Standards did and there have been few changes in the recommended levels between the two editions; but perhaps the greatest change is with respect to:

A) the basic philosophy in their intended interpretation, application and use,

B) their presentation and reporting, and

C) the manner in which the Standards were arrived at back in 1971 as compared to the way the new Guidelines were developed.

The purpose of this paper is not to describe in detail the Guidelines for Drinking Water Quality and the guideline values which WHO is recommending (as given in /1/ & /2/ and as summarized in Table 1-5), but rather to highlight the basic differences between the old Standards and the new Guidelines and to briefly comment on some of the scientific issues which were faced in the preparation of the Guidelines.

Table 1. Microbiological and biological quality

Organism	Unit	Guideline value	Remarks
I. Microbiological quality			
A. Piped water supplies			
A.1 Treated water entering the distribution system			
faecal coliforms	number/100 ml	0	turbidity < 1 NTU; for disinfection with chlorine, pH preferably < 8.0; free chlorine residual 0.2-0.5 mg/litre following 30 minutes (minimum) contact
coliform organisms	number/100 ml	0	
A.2 Untreated water entering the distribution system			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	0	in 98% of samples examined throughout the year—in the case of large supplies when sufficient samples are examined
coliform organisms	number 100 ml	3	in an occasional sample, but not in consecutive samples
A.3 Water in the distribution system			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	0	in 95% of samples examined throughout the year—in the case of large supplies when sufficient samples are examined
coliform organisms	number/100 ml	3	in an occasional sample, but not in consecutive samples
B. Unpiped water supplies			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	10	should not occur repeatedly; if occurrence is frequent and if sanitary protection cannot be improved, an alternative source must be found if possible
C. Bottled drinking-water			
faecal coliforms	number/100 ml	0	source should be free from faecal contamination
coliform organisms	number/100 ml	0	
D. Emergency water supplies			
faecal coliforms	number/100 ml	0	advise public to boil water in case of failure to meet guideline values
coliform organisms	number/100 ml	0	
Enteroviruses	—	no guideline value set	
II. Biological quality			
protozoa (pathogenic)	—	no guideline value set	
helminths (pathogenic)	—	no guideline value set	
free-living organisms (algae, others)	—	no guideline value set	

Table 2. Inorganic constituents of health significance

Constituent	Unit	Guideline value	Remarks
arsenic	mg/l	0.05	
asbestos	—	no guideline value set	
barium	—	no guideline value set	
beryllium	—	no guideline value set	
cadmium	mg/l	0.005	
chromium	mg/l	0.05	
cyanide	mg/l	0.1	
fluoride	mg/l	1.5	natural or deliberately added; local or climatic conditions may necessitate adaptation
hardness	—	no health-related guideline value set	
lead	mg/l	0.05	
mercury	mg/l	0.001	
nickel	—	no guideline value set	
nitrate	mg/l (N)	10	
nitrite	—	no guideline value set	
selenium	mg/l	0.01	
silver	—	no guideline value set	
sodium	—	no guideline value set	

Table 3. Organic constituents of health significance

Constituent	Unit	Guideline value	Remarks
aldrin and dieldrin	μg/l	0.03	
benzene	μg/l	10[a]	
benzo[*a*]pyrene	μg/l	0.01[a]	
carbon tetrachloride	μg/l	3[a]	tentative guideline value[b]
chlordane	μg/l	0.3	
chlorobenzenes	μg/l	no health-related guideline value set	odour threshold concentration between 0.1 and 3 μg/l
chloroform	μg/l	30[a]	disinfection efficiency must not be compromised when controlling chloroform content
chlorophenols	μg/l	no health-related guideline value set	odour threshold concentration 0.1 μg/l
2,4-D	μg/l	100[c]	
DDT	μg/l	1	
1,2-dichloroethane	μg/l	10[a]	
1,1-dichloroethene[d]	μg/l	0.3[a]	
heptachlor and heptachlor epoxide	μg/l	0.1	
hexachlorobenzene	μg/l	0.01[a]	
gamma-HCH (lindane)	μg/l	3	
methoxychlor	μg/l	30	
pentachlorophenol	μg/l	10	
tetrachloroethene[d]	μg/l	10[a]	tentative guideline value[b]

Table 3 (*continued*)

Constituent	Unit	Guideline value	Remarks
trichloroethene[d]	μg/l	30[a]	tentative guideline value[b]
2,4,6-trichlorophenol	μg/l	10[a c]	odour threshold concentration, 0.1 μg/l
trihalomethanes		no guideline value set	see chloroform

[a] These guideline values were computed from a conservative hypothetical mathematical model which cannot be experimentally verified and values should therefore be interpreted differently. Uncertainties involved may amount to two orders of magnitude (i.e., from 0.1 to 10 times the number).

[b] When the available carcinogenicity data did not support a guideline value, but the compounds were judged to be of importance in drinking-water and guidance was considered essential, a tentative guideline value was set on the basis of the available health-related data.

[c] May be detectable by taste and odour at lower concentrations.

[d] These compounds were previously known as 1,1-dichloroethylene, tetrachloroethylene, and trichloroethylene, respectively.

Table 4. Aesthetic quality

Constituent or characteristic	Unit	Guideline value	Remarks
aluminium	mg/l	0.2	
chloride	mg/l	250	
chlorobenzenes and chlorophenols	—	no guideline value set	these compounds may affect taste and odour
colour	true colour units (TCU)	15	
copper	mg/l	1.0	
detergents	—	no guideline value set	there should not be any foaming or taste and odour problems
hardness	mg/l (as $CaCO_3$)	500	
hydrogen sulfide	—	not detectable by consumers	
iron	mg/l	0.3	
manganese	mg/l	0.1	
oxygen—dissolved	—	no guideline value set	
pH	—	6.5–8.5	
sodium	mg/l	200	
solids—total dissolved	mg/l	1000	
sulfate	mg/l	400	
taste and odour	—	inoffensive to most consumers	
temperature	—	no guideline value set	
turbidity	nephelometric turbidity units (NTU)	5	preferably <1 for disinfection efficiency
zinc	mg/l	5.0	

Table 5. Radioactive constituents

Constituent	Unit	Guideline value	Remarks
gross alpha activity	Bq/l	0.1	(*a*) If the levels are exceeded more detailed radionuclide analysis may be necessary. (*b*) Higher levels do not necessarily imply that the water is unsuitable for human consumption
gross beta activity	Bq/l	1	

2.2 Application and Interpretation

Possibly the best illustration of the change which has taken place in the basic approach used is the change in the title of the document itself, i.e. from "Standards" to "Guidelines". This change is intended to reflect more accurately the advisory nature of WHO recommendations so as not to confuse these with legal standards which are the responsibility of the appropriate authorities in Member States.

In contrast to the old Standards, the Guidelines clearly recognize the desirability of adopting a risk-benefit approach (qualitative or quantitative) to national standards and regulations. The establishment of drinking-water quality standards must follow a very careful process in which the health risk is considered alongside other factors such as technological and economic feasibility. The establishment of standards without considering the practical measures which will need to be taken with respect to either finding new sources of water supply, instituting certain types of treatment, and in providing for adequate surveillance and enforcement, will not yield the desired results. In the Guidelines the need for careful consideration of the Standard setting process including follow-up activities are very much emphasized.

With respect to the above, the old Standards were rather inflexible, although some consideration was given to the difficulties which might be faced with respect to meeting the standards in areas with water resources which were inadequate in volume or quality. In the years since the last edition of the Standards was published, literally hundreds of comments have been received concerning the standards, with many of them citing the difficulties they had encountered in applying them.

It goes without saying that the possibilities for providing safe water differs greatly among the different areas of the world. There are differences between the areas of plentiful water and areas of water scarcity. There are differences with respect to ability to provide for treatment technology between the developed countries and the developing countries. There are differences between the water supplies for large metropolitan areas and those for villages and rural areas. Each case will require separate considerations if the resulting strategies, including the enactment of standards, are to be meaningful and achievable.

In the development of the Guidelines a debate took place as to whether or not WHO should prescribe different levels of water quality for different areas or for different types of water distribution systems. There were those that argued for a two-tiered or perhaps even a three-tiered approach whereby minimal guidelines would be proposed for those areas which could not, either for technological or economic reasons, meet the more desirable or safer levels which would be recommended for application elsewhere.

It was realized, however, that the WHO Guidelines are concerned with establishing the health basis and the health risk and as such they should provide a common basis for setting for individual standards. For this reason it was decided that only one degree of water purity could be recommended by WHO, while at the same time recognizing that in certain areas it would take a longer time to attain them which might include the adoption of some more inferior interim standards, but where the ultimate aim would be to attain at least the levels which have been recommended in the new Guidelines.

The emphasis of the Guidelines is placed first and foremost on the microbiological safety of drinking water supplies. More than half of the world's population is still exposed to waters that are not free from pathogenic organisms, resulting in infectious diseases that ultimately lead to increased mortality rates in the population. Those at greatest risk to water-borne diseases are infants and young children who have not yet developed a natural immunity, those people who are debilitated and the aged. For these, infective doses are often significantly lower than those required for infecting the major segment of the adult population. It is quite clear that in those areas of the world, programmes for assuring the chemical safety or the organoleptic qualities of drinking waters will be delayed except in those cases where it is quite evident that industrial effluents or agricultural run-offs are seriously endangering the water supply.

The new Guidelines while stressing the importance of monitoring and surveillance, clearly recognize their limitations, particularly for the small water supplies. For these in particular, it is emphasized that routine sanitary surveys and other protective steps are useful and often the only practical means for identifying existing or potential contamination problems and for instituting remedial measures.

2.3 Form of Presentation

In contrast to the 1970/71 WHO International and European Standards, both of which were issued as single volume documents, the new WHO Guideline are being published en three volumes. Each of these is intended to serve a different purpose and to a certain extent they are also directed towards different audiences. Volume
I will present the recommended guideline values per se (as shown in Annex I), together with essential information required to understand the basis for the recommended guideline values as well as information on monitoring requirements and where possible suggestions regarding remedial measures. This volume is primarily intended for those who are engaged in the standard setting process, as well as those that are responsible for the provision of safe drinking water. For each of the recommended guideline values, the toxicological and epidemiological basis for choosing a given value, and the health risk involved, are summarized including information on uncertainties, safety factors, multimedia routes of exposure, etc. Special attention are given to the ways and means in which these guideline values ar e to be applied and used.

The second volume, which will contain some 400 pages, is essentially an environmental health criteria document covering those substances/contaminants which were examined with a view to recommending guideline values. This volume contains a review of the toxicological, epidemiological and clinical evidence which is available. this volume elaborates greatly on the health risk information presented in Volume I and should be considered as a vital companion document.

Volume III of these Guidelines is intended to serve a very different purpose. It will contain recommendations and information concerning what needs to be done in small communities and in rural areas with respect to safeguarding their water supply. While it will detail some methodology concerning sampling and analysis of water supplies, a much greater emphasis is being placed on sanitary surveys and similar means of investigating the possibilities of contamination, particularly due to the presence of pathogenic organisms. The sampling and analysis of water supplies are limited to the basis techniques of multiple tube and membrane filtration as concerns bacteriology and simple methods for residual chlorine determination. This third volume is intended primarily for those authorities and people at the community level whose responsibilities entail the protection of public health or who may work in areas of general sanitation, etc. This volume is to be produced in much greater number and in more languages than will be possible with other two in the hope that these Guidelines can reach and be used by the local authorities in as many developing countries as possible.

2.4 Preparation

The way the new Guidelines were prepared also differs greatly from the previous editions. The approach used in preparing the earlier editions was generally for a few experts of an institution to prepare a draft document which, after some external review, was then submitted to a WHO expert committee for the final review and determination of the standards which were to be issued.

The preparation of the new Guidelines took over three years and involved the active participation of nearly 30 member States, literally hundreds of scientists and meeting of ten Task Groups. This effort was started in 1978 as a collaborative activity between WHO Headquarters and the WHO Regional Office for Europe. A planning meeting was convened in Copenhagen in 1978 where the basic plan for the development of the Guidelines was made. During 1979 the Danish International Development Agency (DANIDA) joined this effort by contributing funds to cover much of the cost involved.

Each of the major aspects of drinking water quality, i.e. microbiological, biological, chemical, organoleptic and radiological, was covered separately, in each case the relevant chapters being reviewed and finalized by a group of experts in the respective fields who made recommendations concerning the Guideline values themselves. In the case of the chemical aspects, this was further divided into two sub-groups - one concerning with health-related inorganics, with the other dealing with health-related organic constituents of drinking water. At various stages, the different sections of the document were reviewed by a national focal points for the WHO Environmental Health Criteria Programme which in many cases provided valuable inputs with regard to information available within their respective countries. The document was also reviewed by other international organizations and individually experts.

A final meeting to approve Volumes I and II of the Guidelines in their entirety, and in particular the recommended guideline values, was convened in Geneva in March 1982. It is expected that Volume I of the Guidelines will be issued prior to the end of March 1982, with Volume II being issued during 1983.
Volume III, I.E. Guidelines for Drinking-Water Quality: Surveillance of Rural Community Supplies, is still under preparation and a meeting to review and finalize it is to be convened in Bangkok in December of this year.

2.5 Guideline Values

The nature of the guideline values for drinking-water quality which WHO is recommending is not to be interpreted along the following lines:

A) A guideline value represents a concentration or a number which ensures an aesthetically pleasing water and does not results in any significant risk to the health of the consumer.

B) The quality of water defines by the Guidelines for Drinking-water Quality is such that it is suitable for human consumption and for all usual domestic purposes, including personal hygiene. However, water of a higher quality may be required for some special purposes such as renal dialysis.

C) A guideline values is to be used as a signal: (i) to investigate the cause when values are exceeded with a view to taking remedial action; (ii) to consult with authorities responsible for public health for advice.

D) The guideline values specified have been derived to safeguard health on the basis of lifelong consumption. Short-term exposure to higher level of chemical constituents, such as might occur following an accidental spill, may be tolerated. The amount by which, and the duration for which, any guideline value can be exceeded without affecting public health depends on the specific substance involved.

E) In developing national drinking-water standards based on the WHO Guidelines, it will be necessary to take account of a variety of local geographical, socioeconomic, dietary and industrial conditions. This may lead to national standards that differ appreciably from the guideline values.

In the following few sub-sections some of the basic technical issues involved with respect to the various aspects of water quality are highlighted. As mentioned before, the recommended guideline values are presented in Annex I. It is important to underline here that the guideline values by themselves are not a sufficient basis for their application or use - they must be taken into consideration along with the information contained in Volume I of the Guidelines and in some cases with respect to Volume II as well.

Microbiological and Biological Quality

To ensure the absence of pathogenic bacteria and viruses, the new Guidelines recommend that for all types of water supplies, whether they be piped or unpiped, treated or untreated, or bottled water, faecal coliform indicator organisms should be absent. With respect to total coliform counts, some leeway is permitted ranging from absence of total coliforms in treated waters entering the distribution system of piped supplies, to a limit of an occasional 10 organisms in unpiped supplies.

Routine methods for detection of pathogenic protozoans and helminths in water supplies are not currently available and coliform organisms are not good indicators for the presence or absence of these biological contaminants. For these reasons, guideline values were not proposed for these biological organisms.

Chemical Safety

Some 800 organic and inorganic chemicals have been found in drinking-water. It is of course not possible (because of lack of health effects data) nor practical to derive guideline values and subsequently standards for all of these. When selecting the chemicals for which guideline values were to be established, the following criteria were used:

A) The chemical were known to occur relatively frequently in drinking-water in significant concentrations;
B) The chemical in question had been identified as being potentially hazardous to human health; and
C) The means for monitoring (analytical methods) were known to be available for monitoring and control purposes.

The Task Groups concerned with chemical safety of drinking-water investigated in depth 37 and 46 inorganic and organic chemicals respectively and it was decided that sufficient health effects information was available for 9 inorganic and 18 organic constituents for which guideline values are now recommended. Where applicable, guideline values were based on an assumed daily water consumption rate of 2 liters per person. It was also considered that the guideline values should be protective for exposure to the chemical in question over a lifetime. In all cases, the recommended guideline-values were strictly designed to protect human health and thus may not be adequate for the protection of aquatic life.

For the majority of chemicals for which guideline values are recommended, the toxic effect in man was predicted from studies with laboratory animals. Considerable uncertainties are inherent in doing this which arise from the following factors:

A) Extrapolation of toxicological data from animal to man;

B) Extrapolation from high to low dose range at which the escape of the dose/response curve is not experimentally verified:

C) Lack of information about the intake of the chemical from water as compared to other routes of exposure, e.g. food and air.

For a number of the chemicals guideline values were derived from the no-adverse-effect dose in animals (or man where such data are available) and applying a safety factor in order to arrive at an acceptable level of exposure.
Guideline values recommended for a number of organic substances that are carcinogens or suspect carcinogens were based upon a linear multi-stage extrapolation model. These guideline values are based upon the selection of acceptable risk of less than one additional case of cancer per 100 000 population assuming again a 2-liter daily consumption of drinking-water by a 70 kg man.

In case of pesticides, the guideline values were derived from the acceptable daily intake (ADI) value set by the FAO/WHO Joint Meeting on Pesticide Residues with the assumption that not more than 1% of the ADI is allowed through drinking water. Since the ADI is derived on the basis of lifetime exposure, short-term excursions above the value such as those resulting from vector or aquatic weed control operations may be acceptable but would require careful surveillance.

Based on most recent information it has been found necessary to alter certain of the existing international standards for drinking-water. For instance, recent data on lead have determined that children and infants are particularly susceptible to the effects of lead. The guideline value for lead has accordingly been lowered in order to take these groups into consideration.

Considerable new information has accumulated since 1971 on the health effects of synthetic organic chemicals in drinking-water. Accordingly, it was possible to develop guideline values for a series of individual pesticides, polynuclear aromatic hydrocarbons, chlorinated alkanes and alkenes, certain chlorophenols and chloroform. Where the available health effects information was considered not entirely satisfactory, "tentative" guideline values were recommended.

The International Programme on Chemical Safety (IPCS) will considerably influence future updating of the guideline values for chemical substances. IPCS is a cooperative venture of the International Labour Organization (ILO), the United Nation Environment Programme (UNEP) and WHO, and has as two of its main objectives the evaluation of the effects of chemicals on human health and on the quality of the environment and the development of guidelines on exposure limits (such as acceptable daily intakes and maximum permissible or desirable levels in air, water, food and the working environment) for various classes of chemicals. Such an international assessment of human exposure to chemicals will be of considerable help in increasing the data base for any future revision of the Guidelines.

Aesthetic and Organoleptic Constituents and Characteristics

In the case of characteristics based on human sensory evaluation, judgement is often subjective. Aesthetic/organoleptic characteristics are very much subject to social, economic and cultural considerations, and the establishment of standards for the aesthetic quality of drinking-water should take into consideration implementation possibilities, and the existing socioeconomic and environmental constraints. When resources are severely limited, establishment in relation to their direct impact on health.

Radioactive materials

Guideline values for radioactivity en drinking-water are based on the most recent recommendations of the International Commission on Radiological Protection (ICRP). The guideline values recommended for gross alpha and beta activities apply both to naturally-occurring radioactivity and any radioactivity that may have reached the water sources as a result of man'*s activity. They represent a level below which water can be considered potable without more complex radiological examination.

2.6 Implementation

Safeguarding drinking-water supplies is a major health responsibility. The provision of save drinking-water has been identified among the priority elements of primary health care which is the basis of the WHO strategy for health for all by the year 2000. That this element be vigorously pursued is the responsibility of many sectors of the government of the Member States as well as of various professional disciplines. It should be considered of paramount importance not only by the ministries of health, but also by those who are charged with the management of water resources and the provision of water supplies for large cities as well as for small communities and villages.

It is the objective of providing safe drinking-water, with the emphasis on safe, that makes the guidelines an integral element of the International Drinking-Water Supply and Sanitation Decade. Thus the three volumes of the guidelines provide not only an important tool to secure safe supplies but also to set the yardstick for measuring progress and achievements towards the Decade goal.

Their application, however, has to take into account that water-related communicable diseases are rare in developed counties and there the chemical, aesthetic and organoleptic attributes may be of primary interest. Decade activities in countries still suffering from water-borne infections should find useful support from the microbiological and biological parts of the guidelines, and from the advice on their application. Volume III is specially intended to bridge the gab between the mere publication of guideline values and their actual compliance under often adverse conditions, technically and organizationally as well as in terms of the available manpower.

It is in the hope of the Organization that the guidelines will be actively utilized by the government at all levels to set new drinking-water quality standards where they do not yet exist or to up-date and expand existing ones. Standards embodied in the laws and regulations of a national or provincial authority do not automatically translate into improved water supply services and better health protection of the population. Vigorous assessment, monitoring and enforcement are the complementary actions the guidelines are now calling for.

The new guidelines provide a sound scientific basis (although with still some uncertainties) for establishing standards with respect to health protection. Thus, the law and policy makers are hopefully in a better position today to make the existing economic and technological feasibility match the criteria when setting drinking-water quality standards.

2.7 References

/1/ World Health Organization (1971) International Standards for Drinking Water, 3rd ed., Geneva, WHO.

/2/ World Health Organization (1970) European Standards for Drinking Water, 2nd ed., Geneva, WHO.

3 Surveillance Planning

3.1 Introduction

To be successful, any programme of water supply surveillance must be well planned. There are four key stages in planning for water supply surveillance, and each must be addressed and documented if the implementation of the programme is to be effective.

* The first stage is to decide the **objectives** of the programme.

* Secondly, it is necessary to determine who will be participating in the programme and how the different parties will coordinate their activities; this requires the development of an **organizational frame work** for the programme.

* Thirdly, in consultation with all interested organizations it is important to adopt preliminary **procedures** or **systems** for implementing surveillance in a pilot area. Later these procedures may be revised and improved several times, but it is nevertheless essential to agree on the general methodology before commencing activities.

* Finally, it is most important to agree a **strategy** for implementation. The strategy may involve several stages, but the key factors to include here are the time scales and budgets for implementation.

Thus a chronogram of proposed activities should be designed and budgets for all activities agreed.

TAB. 3.1 The Five Key Indicators of Drinking Water Supply Services.

Coverage	The percentage of the population receiving water from a specific system of source.
Quantity	How much water is used for domestic purposes (usually expressed in liters per person per day.
Continuity	The proportion of the time that water is available (which may be at a tap or standpipe, or the proportion of days when water is delivered).
Quality	Where there is a high morbidity due to faecal-oral transmission of diseases (as there is in most "less-developed" countries): * Analysis for faecal indicator organisms (thermotolerant or 'faecal' coliforms). * Sanitary inspection of the system to investigate the risk of contamination.
Cost	Cost of water supplied for domestic use.

3.2 Objectives of Surveillance

The effective surveillance and quality control of public water supplies are vital prerequisites for the protection of public health.

In practice however, the two activities of surveillance and quality control are often confused and inadequately implemented, especially in "less developed" countries. The two are clearly distinguished by WHO (1984):

> "In general, it is the responsibility of the local water authority to ensure that the water it produces meets the quality defined in drinking water standards. However, the surveillance function (ie a policing function on behalf of the public to oversee operations and ensure the reliability and safety of drinking water) is best conducted in a separate agency (whether national, state, provincial or local). Although these two functions are complementary, experience suggests that they are better carried out in separate agencies because of the conflicting priorities that exist when both functions are combined."

As a distinct activity, surveillance has been defined as "the continuous, vigilant, public health assessment and overview of the safety and acceptability of drinking water services" /WHO, 1976/.

Traditionally, surveillance has been linked to monitoring of water quality, although it is clear from the above definition that it is far broader activity, concerned with all aspects of water supply which may influence health, including both quality and availability.

Thus, surveillance is concerned with such key aspects of water supply as coverage, quantity, continuity, quality and cost, see table 3.1. Consequently, the general objectives of a surveillance programme should include some commitment to improving the health and well-being of the population.

In each country and indeed in each community, the individual influences of water quality, quantity, cost, coverage and continuity on the health or consumers will be different. In some places, water quality will be the most important factor, in others, poor availability may be the greatest threat to the health of the population. In a survey undertaken for the World Health Organization of water supply improvements, it was found that although improving water quality or water availability alone can be very valuable, improving both together was more likely to reduce the incidence of diarrhoea in the community /Esrey et al., 1985/.

Since it will be impossible to provide all communities with an optimal water supply, at least in the immediate future, informed decisions must be made regarding which remedial activities are to be undertaken. Although it might be desirable to research into each community to determine the intervention most likely to produce greatest improvements to public health, this would be impractical and costly. Therefore a more practical approach is to include all of the key criteria in the surveillance programme and to attempt to improve all aspects of the service whenever possible. In this way the programme has the greatest chance of improving the health and well-being of the population concerned.

So the general objective of a surveillance programme could be:

> "to contribute to the improvement of public health by the improvement of water services with respect to quality, quantity, coverage, cost and continuity."

In addition to general objectives, there should be a number of complementary specific objectives which are determined according to local circumstances. These will most commonly encompass the activities to be undertaken during the development of the programme and may for example include the preparation of a comprehensive water supply inventory, provision of training and equipment and coverage targets for surveillance. All of these may be linked to timescales.

Specific objectives should not be limited to data collection however. For example, it may be recognized that there is a particular need to promote public involvement in water supply or integrate aspects of health education and it may be decided that particular emphasis should be placed on these activities. Similarly it may be the case that there is a need to research and develop novel or different technologies for water treatment or supply and that some attention should be devoted to setting up experimental plants to prove and then demonstrate the technologies.

However, the specific objectives should not be over-ambitious. They should be clear and achievable within a sensible- and preferably defined-timescale.

There is no value in setting impossible targets. Evaluation is a necessary stage in project implementation and is greatly assisted by clearly defined project objectives against which progress can be assessed.

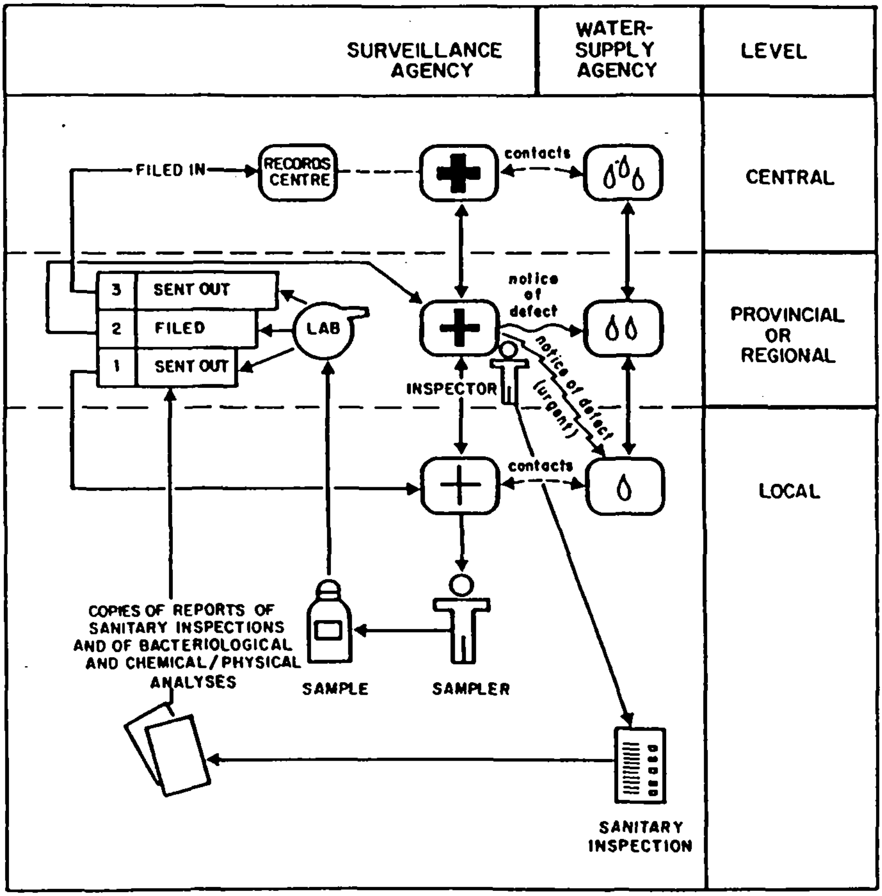
Finally, it is important to note that objectives should not be set in the capital city and simply imposed on those supposed to implement the programme. Objectives must be discussed and agreed at all levels following a period of genuine and wide consultation. If people are committed to a common goal and a common set of objectives, many of the problems of commonly encountered when implementing a project will be overcome simply and with good will. Time spent at this stage is never wasted.

3.3 Organizational Frameworks

In the World Health Organization's 'Guidelines for Drinking Water Quality (Volume 3)' a scheme for communication and coordination between the water supply and health sectors is proposed, see figure 1.

Experience has shown that surveillance is best undertaken by an independent agency - not the water supplier (who should, nevertheless, have their own quality control programme).

Since water supply surveillance is concerned with health, it is best carried out be the agency responsible for the protection of health. In most countries this is the Ministry of Health (or Public Health) and its regional or departmental offices. In some countries, there is an Environmental Protection Agency and in others, local government Environmental Health Departments may have some responsibility.



After WHO, 1985

FIG. 3.1 Flow chart for Communications and Action Related to Water Supply Surveillance.

But this does not exclude water supply and construction agencies from involvement in surveillance. In fact it is vital that they are involved.

While it is the responsibility of the health agency to generate and summarize surveillance data and to promote improvements, it is the water supply sector which will carry out many of the actions for improvement.

Personnel of all levels are involved in surveillance. Health promoters or environmental health officers generally collect the information and collaborate with health centre staff, local authorities and local supply agencies and their operators.

However, the information generated by surveillance is analyzed and used at all levels: in local, regional and national officers, in national planning agencies and by national commissions for sectors planning.

In some countries there may not be a clear division between health and water supply sectors, in others there may be a more complicated series of professional and governmental institutions than depicted in Figure 1. However, whatever the existing framework, it is important that the structure for implementing surveillance, disseminating the findings and taking remedial action are drawn in such a way as to make the responsibilities obvious and the lines of accountability and communication absolutely clear.

The organizational arrangements for implementing surveillance may be modified as the programme moves from the pilot stage to regional and then national replication. However, it is important that basic local, regional and national frameworks exist from the very beginning in order to avoid confusion later. Moreover, it is always better to develop and build on existing frameworks than having to invert them or change them radically during a programme.

When the organizational frameworks are settled, then it is possible to develop plans for coordination, mobilization of existing resources and to identify those areas where new resources are required. A list of requirements for each participating institution can then be devised according to the duties to be adopted by that organization.

3.4 Procedures and Systems

To achieve the objectives of a surveillance programme, it is necessary to develop, refine and then standardize methods. The procedures and systems adopted in the early stages of programme development are unlikely to be perfect and so care should be taken to make provision for regular evaluation and improvement of methods.

The most important procedures and systems for ensuring that the output from surveillance activities leads to real improvements in water services are:

A Methods for water sampling and analysis must be appropriate and standardized for both field and laboratory application.

B Methods for sanitary inspection must be developed in a form appropriate for the particular circumstances of the country and adapted for both rural and urban application.

C Systems must be developed for data acquisition, storage and retrieval and linked to effective reporting structure within the appropriate institutions;

D Training strategies must be developed and kept under constant review in order that they may evolve to meet the changing and expanding demands of the surveillance programme;

E Strategies for repairs, rehabilitations and other improvements to water supply services must be promoted and demonstrated to be practical and appropriate;

F Public participation and support must be mobilized and interest maintained by educational and promotional activities and by provision of technical support services to consumers and (where appropriate) caretakers and community drinking water committees.

G Mechanisms for setting, revising and enforcing standards for water supply services should be developed with all relevant Ministries represented.

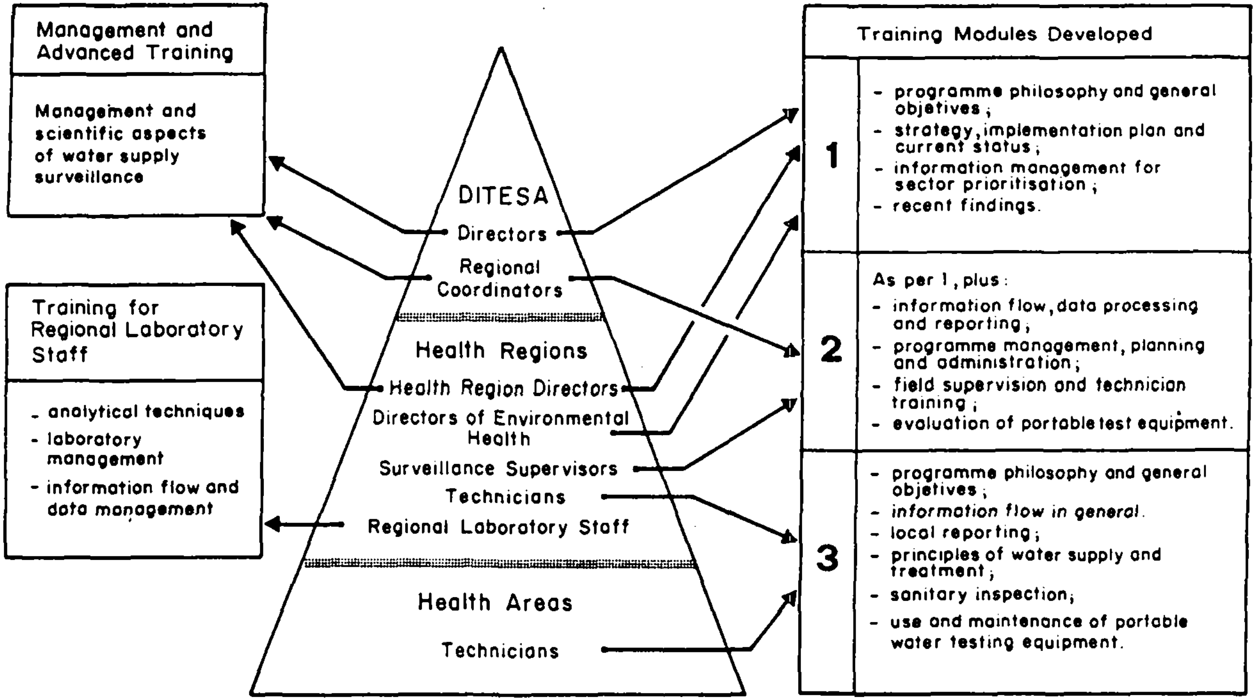


FIG. 3.2 Example of Human Resource Development for Surveillance in Peru.

Appropriate methods for water sampling and analysis and sanitary inspection are described in the next two chapters of this publication. They are also described in a number of World Health Organization publications /WHO, 1985, WHO, 1989/ and in technical manuals (for example Robens Institute, 1988/.

Systems for data acquisition, storage and retrieval can be based on paper records or computer databases. Both can work efficiently, the most important factors being accessibility to decision makers and reliability of reporting. It is very important that data are disseminated rapidly and reliably and in a useful format to all concerned, including the consumers. Only in this way will the output of surveillance be used effectively.

Some successful programmes, such as that undertaken in Peru /Robens Institute, 1990/ have also found it useful to produce regular news broad sheets with summaries of surveillance data in order to provide feedback and raise general awareness of progress. Such broad sheets also act as a mechanism for motivating those participating in the programmes since recognition can be wide and generous.

Training strategies and human resource development are vital to the successful implementation of surveillance /Wheeler, 1990; Robens Institute, 1990/. Ongoing training is required for at least three levels of staff: field workers, regional programme supervisors and national programme managers. In addition it is necessary to run awareness-raising seminars for certain categories of staff who may not have direct responsibility for surveillance but who nevertheless can contribute to achieving its objectives. These may include national and regional directors for health and water services and other policy makers.

3.5 Linking to Improvement

Methods for linking the output of surveillance to improvements are threefold: prioritization of resources at national and regional levels; promotion of public participation via education campaigns and the setting and enforcement of standards /Bartram, 1990/.

National Prioritization

Although in many water supply sector institutions it is the regional office which decides which communities are to receive support, decisions regarding the overall direction of funding (how much participation, for treatment or for research) are generally made at a central level, in the capital. Training curricula, be they for engineering degree courses, health promoters or rural water supply operators, and the structure of programmes such as community participation are also generally decided in the capital.

Often, the findings of surveillance will point to problems that are common or recurrent, for which strategies for improvement are best originated at central level. Corrective actions might include for example: changing training strategies or curricula; re-orientating investment if an area, sector or programme is under-funded; or reorientating programme strategies such as hygiene education if they are not achieving their aims.

Regional Prioritization

Similarly, at regional level, priorities can be better decided when there is hard evidence of problems in certain communities or with certain types of systems. This evidence must be systematic and should be generated by the surveillance programme. Deciding which communities should benefit from limited resources for water supply improvements is much better done on the basis of real priorities.

Surveillance and Education

Some of the problems identified by surveillance are engineering-based and require the support of a supply or construction agency involving them. Other problems, for instance those relating to operation and maintenance, also need the involvement of these agencies.

However, some of the findings of surveillance are not related to the supply system itself, but to the use of the water in the home. These include for example observations concerning:

A Water collection from standpipes, open wells, springs etc.

B Transport of water from a collection point to the household.

C Water storage in the home.

D Personal hygiene.

E Food hygiene.

The solution to problems in these areas cannot come from the supply or construction agency, or indeed from the community as a whole, but from families and individuals.

Education activities to help solve such problems are classified as health education or, more specifically, as hygiene education. They are generally carried out by the health agency, which is also responsible for surveillance. These educational activities can therefore be usefully carried out in parallel with surveillance and often by the same personnel during the same community visits. This reduces transport and sometimes personnel costs considerably and also ensures that the educational message is targeted according to the most common problems encountered in the community.

Enforcement of Standards

Finally, many countries have standards relating to water supply services and laws to enable their enforcement.

Water supply standards are not only related to water quality, they may include for example:

A Water quality as measured by microbial indicator organisms or physico-chemical parameters.

B Minimum requirements for chlorine residual in distribution networks.

C Plumbing codes and standards for construction and materials.

D Stipulations regarding the continuity of service; coverage, or volume requirements for domestic use.

E A national commission for regulation of tariffs.

The surveillance agency may decide to use these when they are not met as a means to ensure that actions for improvement are undertaken by the responsible agency.

However, enforcement of standards should take into account criteria such as feasibility and priority. To ask the impossible, whether due to financial, technical or personnel limitations is always unreasonable and may lead to a loss of credibility by the surveillance agency. The progressive enforcement of standards may, however, provide a means to ensure that improvements are made and that priority is given to communities where water supply services are worst. In some cases it may also provide a source of additional income for the surveillance agency.

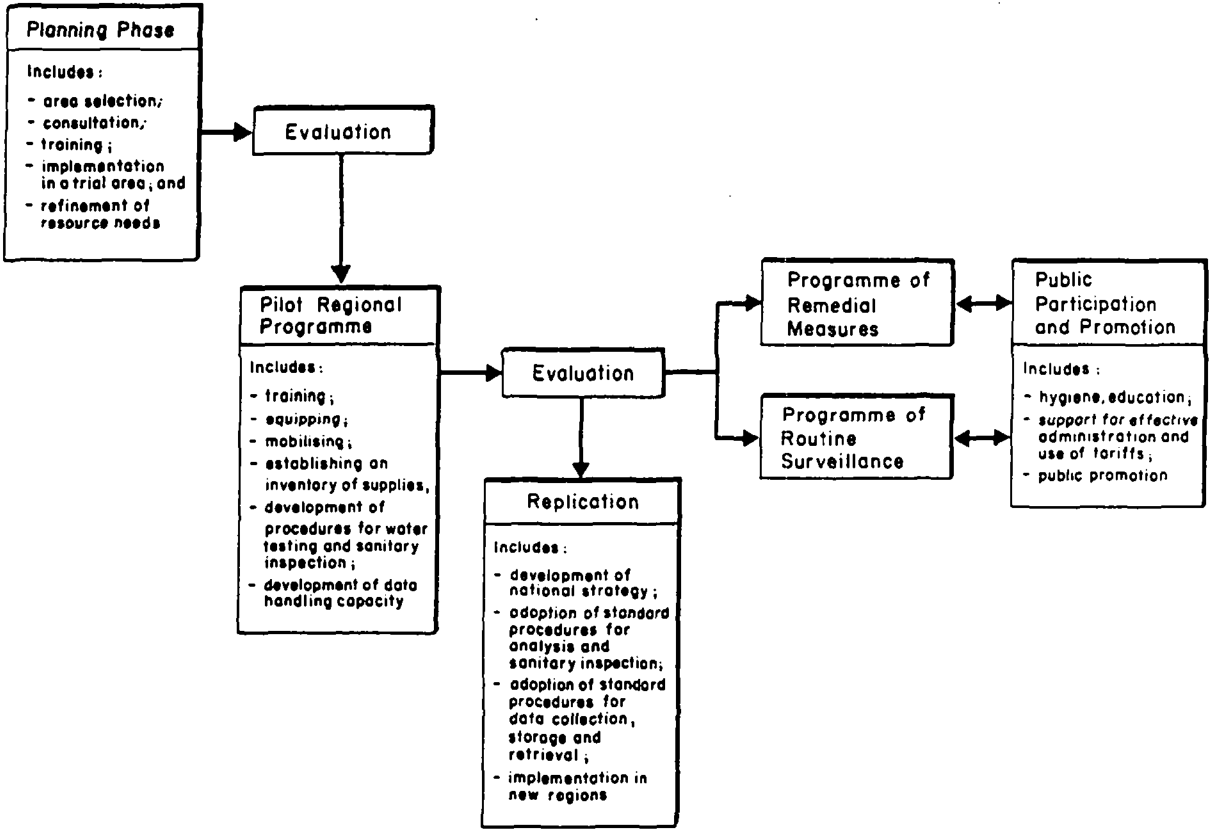


FIG. 3.3 Strategy Adopted for Progressive Implementation of Surveillance in Peru.

3.6 Strategies for Developing Surveillance

In the surveillance programmes implemented in less developed countries to date, it has been customary to commence activities with a pilot project before replication at regional and national levels. The pilot project allows the development, trial and revision of methods. Training syllabuses can be developed and plans of work tried. Eventually, routine surveillance can be established in the pilot region and serve as a model for replication to other regions.

The strategy for implementation must take account of the need for frequent evaluation and revision of methods during the pilot stage. Evaluation should be a programmed activity. It is often most conveniently done at the same time as training courses when project participants are brought together and can share problems and experiences.

There are several reports available on the strategies adopted in surveillance programmes sponsored by the World Health Organization /WHO, 1989; Helmer, 1989; Lloyd and Bartram, 1990; Lloyd and Helmer 1990/. The strategy adopted in Peru is illustrated in Figure 3. It shows how preparatory activities lead into a pilot regional programme and how this pilot programme reaches the level of routine surveillance, replication may occur. Employing this strategy, the Peruvian Government were able to establish the basis for a national programme of water supply surveillance over a period of five years.

For any strategy to be successful, there should be clearly defined timescales and budgets for each stage. Resources must be mobilized efficiently if objectives are to be realized and there should be regular revision of progress to ensure that both timescales and budgets are monitored.

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This Chapter is prepared by Wheeler D. & Bartram J. Robens Institute, 1988

4 Community Education & Involvement

4.1 Introduction

In recent years community participation has assumed an increasingly important role in development philosophy. This has been especially so in the health sector where, within the framework of primary Health Care, it has been stated that communities have both the right and the responsibility to be involved in the planning and implementation of their own health programmes. Similarly, in water supply and sanitation programmes, planners have come to realize that community participation is an essential ingredient for projects to be successful.

It cannot be expected that the switch-over from centrally managed to community based projects will happen overnight. In many countries it will require significant changes in policy together with the reorganization and reorientation of staff. There are some noteworthy examples where the switch-over has taken place and where communities have been encouraged to become involved in the solution of their water supply and sanitation problems. Where this has happened the role of Government has been to provide support to communities in their efforts to achieve their objectives.

The main components essential for community-based-health related activities are:

* Health Education.
* Government Involvement and Technical Assistance.
* Community Involvement in Water Quality Surveillance.

4.2 Health Education

Health Education can be defined as: the provision of information designed to arouse the perfection of people to have safe water supplies. Here a multifactoral approach often is necessary to achieve a substantial improvement of the health of the community members.

A safe, convenient reliable water supply is a basic need without which it is practically impossible to maintain a healthy environment. Nevertheless, it is not in it self sufficient to ensure god health; the water supply must be properly used, accompanied by adequate nutrition and food sanitation, as well as by proper excreta disposal. It is important for the health education programme to avoid creating an impression that water-quality surveillance by itself will prevent illness. It can lead to an improvement in health status but does not solve all problems.

These health-impact effects has been demonstrated in a study in Malawi (Young & Briscoe 1986) where it was shown that the risks of diarrhoea associated with the use of piped water were minimized when other environmental improvements had been made. When piped water or latrines were available no reduction in the risk of diarrhoea was observed compared to the risk for those children with traditional water sources and no latrine. However, the combined effect of safe water supplies and a latrine reduces the risk of diarrhoea 2 - 4 times. If the children also were breastfed the risk were reduced 3 - 8 times. Other studies however, have shown a clear effect solely on the intervention on drinking water.

In a controlled experiment, household water containers were regularly cleaned and refilled with chlorinated water, while a control group received a placebo of distilled water. The reduction in childhood diarrhoea in the group receiving the chlorinated water was 75% greater than in the placebo group.

An interesting outcome of this experiment was that the placebo group recognized the improved health status of the group receiving chlorinated water and concluded that the waters were being treated differently. This led to the demand for similar treatment, and all of the families were eventually given chlorinated water. The results obtained in this experiment suggest an approach that can be followed by health workers concerned about water quality. Similar demands from the community, and greater perception towards sanitary precautions have been achieved by using bacteriological tests to demonstrate contamination of water in water sources and drinking water containers in the houses (Enge 1985, Lindskog 1986) in Botswana and Malawi. A summary of the health education approach of the Water Hygiene Camapign in Botswana are given as Annex 1 of this paper.

4.3 Government Involvement

Programmes which involve more participation increase the emphasis on planning at the community level. However, most communities need the support of regional and national agency offices.

Increasing participation at the community level therefore means increasing the demand for support services on sector agencies at all levels. In particular, heavier demands are made for manpower and training - both of which have been constraints to progress in many countries in the past.

Community participation places heavier demands on human resources, training and evaluation but results in continued operation and maintenance of facilities.

The role of the agencies, coordinations and manpower requirements have been exemplified in the recent "Guidelines for Planning Community Participation" (Whyle 1986).

However, it must be emphasized that an overorganization of the role of central or local administration may be as bad for the communities as no activities at all. The essential steps are:

* The perception and concern of the administration and agencies of the goals of the activities
* Functioning information channels to respond to simple needs in relation to facilitators
* Simple technical assistance

To many programmes have been started in developing countries with the sole goal to provide a stated number of new water sources or sanitation facilities. These activities are deamed to fail, if the activities are not combined with proper operation, maintenance and integrated approach of channels of technical assistance within the local organization and combined with health education. Estimation of the needs of spare parts and channels for providing them are common failure. Similarly, the identification of key persons within the communities and the provision of simple training are also often lacking.

As an understanding of the water/disease relationship grows, and people recognize a need for surveillance in order to maintain the good quality of the water supply, the community should be encouraged to increase its surveillance activities and improve the water system. Several options are available whereby such activities may be implemented. One is the selection of community volunteers to undertake the surveillance activities.Another is for the community to provide a stipend to local worker to carry out whatever day-to-day tasks are needed.

In either case, some minimal amount of training by the Ministry of Health of the water-supply agency will be needed, as well as the establishment and maintenance of a reporting system. At the local level, some measure of management will be required through a community water committee, health committee, or similar structure.

4.4 Community Involvement

If motivation and perception of health-related water and sanitation aspects has become a part of the community through proper health education and through provision of simple technical assistance the communities will be partly independent and self-reliable in these aspects. By identifying key persons within the community to keep up with specified objects of surveillance activities the gained positive effects may be ensured. Tasks for such key persons may be:

* inspecting supplies in order to detect actual or potential contamination of water resulting from human or animal activities near the source of supply;
* devising and implementing, possibly with help from the community, methods for protecting the water source for contamination;
* advising water users on procedures that will prevent or diminish the chances of contamination of the water supply and the containers used to transport and store water;
* taking samples of water periodically for transport to the nearest laboratory for analysis; alternatively, tests may be carried out in the field if suitable equipment is available;

* reporting the findings of inspections to the local committee and the Ministry of Health and/or the water-supply agency;
* if the water supply is chlorinated, carrying out periodic field analyses for residual chlorine;
* informing the community of the results of analyses and inspections and explaining the implications of these results with respect to health, with the objective of stimulating involvement in actions to keep the water clean and safe.

By bringing up these or other actions in village committees (or similar) continuous protective actions may be ensured within the communities.

4.5 Campaign in Botswana

During the water quality Study in Botswana 1982 it was concluded that about 85% of the water sources (mainly deep drilled wells) had a good water quality. It was also observed that most of the traditional water sources was heavily contaminated, although the water was fetched from good quality sources.

The contaminated water in the household containers and the disease pattern in the country demonstrated the need to make an educational programme in relation to water and hygiene. Therefore a Water Hygiene Campaign was started in August 1984 and proceeded in its first phase until July 1985. The programme has been a country-wide information programme, aimed towards a higher awareness of the link between water and health, both at the central, regional and village levels. The campaign has been launched under three simple messages, namely:

* Keep the water clean
* Use more water for personal hygiene
* Keep to standpipe water

Many of the activities have been directed towards key groups that in its turn would be able to influence and bring the messages forward to the village people. The key groups were:

* The Regional Health Teams.
* The Family Welfare Educators.
* Literacy Workers.
* Water Technicians and Pumpers.

Educational material, bringing forward the messages in a simple and easily understandable manner is an essential ingredient for a successful start and for long lasting effects in relation to information and educational programmes. Therefore the following material was produced:

* Water Hygiene Handbook (directed towards all primary and secondary schools, Teachers Training Colleges, Regional Health Teams, Water Units, District Councils etc). This handbook will be translated into the local language - Setswana.
* Water Hygiene Workbook (directed towards primary and secondary schools).
* Moloi wa Metsa and Phepafatsang Metsi (booklets for the literacy programme in local language).
* pamphlets, group-works and posters were also produced and distributed; and the awareness were kept up by articles in the newspapers as well as radioprogrammes.

In addition the message was brought forward in two national workshops in eleven regional workshops (participants were health personnel, extension workers, teachers, district councils staff, water unit staff, voluntary organizations etc) and village workshops (for key persons within the community).

The local key groups have brought the activities further on in their day to day work in the villages and by that, hopefully, gradually changes the habits of the people and enhancing the hygienic awareness. Storing the water in a hygienic manner in the houses, hand-washing campaigns and linking the work with the primary health care and educational activities have been essential approaches.

Water analysis has proved to be a very useful tool in the programme. By using bacteriological water analysis as a tool to demonstrate fecal contamination;

* a greater awareness has been reached among the key groups for the need of the campaign.
* a tool exists to evaluate the hygienic influence of new storage habits of water in the houses.

The programme has brought forward the following essential issues of a community education programme.

* Training of trainers. The programme has largely been directed towards local groups of people working in the villages and regions.

* Links to education and health. Changing of habits are a gradual process. The messages has to be brought forward continuously. This can only be ensured if the work is brought into the system.

* Evaluation and assessment. Bacteriological analysis has proved to be a useful tool in:

  A) assessing the situation.
  B) enhance the awareness among community workers and villagers
  C) useful in demonstrating the degree of contamination
  D) a tool for evaluating new habits in relation to storage and technical and hygienic preventive measures.

* Intensive, multi-channel approach.

* Simple, understandable messages.

* Simple booklets, linked towards literacy programmes and primary/secondary schools will ensure a lasting effect.

The deficiencies with the programme is that its continuation and feed back channels are not ensured. That follow-up activities of trainers are essential to bring back positive and negative aspects etc.

4.6 References

This chapter is based on a paper given by T. A. Stenström.

5 Sanitary Inspection

5.1 Introduction

In chapter 3 attention was drawn to the importance of linking the outputs from surveillance activities to the prioritization of improvements in water services. In this context, two important outputs from surveillance are the results of water quality analysis and sanitary inspection. Together they provide the basis for assessing the risks to human health from poor water quality.

Water quality analysis and sanitary inspection are complementary in that some correlation between risk factors identified by visual inspection and the presence and degree of contamination identified by water quality testing is often observed (Lloyd and Suyati, 1989, Lloyd and Bartram, 1990). However, it is important to note that they are not interchangeable. Sanitary inspection enables detection of risks of contamination which will not be found by analysis unless contamination is occurring at the moment of sampling; it is also important in identifying the source of sources or contamination. In contrast, analysis provides solid evidence that contamination is occurring, can quantify the degree of contamination and also enables detection of invisible sources of contamination such as that which occurs in pipes of distribution networks or distant contamination of aquifers.

In some surveillance programmes a great deal of attention has been devoted to the development of simple-to-use sanitary forms. These generally take the form of either pictorial or written checklists which assist the inspector to make a rapid assessment of risk factors for onward communication to those responsible for the water supply. Some examples are shown in figures 1-3. An important aspect of these forms is the use of clear questions leading to yes/no answers which will be answered in the same way by all technicians; thereby minimizing subjectivity in reporting.

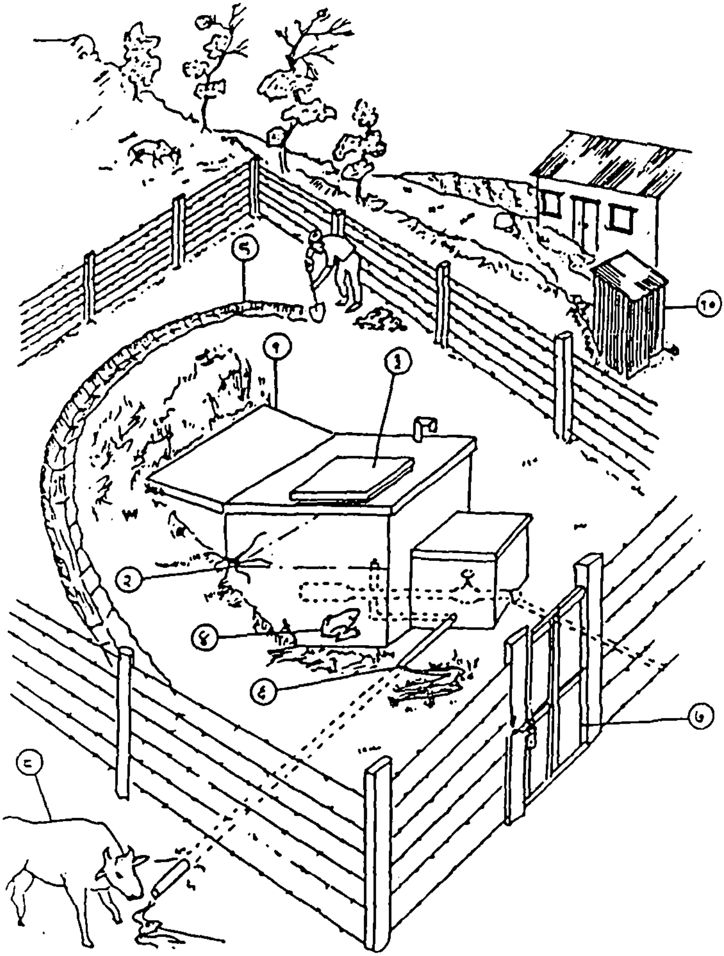

FIG. 5.1 Example Sanitary Inspection Form for Protected Spring Source (Nepal).

TAB. 5.1 *A scheme used for surveillance of spring water in Nepal.*

Nepal: Rural Water Supplies - Gurkha Welfare Trust
Water Surveillance and Improvement Programme

Sanitary Survey for the Assessment of Risks of Contamination of Drinking Water Sources

A Type of facility: **SPRING SOURCES**

B General information:

1 Welfare Centre________________ Village________________
2 Date of visit____/____/______ Code No________________
3 Sponsor________________
4 Water sample taken?____________ Sample no________________

C Specific information concerning risks at points of abstraction:

		Risk	No Risk
1	Is the spring source unprotected by masonry or concrete wall or spring box ? Open to surface contamination.	___	___
2	Is the masonry protecting the spring source faulty ?	___	___
3	If there is a spring box, is there an insanitary inspection cover in the masonry ?	___	___
4	Does the spring box contain contaminating silt or animals ?	___	___
5	If there is an air vent in the masonry? Is it insanitary ?	___	___
6	If there is an overflow pipe, is it insanitary ?	___	___
7	Is the area around the spring unfenced ?	___	___
8	Can animals have access within 10 m of the spring source?	___	___
9	Is the spring lacking a surface water diversion ditch above it or, if present, is it non-functioning ?	___	___
10	Is there any latrine upstream of the spring?	___	___

D Result and recommendations:

Total score of risks : ______________ (out of 13)

Contamination risk score: ______________
(9-10 = Very High, 6-8 = High, 3-5 = Intermediate, 0-2 = Low)

*Comments on required remedial action:*____
____
____

E Signature of sanitarian ____________________ , date ______________

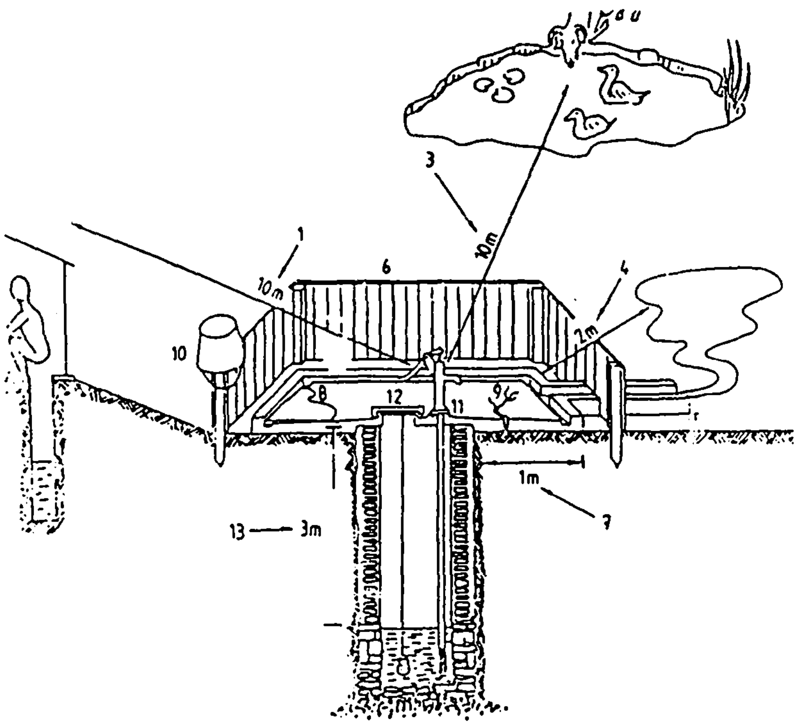

FIG. 5.2 Example Sanitary Inspection Form for Dug Wells with Handpumps (Thailand).

TAB. 5.2 A scheme used for surveillance of Handpump/Dugwell in Indonesia.

Environmental Health Division — Department of Health, Ministry of Public Health

Water Surveillance and Improvement Programme

Sanitary Survey for the Assessment of Risks of Contamination of Drinking Water Sources

A Type of facility: **Hand Pump on Dugwell**

B General information:

1 Health Centre ____________ Village ____________
2 Date of visit ___/___/___ Code No. ___/___/___/___
3 Community representative ____________
4 Water sample taken ? ____________ Sample No. ____________
Faecal count ____________ Grade ____________

C Specific information concerning **Risks at Point of Abstraction**:

		Risk	No Risk
1	Is there a latrine within 10 m of handpump?	___	___
2	Is the nearest latrine on higher ground than the handpump?	___	___
3	Is there any other source of pollution within 10 m of the handpump? e.g. animal excreta, rubbish, surface water.	___	___
4	Is there any ponding of stagnant water within 2 m of the cement floor of handpump?	___	___
5	Is the handpump drainage channel faulty? Is it broken permitting ponding? Does it need cleaning?	___	___
6	Is there inadequate fencing around the installation, which would allow animals in ?	___	___
7	Is the cement floor less than 1 m radius all round the handpump ?	___	___
8	Is there any ponding on the cement floor around the handpump ?	___	___
9	Are there any cracks on the cement floor around the handpump?	___	___
10	Is a bucket also in use and left in a place where it could be contaminated ?	___	___
11	Is the handpump loose of the point of attachment to base? Which could permit water to enter the casing.	___	___
12	Is the cover of the well insanitary?	___	___
13	Are the walls of the well inadequately sealed at any point for 3 m below ground level?	___	___

D Result and recommendations:

Total score of risks : ____________ (out of 13)

Contamination risk score: ____________
(10-13 = Very High, 6-9 = High, 3-5 = Intermediate, 0-2 = Low)

Comments on required remedial action: ____________

____

____

D Signature of sanitarian ____________ , date ____________

TAB. 5.3 Checklist Used for Sanitary Inspection of Piped Water Supplies (Peru).

I Distribution
- Free of leaks
- Permanent pressure

II Conduction line
- Free of leaks

III Reservoir
- Sanitary lid ?
- Secure (locked)?

IV Disinfection
- Is there chlorination equipment ?
- Is there a stock of chlorine?
- Is the equipment operating?

V Treatment
- Is there a sedimentation basin ?
- With diffusing baffle ?
- Outlet occupies full width ?
- Is there a roughing pre-filter ?
- Is there a slow sand filter ?
- With a minimum head mechanisms ?
- Is the plant secure (locked) ?

Spring source
- Is there a protecting plinth?
- Is there a sanitary lid ?
- Animals excluded within 10 m ?
- Secure (locked) ?
- Surface water diversion ditch ?

Conduction line to reservoir ?
- Free of leaks ?
- Pressure break boxes with sanitary lid and secure.(answer yes if no p.h boxes).

VI Intake
- Secure (locked) ?
- Flow control.

5.2 Programme Planning

Usually, sanitary inspection will be accompanied by water quality testing and so many of the pre-requisites for effective water sampling apply to inspections. They include the availability of well-trained and motivated staff, the provision of adequate transportation and logistic support, and access to financial resources for operating costs.

5.3 Inventory

An important early step is to construct a comprehensive inventory of all water supplies. This can initially be based on the registers of construction and administration agencies and subsequently be expanded to incorporate other supplies when they are identified.

The inventory enables planning of inspections and will be of use later when promoting remedial actions.

Information which must be contained in the inventory for each system includes its location and the agency responsible for the system, the type of system and its components, the total population and population served, and the arrangements for operation and maintenance.

An inventory form may be used for initial registration of systems which is distinct from the sanitary inspection form. It contains information which is not prone to change such as location, system components, administrative agency and the presence of a health post.

5.4 Field Report Forms

The field report form may incorporate the inventory form, or may be a separate form to facilitate rapid assessments. It should encompass sanitary inspection and should therefore include at least a checklist of the components of the system from source to distribution incorporating the key points of risk pertaining to each. Any problems with a particular component can then be highlighted and a report provided to the community, the agency responsible for the supply and the surveillance authorities. The field report form should also include assessments of water supply service quality other than water quality, such as a cost, coverage, continuity and quantity. In countries where there are many different types of supply, several district field report forms may be used or a standard form may run to several printed pages, see table 5.2 & 5.3.

The design evaluation and revision of adequate field report forms is an important aspect when developing a surveillance programme. Aspects to be borne in mind include:

* Ensuring that only the necessary information is collected. It is all too easy to over-burden field staff with collecting superfluous data;

* Ordering the questions to coincide with the order in which work is undertaken;

* Where on-the-spot reporting is to be undertaken, the field form may incorporate or be accompanied by an appropriate report form.

5.5 Risk Analysis

Attempts have been made in some surveillance programmes to quantify the output from sanitary inspections by means of a numerical score which reflects the degree of risk which the system represents. In Indonesia pictorial forms were used to generate risk scores on a scale of 0-10. In Peru, a similar numerical classification scheme was developed (Table 1).

These scores have all been based on the number of risks identified from a pre-determined list of recognized sanitary risks. When the sanitary inspection forms used provide yes/no answers, the degree of risk is readily quantified by calculating the proportion of answers which indicate that there is a risk of contamination occurring. This is facilitated by phrasing questions in such a way that all "yes" answers indicate that a risk exists and "no" answers that it does not.

Clearly the ideal method of calculating a risk score would assign higher scores to risk factors of greater importance. To date however, an adequate scientific basis for such relative score has not been developed.

The principal advantage of making the sanitary inspection quantitative is that prioritization of remedial actions can be based on a rational comparison of the degree of risk presented by a number of water supply schemes. This is especially important where funds available are limited and must be employed to maximum public health benefit as is the case in many less-developed countries.

TAB 5.4 Classification scheme for sanitary inspection score for Peruvian drinking water supplies.

Sanitary Inspection Score		Risk Classification
0	≈	No risk
1 - 4	≈	Low risk
4 - 6	≈	Intermediate to high risk
7 -10	≈	Very high risk.

5.6 References

Lloyd, B. J. & Bartram, J. K. 1990. Surveillance Solutions to Microbiological Problems in Water Quality Control in Developing Countries. Proceedings of International Conference on Health-Related Water Microbiology, IAWPRC, Tubingen, Germany, April 1990 In press in J Water Sci Tech.

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This chapter is prepared by David Wheeler & Jamie Bartram, Robens Institute 1990.

6 Analytical Programmes

6.1 Introduction

In many less developed countries it is not presently possible to establish a laboratory infrastructure which will enable all water samples to be returned to a central or regional laboratory within a few hours of being taken. This is an ideal which depends on excellent roads and the availability of reliable motorized transport for all sampling officers. Thus, some compromises have to be made.

Whereas it may be possible to establish well equipped central and even regional laboratories for water analysis, at the provincial and district levels reliance may have to be placed on relatively few simple tests to ascertain if water supplies are wholesome. This approach is sometimes called "critical parameter" water testing. The justification for relying on a few key water quality tests for remote small communities is described in WHO's 'Guidelines for Drinking Water Quality', (vol. 3). The most important point is that in most rural locations, the principal risk to health derives from faecal contamination.

In some countries there may also be hazards associated with specific chemical contaminants such as fluoride or arsenic. However, the level of these compounds is unlikely to change significantly with respect to time and thus if a full range of chemical analysis is undertaken on new water sources and thereafter at extended intervals, any chemical contaminants are unlikely to represent an unrecognized hazard. In contrast, in untreated or inadequately treated small community supplies from unprotected sources, the potential for faecal contamination is ever-present. Thus, the minimum level of analysis should always include testing for indicators of faecal pollution, turbidity and chlorine residual (if disinfection is practiced).

Even in a developing country which is poorly serviced with respect to roads and transportation it is usually possible to devise a rational sampling and analytical strategy. This should incorporate carefully selected critical parameter testing in remote, usually rural locations using simple methods and portable testing equipment when appropriate.

In the following sections it is envisaged that a central laboratory facility is established to undertake a full range of chemical, physico-chemical and microbiological tests on water. This central laboratory should take responsibility for training laboratory technicians in regions and provinces according to nationally accepted standard methods. The central laboratory is expected to have the capacity to conduct quality assurance procedures for its own analysis and provide external quality control for those of any regional laboratories.

The regional laboratories are expected to have the capacity to undertake a moderate range of analyses including anions and some metals. In addition, regional facilities should provide a back-up service to remote areas, providing media and consumables to those technicians who are conducting a strictly limited number of tests using simple office-based or portable equipment.

In general, simple analyses which provide information of immediate value should be conducted more frequently than complex analyses, particularly for compounds of little relevance to health or process control. Analytical procedures should wherever possible be standard and subject to good laboratory practice and analytical quality control. Finally, some analyses should be conducted on every occasion that a water supply system is visited; these analyses are termed 'critical parameters', and include faecal (thermotolerant) coliforms, chlorine residual and turbidity.

6.2 Laboratory Preparation

Information on equipping laboratories for water analysis is contained within the WHO publication 'Equipping Laboratories in Developing Countries'.

In order to establish a water quality assessment programme, suitable laboratory facilities must be established. The laboratories must be adequate for their purpose, kept clean and free from contamination and other operations carried out in the laboratory must not adversely affect the water analysis programme. Each laboratory must be equipped with appropriate apparatus and staff capable of carrying out the desired tests.

TAB. 6.1 Considerations in Quality Assurance.

A Lab personnel:	1 Qualifications. 2 Experience. 3 Training. 4 Clearly defined responsibilities
B Space sufficient:	* For the types of analyses being undertaken. * For the numbers of analyses being undertaken.
C Equipment:	* Adequate * Regularly serviced and maintained * Calibrated and used only by authorized personnel
D Samples:	* Facilities for receipt and storage.
E Data:	* Archived. * Retrievable.
Methods:	* Validated. * Documented. * Monitored (quality control).

Instruments should be regularly serviced, maintained and calibrated and records of these checks should be kept. It is also desirable that standard operating procedures (SOPs) for all equipment be written and that these include the name of the person responsible for that equipment.

Sensitive analytical equipment such as balances, spectrophotometers and chromatographic equipment should be installed in suitable locations. Their performance can be adversely affected by excess vibration, fluctuations in power supplies and excessive variations in temperature and humidity. Most instrument manufacturers list specifications for their instruments and these should be adhered to. Some instruments have special requirements such as high purity gas supplies for gas liquid chromatographs and fume extraction facilities for atomic absorption spectrophotometers. Adequate facilities for storing samples must also be available.

Individual analytical methods should also specify all relevant details on the preparation and storage of reagents. Reagents should be clearly labelled with their nature, concentration, storage conditions, expiry date, when they were prepared and by whom. It is usually desirable to obtain reagents of the highest purity commonly available since trace impurities may interfere with a method. Reference standards require particular attention.

6.3 Laboratory Safety

All laboratory staff should be trained in laboratory safety. This training should include, where appropriate, ancillary staff such as cleaners. The training programme should include items such as an appreciation of biological, radiological and chemical hazards, information on the safe use of all instrumentation, including ancillary equipment such as gas cylinders, on safe clean-up of spillage, and an appreciation of laboratory discipline; for example, smoking, eating and drinking should not be allowed. Trainees should work under supervision until they are fully conversant with safe working procedures.

The laboratory should be equipped with fire protection equipment, hand and eye-wash facilities and personal protection items such as gloves, goggles and overalls. A member of staff should be nominated as Safety Officer. The Safety Officer is responsible for the implementation of a laboratory safety programme. This should encompass procedures for accident reporting and for authorization of 'out of hours' work. It is desirable that someone qualified in first-aid be readily available to deal with minor injuries.

6.4 Quality Assurance

The use of standard methods does not in itself ensure that reliable and accurate results are obtained.

In the context of analytical work, the terms quality assurance and quality control are often treated as synonymous although this is not strictly true.

For the purpose of this section the term 'quality control' is used to describe the generation of data to assess and monitor how good an analytical method is and how well it is operating. This is normally described in terms of within-day and day-to-day precision.

The term 'quality assurance' is used here to describe all the steps taken by a laboratory to assure those who receive the data produced that the laboratory is producing valid results. Quality assurance thus encompasses quality control but also includes many other aspects such as proving that individuals were competent to carry out an analysis, and ensuring that the laboratory has established and documented analytical methods, equipment calibration procedures, management lines of responsibility, systems for data retrieval, sample handling procedures, etc.

For each parameter to be determined, the most suitable method should be chosen and validated. Whenever possible standard methods should be chosen as these have usually been validated in other laboratories. However, it is still necessary to demonstrate that the method is working using local reagents and apparatus, and this does not obviate the need for quality control (see section 6.5).

Once a method has been validated, it is important to document the procedure and to have a formal system for implementing any updates or modifications. Other aspects which need to be considered include the production of standards, regular calibration of balances and pipetting aids and care in the keeping of records. Perhaps the most important aspect of quality assurance is to implement a quality control programme.

When a piece of work is complete, all results should be checked and only issued by authorized personnel. The raw data used to generate results should be retained for a specified period, and should be identifiable.

The aim with quality assurance is not just to provide valid results but to prove that they are valid. The approach required is to establish and document good procedures rather than relying solely on scientific and professional judgment.

6.5 Analysis Quality Control

Before analyzing samples with a particular method, tests should be carried out to provide an estimate of the within-day and day-to-day precision of the method.

Precision is defined as the spread of results around the mean result, whereas accuracy is the spread of results around the true result. A method may therefore be very precise but not accurate. In order to determine precision, replicate measurements are carried out on aliquots of the same sample from which precision may be calculated.

Calibration standards and blanks (including field blanks if available) should be analyzed with every batch of samples.

Quality Control schemes may be 'internal' or 'external'.

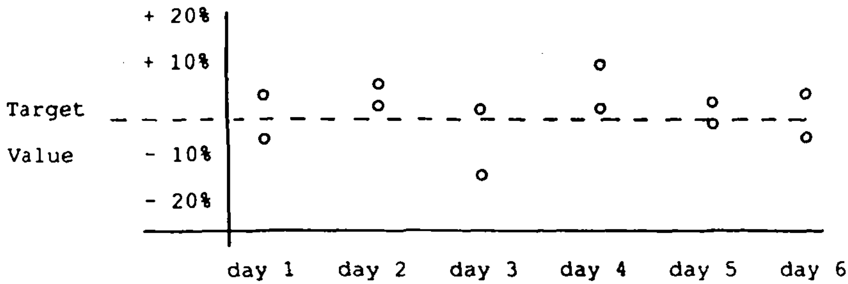


FIG. 6.1 Example Internal Quality Control Chart.

Internal schemes provide an understanding of day-to-day variation due to the intrinsic characteristics of the method or operator changes. However, internal quality control alone does not ensure reliable results since operators may be able to give special care to such samples. External quality control is not subject to such bias. Normally, external quality control is coordinated by a reference laboratory who provide samples to be analyzed by associated laboratories. Since the results are unknown to the associated laboratories, operator bias is limited, but quality control samples may still be afforded special attention.

A simple internal quality control programme can be set up by taking a large water sample and spiking it with the desired analyte (or using a 'real sample') at a suitable concentration. The sample is then aliquoted and stored under suitable conditions. Each time a batch of unknown samples is assayed, one or more quality control samples is assayed along with unknowns, blanks and calibration standards. A quality control chart (see figure 6.1) is then constructed allowing the laboratory manager to monitor performance of the method.

In addition to internal quality control programmes, whenever possible it is desirable to set up external quality control schemes. These involve the central laboratory preparing samples to be sent to the regional laboratories for analysis. All laboratories assay the same sample and send in their results to the central laboratory. Regional laboratory managers receive a chart telling them how well their results agree with other laboratories carrying out the same assay. An example of a simplified result sheet is shown in figure 6.2.

The advantage of an external scheme is that it allows the laboratory to compare its own performance with others, thereby allowing greater confidence in its own results and also highlighting particular analytes requiring improvement. An external quality control programme should be used in conjunction with a good internal programme.

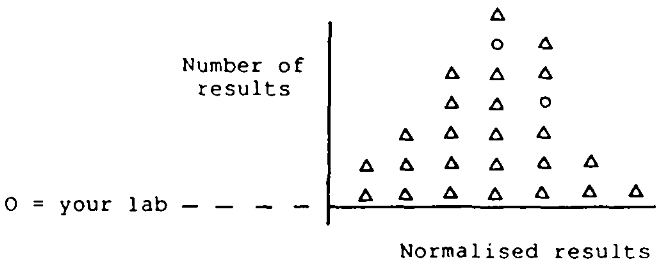


FIG. 6.2 **Example External Quality Control Result Sheet.**

6.6 Training

In addition to safety training it is important to have regular training of staff in laboratory methods.

Before staff can carry out tests on samples, they should have been shown how to carry out the method. Staff should then work from a method sheet and show that they can produce valid results, for example by producing at least two standard curves for a quantitative analysis or by assaying quality control samples or samples previously assayed by an experienced analyst before being allowed to analyze "real" samples. Records of each individual's training should be kept. One useful system is for the laboratory manager to categorize staff into, for example:

* Competent to carry our work under supervision.
* Competent to carry out work unsupervised.
* Competent to provide training and supervise others.

Movement between these categories should be linked to defined performance targets and should be possible in both directions.

As an individual attains each category the manager signs and dates the individual's record. The training record could include a list of equipment the individual is authorized to use and individual tests they are authorized to undertake.

A more general training programme should include items such as safety, fire fighting, data handling, quality assurance and also an appreciation of how their results will be used and their importance. Training records also ought to include attendance at any relevant training courses and symposia.

6.7 Data handling

Results should be authorized by laboratory management only after they have been checked for calculation errors and that quality control is satisfactory. The results should be quoted in the appropriate units (for example mg/liter), and should only use the appropriate number of significant figures. The results should be presented in a form designed to satisfy the needs of the user. All raw data should be placed in an appropriate archive for a specified time period.

6.8 Sampling Frequency

Samples should be taken from locations which are representative of the water source, treatment plant, storage facilities, distribution network and household connections. Where there are several sources and a mixed distribution system, it is necessary to take account of this. Where there is a branched distribution system, samples should be taken at random points spread evenly throughout the system. Where there are main branches and a remote periphery, greater attention should be devoted to these main branches and remote parts of the network.

Three critical parameter tests for water quality surveillance or monitoring are bacteriological quality, chlorine residual and turbidity. These tests may be described as 'minimum monitoring' and should be undertaken each time a sample is taken, regardless of how many other chemical or physico-chemical tests are performed.

As a guideline, in large urban populations (of greater than 50,000 inhabitants) samples should be taken for minimum monitoring from the distribution system at a rate of at least one sample per 5,000 of the population per month. For smaller populations the scheme outlined in table 2 may be followed:

TAB. 6.2 Suggested Sampling Frequency for Analysis of Faecal Coliforms, Turbidity and Chlorine Residual.

Population	No of samples taken at the treatment	No of samples taken from plant distribution	Max sampling interval
<1,000	1 per quarter	4 per quarter	3 months
1,001 - 2,000	1 per quarter	6 per quarter	3 months
2,001 - 3,000	1 per month	4 per quarter	1 month
3,001 - 5,000	1 per month	6 per quarter	1 month
5,001 - 10,000	1 per month	11 per quarter	1 month
10,001 - 20,000	2 per month	22 per quarter	2 weeks
20,001 - 30,000	2 per month	34 per quarter	2 weeks
30,001 - 50,000	4 per month	60 per quarter	1 week

The frequency of testing for other parameters and of water not used for drinking should be determined with reference to local conditions and laboratory resources. If a parameter has particular local significance for health, eg. fluoride, arsenic nitrate, etc. then the frequency of analysis should be increased accordingly.

6.9 Sampling for Chemical Analysis

Analytical results are of no value if the sample tested is not representative. This has important consequences for sampling regimes, sampling procedures and methods for sample preservation and storage. In general the time between sampling and analysis should be kept to a minimum. Storage in glass or polytene bottles at a low temperature (eg. 4 °C) in the dark is recommended. Sample bottles must be clean and free from contamination but sterile containers are not required. Special preservatives may be needed for some analytes.

All samples should be accompanied by an appropriate sample collection form. (see figure 6.3).

Water Quality
Control Programme

Name of body responsible ....

Sampling and Bacteriological Analysis

Sampling Data:

Locality ____________________

Sample site ____________________

Place ____________________

Source ____________________

Sender ____________________

Date collected ____________________

Hour collected ____________________

Date of analysis ____________________

Time of analysis ____________________

Residual chlorine ____________________ mg/l

Results:

TOTAL COLIFORMS .... __________ /100ml

FAECAL COLIFORMS............ __________ /100ml

(OTHER)..................... __________ /100ml

Laboratory Sample No. __________

WATER BACTERIOLOGICALLY GOOD BAD

ACTION TAKEN

____

____

____

____
signed

SAMPLE DATA

Locality __________

Sample site __________

Place __________

Source __________

Residual chlorine __________

Date of sampling __________

Time of sampling __________

Sender __________

Section detached and stuck to the sample bottle

Section kept in the local control agency or by the sampler

FIG. 6.3 **Example of a Sample Collection Form.**

6.10 Sampling for Microbiological Analysis

Use only sterile bottles reserved specifically for the purpose of microbiological sampling.

Tape Water

When sampling from a tap or public standpost remove any attachments, eg. nozzles, pipes, etc. Check that the tap does not leak and that the seals are in good condition otherwise these may lead to invalid results as contamination may enter from the outside of the tap. Carefully clean the mouth of the tap with a clean cloth or tissue to remove any dirt or grease. Open the tap and allow the water to flow at *medium speed* for *at least one minute* to wash out any deposits in the pipe or tap itself. Open the sterilized bottle, and holding the cap face downwards to avoid contamination, fill the bottle leaving an air space at the top to facilitate sample mixing just before analysis. Avoid touching the neck of the bottle or the inside of the cap during sampling. Replace the cap and tighten firmly.

Surface Water

When sampling from a lake, reservoir or other water course, care must be taken to avoid personal injury. However, where there is adequate access, it may be possible to take samples by hand. Having removed the sample bottle top, grasp the bottle firmly and submerge the top to at least 20 cm below the surface of the water. If there is a current of water, the mouth of the bottle should face the flow of water. When sampling in this fashion, samplers should take great care not to introduce external contamination or 'stir up' sediment in the water course or reservoir.

Wells

When sampling from a well or similar source, it may be necessary to weight the sample bottle and lower it on a string or rope to obtain the sample. In such cases, great care must be taken to tie the bottle and weight firmly. The bottle should be lowered and raised with great care, avoiding any external contamination, eg. direct contact with the walls of the well.

In all cases, sample bottles should be firmly resealed after sampling and all relevant information either written on or attached to the bottle. If the sample is to be returned to a laboratory for analysis, it should be transported in a cool, dark environment such as a cold box with ice-packs and processed within six hours. If the sample is to be processed on site, this should be done immediately in the cleanest area available.

Where drinking water is likely to contain residual chlorine, this should be tested or site. In this case on-site microbiological testing should be undertaken on a freshly-taken samples. Any sample to be returned to the laboratory for microbiological analysis should have the chlorine neutralized. This is usually accomplished by placing a 0.1 ml of 1.8% sodium thiosulfate solution per 100 ml sample volume in the bottle prior to sterilization.

6.11 References

WHO, 1986. Equipping Laboratories in Developing Countries (WHO, Geneva).
WHO, 1984. Guidelines for Drinking Water Quality (Volume 3).

7 Source Protection & Rehabilitation

7.1 Objectives

The main objectives of the rehabilitation of wells and springs are:

A) To improve the water quality and
B) To raise water production to the demand level.

Five steps have been identified to be carried out within the framework of rehabilitation:

A) Identify and correction of faults in the existing well and protected springs to meet the present demand.
B) Carry out engineering studies to prepare a revised design including expansion of full spring protection and any major rehabilitation work of the wells and springs.
C) Establish user groups to take care of and pay for operation and maintenance cost of wells and springs.
D) Plan for the organization and management of the operation and maintenance activities of the rehabilitated wells and springs at a satisfactory level in the future.
E) Train well and spring operators to carry out the necessary tasks of operations and maintenance.

The aim is to improve the existing water sources as rapidly as possible and to establish the basis for insuring that the sources will function properly in the future through better operation and maintenance.

7.2 Important Issues

Implementation of a rehabilitation programme is usually more difficult than a programme for the construction of new water supplies. Planning, design and construction activities for the new scheme can be relatively simply managed by specific project groups, or almost independently by consultants and contractors, with only limited interaction with the potential beneficiaries or with other parts of the organization responsible for providing water.

A rehabilitation programme, on the other hand, has to be much more comprehensive in nature. Reconstruction of existing facilities is only one component. Renovation of many aspects of the system for operation and maintenance is even more important.
Those activities must be carried out mainly by the staff within the water supply sector /Grover 1977/.

A rehabilitation programme is also more complex than a construction programme because of the social climate which prevails. Before a water supply is built the various interest groups, particularly the consumers, lack experience and are generally willing to accept whatever proposal are made by the management of the water authority.

After a water supply has been built and has failed to provide reliable service, however, the climate is quite different. The consumers are disgruntled and skeptical. Those who were previously responsible for the supply are sometimes unwilling to understand or accept the responsibility of its failure. Rational analysis of the past problems can be difficult in this atmosphere and modifications, either to the physical or the administrative system, are not easy to implement.

7.3 Rehabilitation of Dug Wells

Surveys on existing hand-dug wells, normally shows that most, if not all the wells are microbial contaminated. F. ex. a study on Kisii in Kenya, where water from 59 dug wells was tested showed that 34 % of the wells had between 11 and 100 faecal coliforms per 100 ml of sample.

The remaining wells, 66 %, had more than 100 faecal coliforms per 100 ml of water sample. Of the 110 wells visited in the study area, 57 wells had no cover, 91 wells had no superstructure or lining.

All the 110 wells had no sanitary arrangement for drawing water. The rehabilitation of these hand-dug wells if necessary in order to provide water of good quality to the users and a reliable supply in all seasons.

In rural areas and villages, the most serious threat to groundwater quality is contamination by human and animal waste. For the case of shallow wells, pollution occurs mainly from privies, cesspools and seepage pits, septic tanks and farmyard manure. Pollution from these sources results in increased levels of inorganic chemical constituents and micro-organisms, including pathogens.

The spread of pathogens via polluted groundwater sources is related to sanitation practices, the hydrogeology of the region, well location and construction and education of the villagers.

The sources of well pollution are:

* Surface water straight down the hole if the ground surface around the well is sunk.
* Spilt water for wells with no headwall or if people stand on the headwall to draw water from the well, water which has splashed against their feet may fall back into the well.
* Seepage water from the surface through the top few meters of the well lining.
* The vessel used for drawing water can pollute the well. When the vessel is put on the ground, it becomes contaminated by the animal and human wastes on the ground surface.
* Polluted groundwater resulting from the location of the well too close to pit latrines, soakaways of the refuse dumps.
* Rubbish thrown down the well where there is no permanent cover: children playing near the well can throw rubbish into the well, when threes are planted near the well, leaves can fall into the well.

It is essential that any well should be located, designed and constructed in such a way that it protects the groundwater source from contamination. Also it must be used and maintained in a hygienic manner. Failure to ensure adequate protection will turn the well into a potential source of the very disease it was designed to prevent.

In the Kisii Case it was observed that the number of households using wells in the dry season is 5 % lower than in the wet season. This indicates that some wells dry up or do not provide enough water during the dry period.

The simplest, but the most important single improvement to an existing hand-dug well is the construction of a well head consisting of a headwall, drainage apron and approximately 2 m depth of brick lining, figure 7.1.

The well lining should be extended at least 0.5 m above the ground to form a headwall as shown in figure 7.2. This improvement can be done on good solid ground where there is no danger of the shaft collapsing. If the ground is unstable, complete lining with either brick, figure 7.2, or concrete rings, figure 7.3, can be done before the headwall and pump installation.

The drainage apron should slope down away from the well, so that spilt water will drain away to a soakaway, figure 7.4. The concrete apron seals any fissures between the well lining and the walls of the excavated hole and so prevents polluted water form seeping into the well.

A satisfactory safeguarding of the bacteriological safety of the water from a well can only be obtained if the well top is completely sealed with a watertight slab on which a pump is mounted to draw the water.

This point is supported by comparison of the bacteriological analyses of wells with half lined but without a hand pump in the study area and the fully protected wells in the Western Kenya /Kefinco 1983/ respectively.

Some of the hand-dug wells can be rehabilitated through conversion into tube wells by filling the bottom part with gravel and the top with clay or other soil as shown in figure 7.5, leaving a tube in the middle for a hand pump.

Those wells which run dry or do not give enough water can be rehabilitated by sinking a tube well into the bottom of the well and then backfilling the original well with puddled clay. By this method it is possible to reach much further down into the water bearing layers and thus improve the well yield, figure 7.5.

Another alternative is keeping of the rope and bucket away form the ground by hanging the bucket on a tree when not in use. The well should be lined, provided with a raised headwall, cover and concrete apron with good drainage. Animals should be watered at some distance from the well and a fence provided to keep off animals.

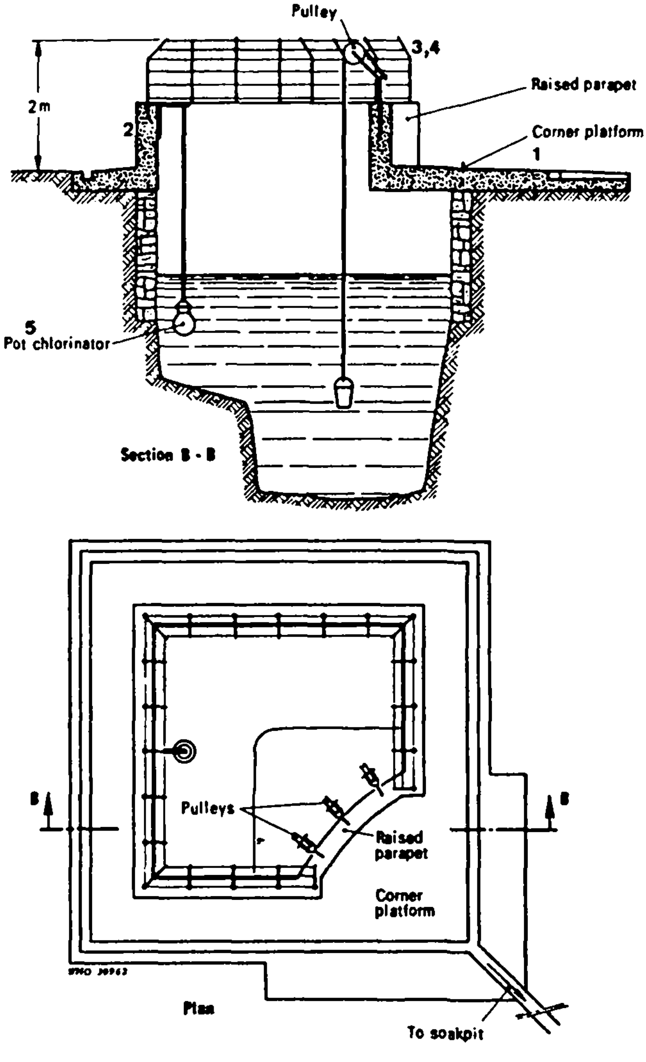


FIG. 7.1 Improving of step well. 1. Impervious apron to exclude surface water infiltration. 2. A parapet to prevent user from entering. 7. Permanent installed rope and pulley and bucket. 5. Pot chlorinator /Rajagopalan & Shiffman 1974/.

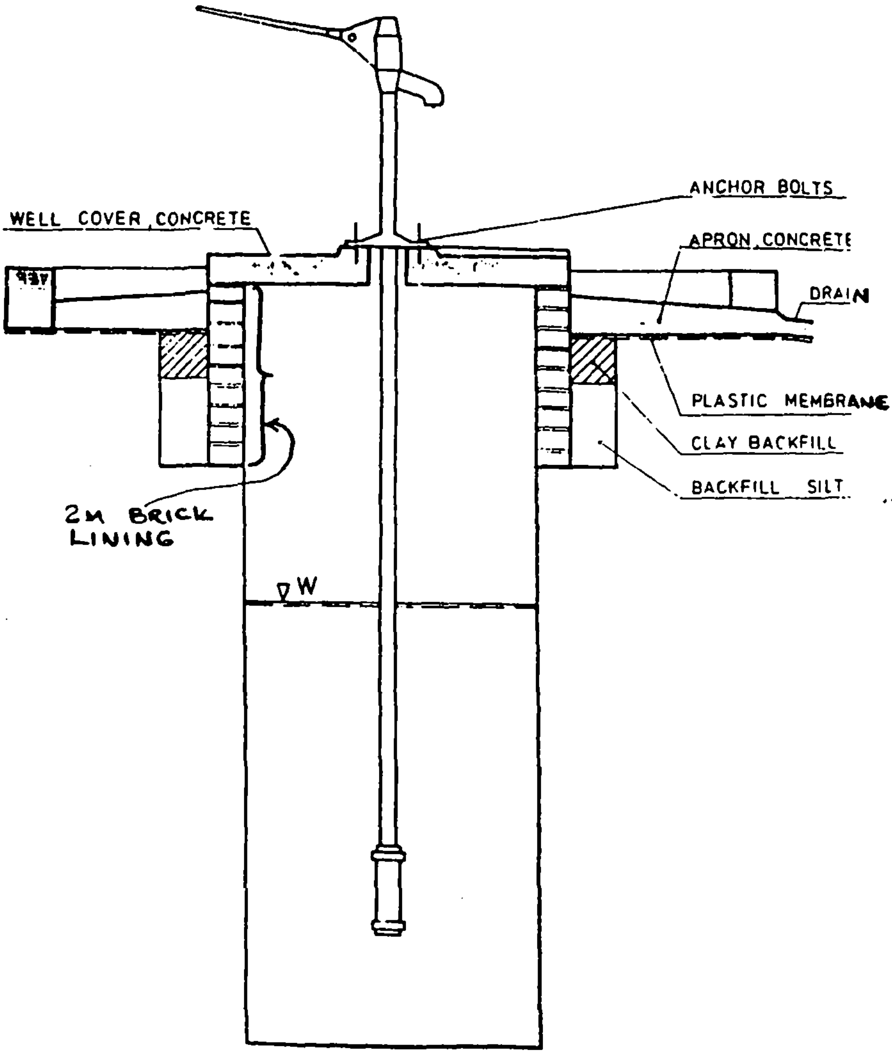


FIG. 7.2a Partly lining of dug wells with bricks.

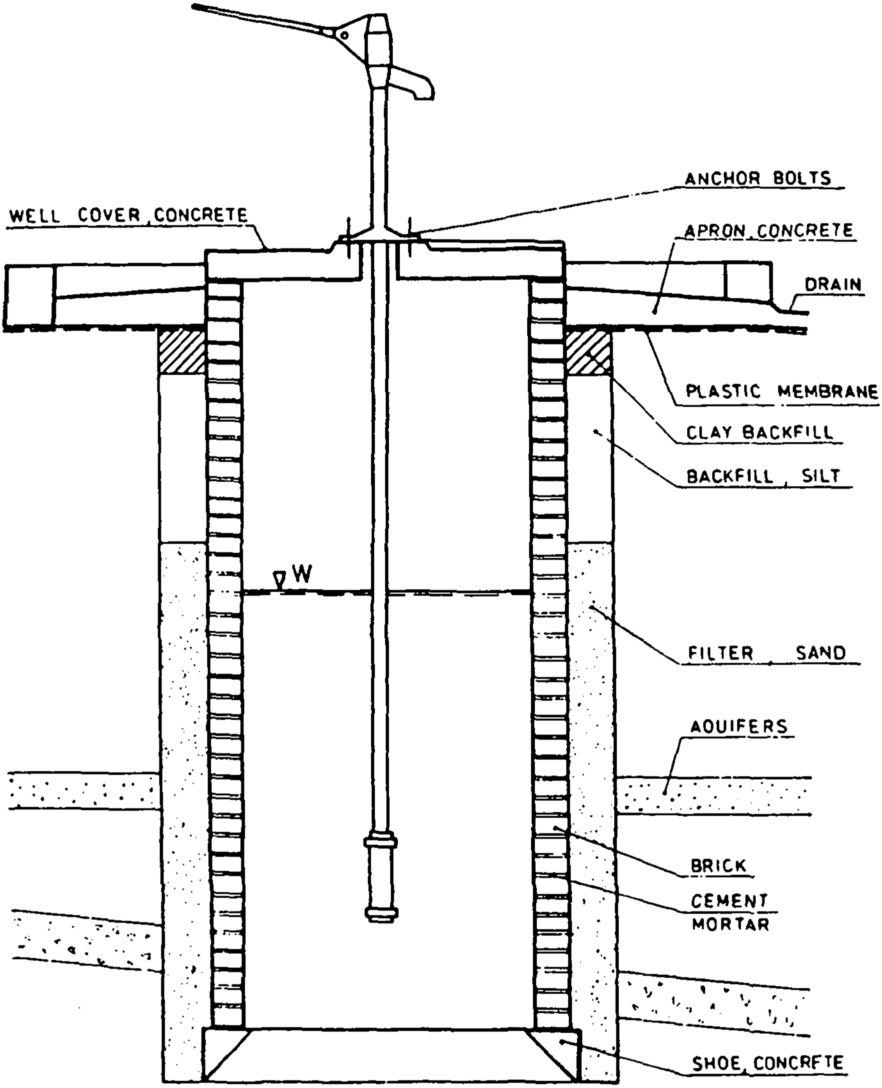


FIG. 7.2b Fully lining of dug wells with bricks.

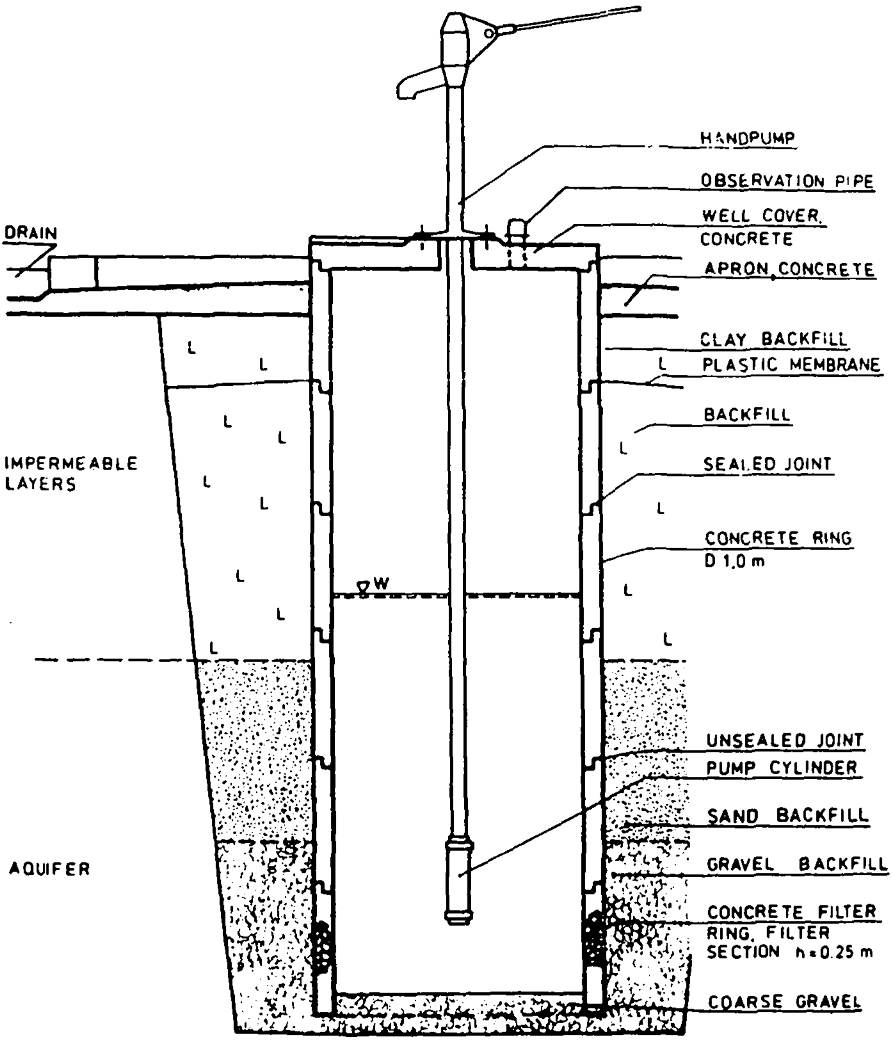


FIG. 7.3 Hand-dug well lined with concrete rings /Kefinco 1983/.

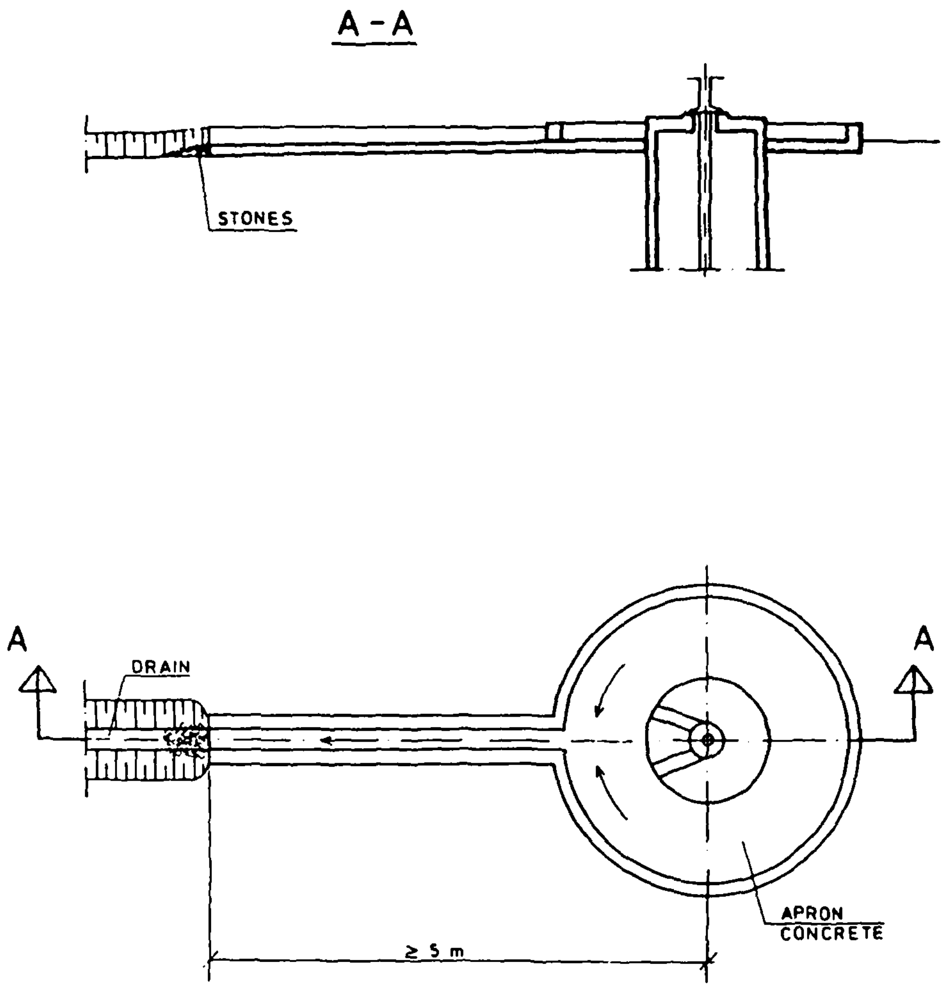
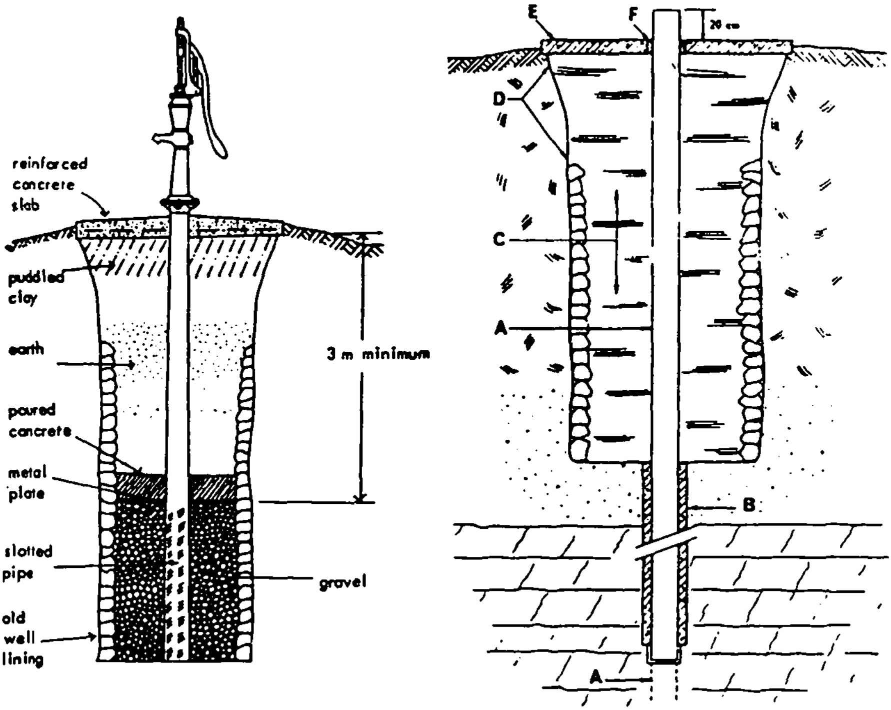


FIG. 7.4 Drainage apron for wells /Kefinco 1983/.



A = Drill hole and casing
B = Standard-weight casing
C = Puddled clay or equivalent
D = Curbing removed
E = New platform
F = Plastic compound

FIG. 7.5 Dug well converted into tube wells from /Cairncross & Feachem 1978/,/Wagner & Lanoix 1958/.

ADVANTAGES	DISADVANTAGES
Concrete ring wells:	
+ Short construction time	- Need of efficient transportation
+ Fewer risks of fracturing	- Higher consumption of cement
+ Suitable method for all dug well	- Need of a tripod and a pulley for construction.
+ Possibility to mould rings in situ	- Need of factory made concrete ring moulds.
Brick lined wells:	
+ Suitable for community participation.	- Takes a longer time to construct.
+ Local brick fabrication can be utilized.	- Vulnerable to break down when sinking.
	- Quality of bricks varies.
	- Transport may be required.
	- Not usable in the area of collapsing soil.

The major cost component in the rehabilitation of hand-dug wells is the installation of the hand pump to improve the sanitary conditions of the lifting method.

Alternative sanitary methods of lifting the water from the well such as the shaduf, figure 7.6, or windlass, figure 7.7, can be used.

The suitability of different well construction methods and materials have been studied. The advantages and disadvantages of both concrete rings and brick lined wells are given in previous page.

Hand pumps to be used in wells should meet the following requirements:

* The pump should be as simple as possible, hardly requiring any maintenance.
* Cost per pump should be as low as possible.
* The pump should be made, as far as possible, form locally available materials so that it can be repaired and preferably manufactured locally.

An introduction of a simple, cheap and easily assembled hand pump is a focal part of a community protected wells programme in general. The pump chosen should have its components below the ground simplified in such a way that replacement of worn or broken parts will be easy and cheap. Attention should be focused on maximum use of different kinds of plastic for the underground components and a way be found to drain the column of water when pulling out the pump.

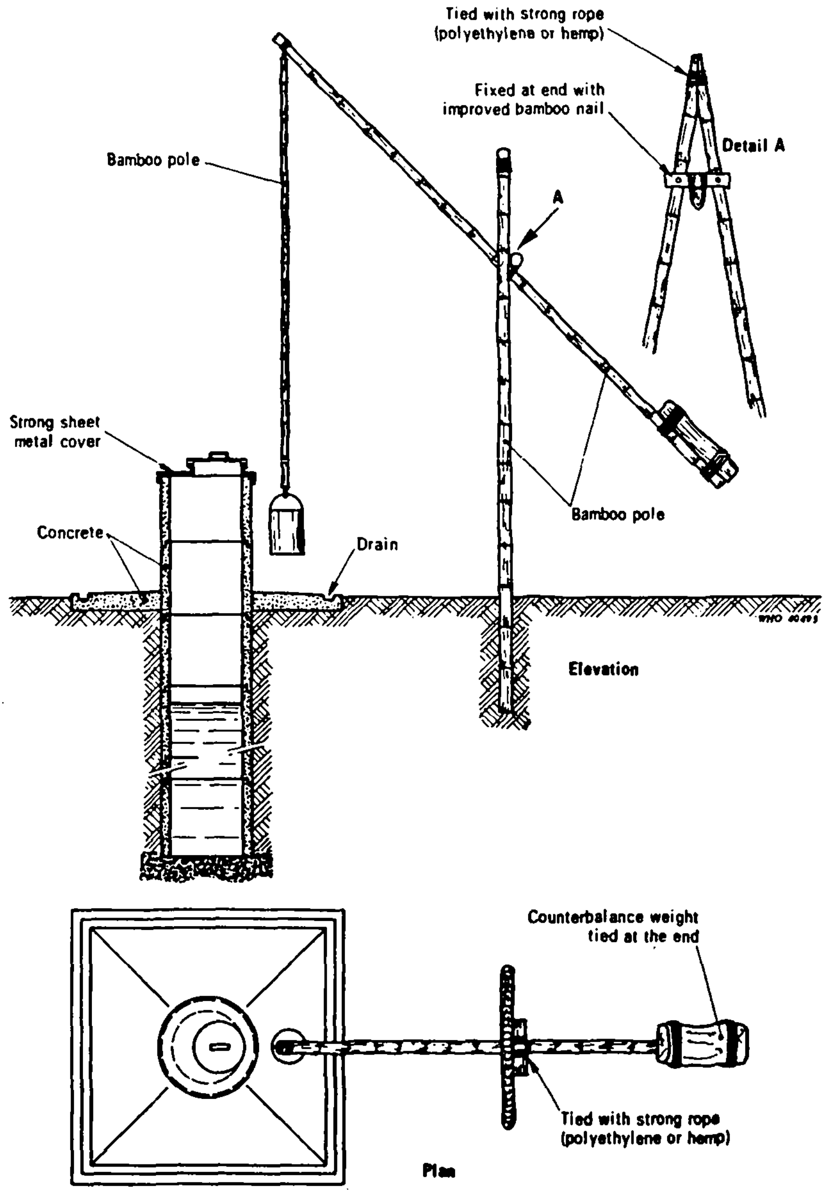


FIG. 7.6 A shaduf used over a hand-dug well /Cairncross and Feachem 1978/

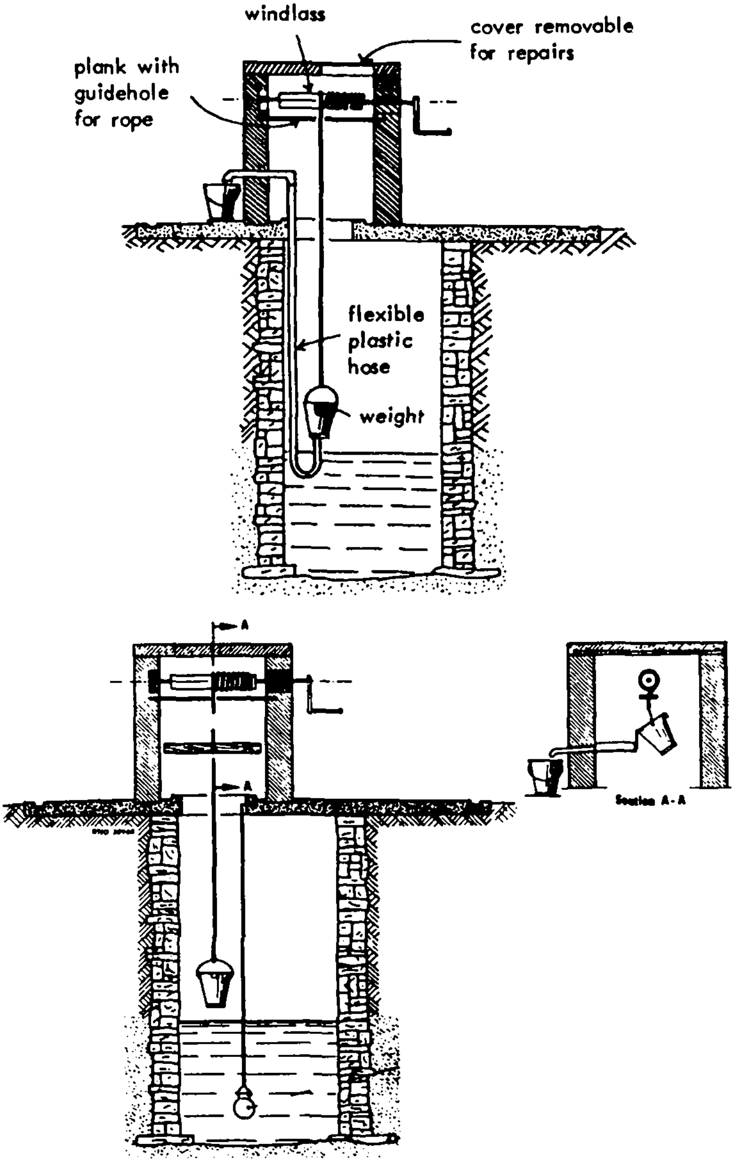


FIG. 7.7 Two methods of protecting a well from pollution /Cairncross & Feachem 1978/, /Wagner & Lanoix 1959/

Use of injection-moulded plastic for the replaceable parts of hand pump mechanisms could have a significant impact on costs of spare parts. Stocks of regularly needed parts could be held in villages, and thus routine maintenance can be managed /Guyumba 1984/.

India Mark II and the Malawi hand pump are best suited to Kenya. Both pumps are manufactured locally by "Nile Investments" and "Kenya Steel" respectively. India Mark II is also manufactured by WECO (Western College of Arts and Applied Science).

The locally manufactured India Mark II can lift water up to a depth of 30 m and yield 1000 l/h sufficient for 250 families. Malawi hand pump manufactured by WECO is under test. This is very encouraging as far as village level operation and maintenance pumps are concerned (Guyumba 1984).

After completion of the well it should be disinfected due to the possible pollution during construction. The contamination can be caused by equipment, materials or surface drainage during construction or repairs. A chlorine compound can be used as a disinfectant. Disinfecting a well involves calculating the required amount of chlorine compound, mixing a chlorine solution, and applying the solution to the well, see chapter 9.

7.4 Rehabilitation of Springs

Inspection of springs in rural areas often shows that most of the spring needs protection and rehabilitation. F. ex. in the Kisii Case, 4 out of 11 initially protected springs should be rehabilitated whereas 7 springs needed new protection. Most of the 7 springs to be newly protected had changed their course while others had two or three springs outcropping at different places.

Existing conditions in such springs are illustrated in the following.

Spring 1:
The spring was visited on 20.9.1985. It is a permanent source protected around 1955. The structure is composed of a brick-made headwall without a top slab. The headwall is not properly anchored to the sides. A loosely fixed 50 mm diameter galvanized iron outlet pipe is in place and still strong for future use. No overflow and drain pipes are provided.

No proper drainage is available. The difference in level between the outlet pipe and the downstream flow water level is less than 100 mm. The base slab of the outflow water is in good condition. The spring is surrounded by banana palms and maize plantations. Surface runoff from the gardens flow into the spring prior to the outlet pipe.

The spring serves approximately 60 people in the vicinity and 15 heads of traditional cattle. Washing clothes is done at the spring. Drinking water from the spring is not boiled normally. No cattle trough is provided for watering and the animals use the stagnant water.

Spring 2:

The spring was visited on 20.9.1985. It is a permanent spring protected on 17.9.1963. The structure is composed of a concrete headwall in an excellent condition with a 75 mm diameter galvanized iron outlet pipe. No overflow or drain pipes are provided. The base slab is in a good condition but no washing basin is provided so the top of the headwall is used as a washing place.

Drainage is not provided bur water runs down easily because of the topography. Clearance between the outlet pipe and outflow drain water level is about 350 mm.The spring catchment area is composed of small scale farms. There is no cover behind the headwall. Surface runoff from the gardens floods the spring reservoir behind the headwall.

The spring serves approximately 300 people and 40 animals in the area. No cattle trough is provided.

Spring 3:

The spring was visited on 20.9.1985. It is a permanent spring protected around 1955. The spring stricture consist of a brick headwall in good condition but without a cover at the backfill. Water behind the headwall is exposed to the surface. The headwall is not properly anchored to the sides. A 50 mm diameter galvanized iron outlet pipe is provided and is still in good condition. The clearance between the outlet pipe and outflow drain water level is about 350 mm.

There is no proper drainage of the outflow water. No washing basin and cattle trough are provided. The headwall is presently used for washing clothes. About 250 people and 10 animals use the spring. These animals started using the spring a year ago, otherwise most people take their animals to the river about 200 m away.

Spring 4:

The spring was visited on 16.9.1985. It is a permanent spring protected about 1960. The spring structure is composed of a brick headwall with a 50 mm diameter galvanized iron outlet pipe. The headwall is in good condition with a firm anchorage to the sides and foundation.

The outflow water is not properly drained. The clearance between the outlet pipe and the outflow drain water is about 400 mm. The splash base slab is not in a good condition. Thus, there is a pool of stagnant water due to the poor drainage.

In the upper part of the spring catchment there are banana palms and small coffee farms. The water behind the headwall is exposed and thus the surface runoff floods the outcrop of the spring. The spring serves about 150 people and 10 heads of traditional cattle. No cattle trough is provided.

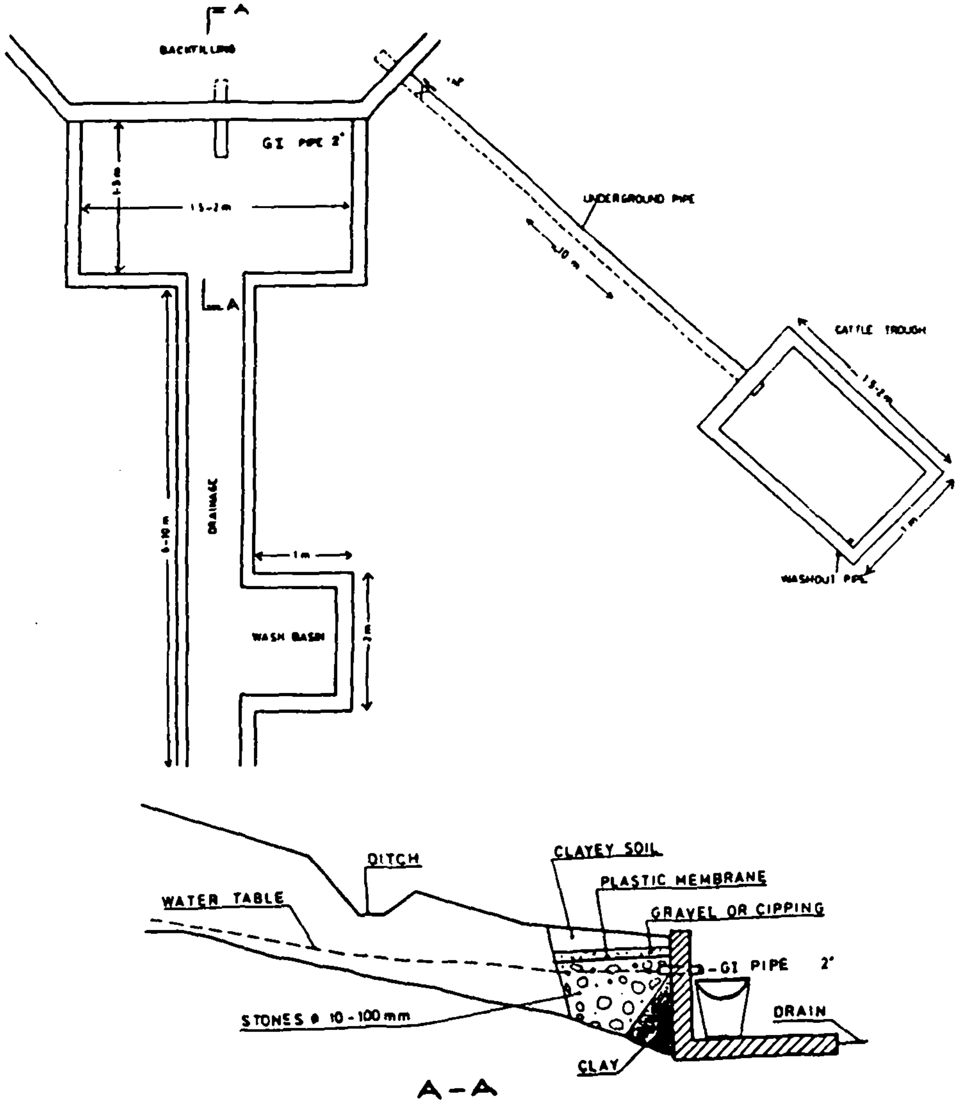


FIG. 7.8 Proposed rehabilitation plan for springs 1, 3 & 4 /Kefinco 1983/

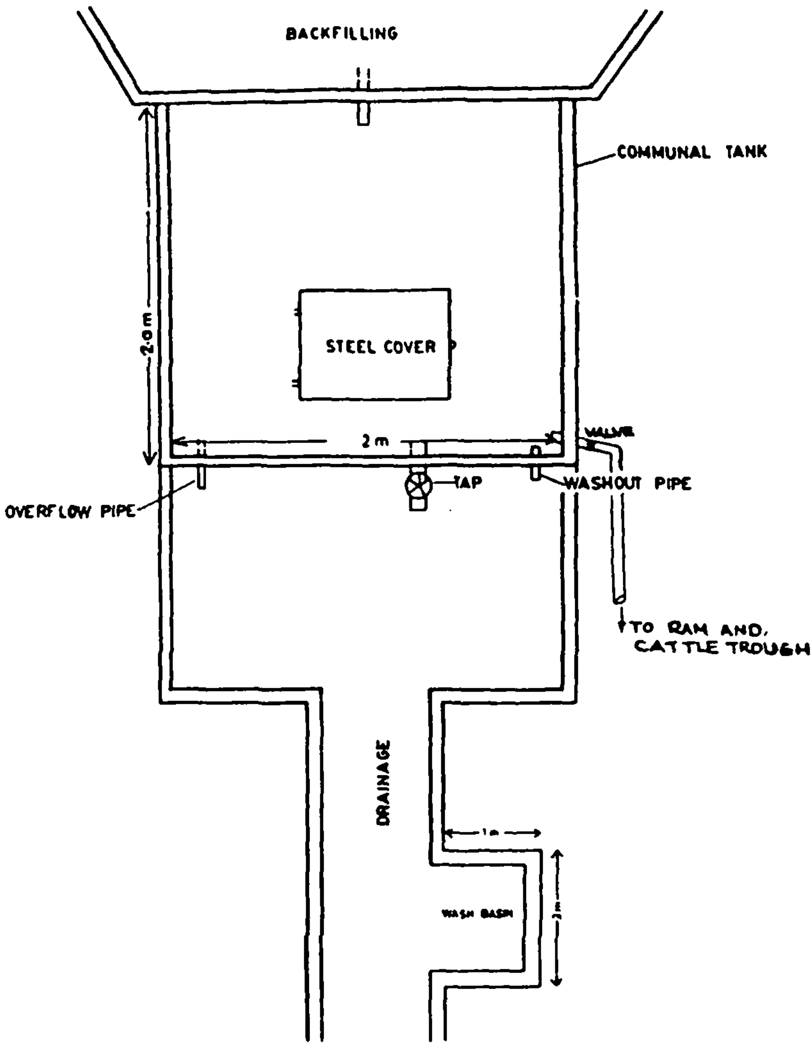


FIG. 7.9 Proposed rehabilitation plan for spring 2 in the Kisii Case.

The general parts to be rehabilitated for all the springs are:

* Cleaning the backfill.
* Placing the backfill with boulders, gravel, sand, plastic sheeting and then clay.
* Repair of drainage channel and construction of washing basin.
* Construction of cattle trough.
* Installation of a pipe to the cattle trough.
* Construction of a drain ditch for surface runoff diversion.
* Fencing the spring site.

FIG. 7.8 shows the technical rehabilitation plan of springs 1, 3 and 4.

The specific rehabilitation for each spring is considered case by case.

Spring 1:
* Repair of the headwall and anchorage to the sides.
* Fixing the outlet pipe firmly to the headwall.

Spring 2:
* Construction of a small storage tank of similar height as the headwall with dimensions 2 m width, 2 m length and 1,5 m height (6 m^3).
* Possibility of utilizing a hydraulic ram about 20 m away from the storage tank with a head of 5 m and a high level storage tank.
* Installation of an interconnecting pipework as shown in figure 7.9.

Spring 3:
* Anchorage of the headwall firmly to the sides.

Spring 4:
* No specific rehabilitation is needed for this spring.

7.5 Community Source Protection

7.5.1 Principles

One of the most essential issues in water management is to establish standards for the protection of the community drinking water source.

The effective protection of the various components of a water supply system requires first, the establishment and maintenance of the protective zones and then a proper standard of construction of the plant and equipment.

Protection zones must give realistic protection to drinking water sources, but should not be unnecessarily large. General rules must be established for travel time from boundaries and, in every individual case, surveys are need to measure groundwater speeds according to the nature of the strata.

The general principle is to define inner and outer protection zones round waterworks plant and structures.

7.5.2 Inner Protection Zones for Groundwater

The inner protection zone is defined as one in which the water may be at risk from direct infection.

Preferably this zone should be under the total control of the water undertaking and fenced to prevent public access. The only buildings and plant within the zone should be those connected with water supply, and entry should be restricted to authorized personnel for the purpose of doing necessary work. Some authorities require that waste water should be discharged outside the zone through double-walled pipes which are leak-tested monthly.

The zone should be kept clean of rubbish and sloped so that surface water does not make pools in wet weather. For preference open areas should be grassed, mown regularly and not treated with anything to promote or control growth.
All personnel working in the zone should be medically examined every year and all their diseases should be recorded.

7.5.3 Outer Protection Zones for Groundwater

The outer protection zone is defined as one in which the water may be at risk from indirection infection.

The boundary of the zone should be marked by signs at every place where it is crossed by a road, footpath, cable or pipe and at the intermediate points. No building or activity should be allowed which may present any hazard to the quality of the water supply and the ground should be cleared and graded to prevent the collection of pools in wet weather. Where the area is subject to flooding, any buildings should be protected against flood and measures should be taken to remove rotting matter when the flood subsides.

Public roads across the zone should have impervious surfaces and drainage should be discharged outside the zone. Living, holidaying and sport in the zone should not be permitted, or the storage of any goods capable of contaminating the environment. Animal husbandry should be adequately controlled.

7.5.4 Catchments

The catchment zone is the whole of the area within which water flows towards the intake. Its boundary should be defined clearly in the records of the undertaking and, if it is not marked on the ground, information about it should be readily available to the public.

No activity should be allowed within the area of a catchment which could have a harmful effect on the quality of the water abstracted for drinking.

This means, for instance:

* No dumping of poisonous wastes.
* Strict control of activities which gives risk to undesirable effluents.
* Control of drilling, mining and quarrying.
* Control of agricultural use of fertilizers and pesticides.

Control of activities does not mean that they should be banned, but that, in the interest of public health, they should be open to inspection and monitoring in matters that could affect water quality. Where potentially harmful (to water) substances are handled or made, steps should be taken to make sure that their effluents are either treated to make them fully safe or else are conveyed safely over the catchment boundary. It is advisable to publish the regulations for using the catchment to activities such as:

* Domestic housing.
* Farming.
* Extractive industry.
* Manufacturing industry.
* Service industry.

TAB. 7.1 Typical sizes of protection zones in France. From Warden 1989.

	Alluvial soil	Karstic area
Immediate area (m^2)	100 - 1000	100 - 1000
Close area (km^2)	0.05 - 0.2	1 - 50
Distant area (km^2)	0.5 -5	5 - 100

7.5.5 Protection Zones for Surface Water

Protection of open surface water is a problem. It may be possible to protect a reservoir from major human activity but in the case of a river, if protection is possible at all, it may be possible only over a limited reach. Often it is necessary to accept existing and historical uses of a river or lake and to design the treatment accordingly. Adequate sewage treatment is important in preserving water quality at downstream intake.

7.5.6 Design of Protection Zones

Regulations and practice vary from one country to another. F. ex. in Hungary,
the boundary of the inner zone should be 60 day's detention time from the intake or, as a rough rule, 50 m for shallow wells, springs and infiltration galleries. For deep wells into protected groundwater a radius of 10 m is enough, and an outer protection zone is not required. In all other cases the boundary of the outer zone should be 300 day's travel from the intake or, as a rough rule, 100 m.

In France, the law requires the definition of three protective zones for every supply as follows:

Immediate area: Must belong to the supply authority, be securely closed and maintained like a public garden.

Close area: Subjects to controls on activities such as building quarrying, storage of toxic materials, etc.

Distant area: Defines the zone where most of the abstracted water comes from, subject to controls on district and public services and strict prohibition of groundwater pollution from septic tanks, silo seepage, motorway runoff, etc.

7.6 References

Cairncross & Feachem (1978)

Grover (1977)

Guyumba (1984)

Kefinco (1983)

Nyangeri Ezekiel E. N.(1986). Rehabilitation of Hand-Dug Wells and Protected Springs. Case Kisii, Kenya. FINNIDA.

Rajagopalan, S. & Shiffman, M. A. (1974). Guide to Simple Sanitary Measures for the Control of Enteric Diseases. WHO. Geneva.

Wagner & Lanoix (1958). Excreta Disposal for Rural Areas and Small Communities. WHO, Geneva.

Warden, J. (Edit 1989). Disinfection of Rural and Small-Community Water Supplies. WHO, Geneva.

8 Slow Sand Filtration

8.1 Introduction

Properly protected groundwater sources such as springs and wells may produce water of high quality with respect to microbiological criteria. Unfortunately, few countries are sufficiently well endowed with groundwater resources to rely on this high quality water and therefore depend to a greater or lesser extent on surface water sources. These, by there very nature have been exposed to contamination and vary widely in their microbiological, physical and chemical characteristics. Most surface water sources should therefore ideally be treated before being supplied for consumption.

Amongst the technologies available for treatment of water for community water supplies is that of slow sand filtration (SSF). Slow Sand Filtration has a number of characteristics which have made it popular such that it is used for drinking water treatment for several major european cities (such as London and Amsterdam), is attracting new interest in north america (Logsdon and Fox, 1988) and has long been promoted for the treatment of small community supplies in 'less-developed' countries (NEERI, 1977; Huisman and Wood 1974).

The attractive characteristics of SSF include:

* Low personnel requirements for operation and maintenance.
* Independence from chemical dosing.
* Independence from backwash pumping
* High efficiency in microbial removal (parasites, bacteria and viruses).
* High reduction in organics (decreasing chlorination costs where it is practiced and reducing formation of trihalomethanes and chlorophenols).
* Simple design, construction, operation and maintenance.
* High reliability.

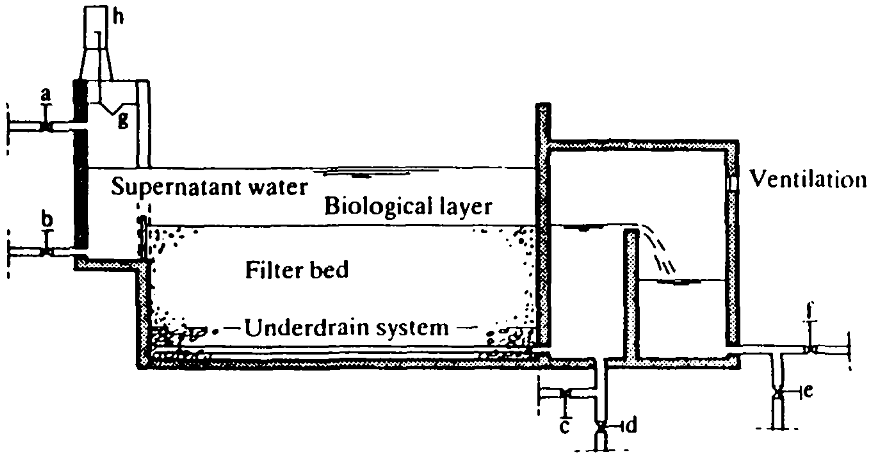


FIG. 8.1 Basic components of an inlet controlled slow sand filter. After Visscher, 1988.

a: valve for water inlet and regulation of filtration rate.
b: valve for drainage of supernatant water layer.
c: valve for back-filling the filter bed with clean water
d: valve for drainage of filter bed and outlet chamber
e: valve for delivery of treated water to waste.
f: valve for delivery to the clear-water reservoir.
g: inlet weir.
h: calibrated flow indicator.

However, no technology is a panacea and SSF in common with other water treatment technologies has certain disadvantages. These include:

* Relatively high space requirements (especially important for peri-urban sites supplying urban population centers).
* The requirement for a relatively low-turbidity influent water.
* An attitude that SSF is a technology appropriate (only) for small (rural) communities has developed.

While it is true that SSF is often an appropriate technology for drinking water treatment in small communities, studies have revealed that SSF also compares favorably with other treatment technologies for intermediate-sized centers of population.

8.2 Description and General Characteristics

A typical slow sand filter is a tank, most frequently uncovered, which contains a system of underdrains covered with graded gravel supporting a filter bed of fine sand capped with a layer of water. The water flow may be controlled at the inlet or at the outlet of the filter, see figure 8.1 and 8.2.

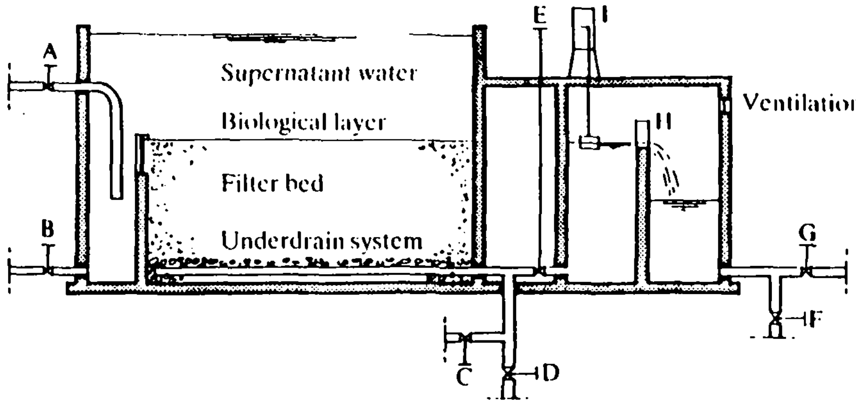


FIG. 8.2 Basic components of an outlet controlled slow sand filter. After Visscher, 1988.

A: raw-water inlet valve.
B: valve for drainage of supernatant water layer.
C: valve for back-filling the filter bed with clean water.
D: valve for drainage of filter bed and outlet chamber.
E: valve for regulation of the filtration rate.
F: valve for delivery of treated water to waste.
G: valve to the clear-water reservoir.
H: outlet weir.
I: calibrated flow indicator.

During operation, water percolates slowly through the filter bed and during its passage, its quality improves dramatically through a number of processes. Thin layer or filter skin develops on the surface of the filter which contributes significantly to the purification process. After several weeks or months, the filter becomes clogged. Filtration capacity may then be restored by cleaning; this is undertaken by scraping off the top few centimeters of the filter bed with the filter skin.

Flow control is essential and may be provided at the inlet or outlet. In smaller installations, where there is no full-time operator, a minimum head mechanism to prevent drying of the filter bed is advantageous, especially if the source flow is variable.

8.3 SSF Processes

Filtration of water intended for drinking has a long history and technical descriptions of treatment processes incorporating filtration through sand were to be found from the late 17th century onwards; such that by the end of the 19th century a process recognizable as Slow Sand Filtration had been proven effective and gained widespread application in northern Europe.

A large scale slow sand filter was constructed by James Simpson in 1829 for the Chelsea Water Company but even by this time the process was perceived to be no more than a strainer for removal of suspended solids and the perceived benefits related largely to improvements in the aesthetic quality of the water.

In fact, SSF effects significant improvement in the physical, chemical and microbiological quality of water intended for drinking.

It is now recognized that SSF is not simply a straining process, but that improvement in water quality is due to a combination of processes including mechanical straining, sedimentation, adsorption, chemical and, especially, biological activity (Huisman, 1978).

Briefly, the processes can be summarized as follows:

8.3.1 In the Supernatant

* larger particles settle (sedimentation)
* smaller particles may agglomerate and settle
* algae grow (unless the filter is protected from sunlight), affecting the levels of dissolved oxygen in the water entering the filter bed.

8.3.2 On the Surface of the Filter Bed

* mechanical screening occurs
* a slimy layer, known as the 'Schmutzdecke' develops, made up of algae, cyanobacteria, plankton, diatoms, rotifers and bacteria. This layer contributes significantly to the improvement of the microbiological quality of the water.
* As this layer develops, so its straining and purification capacity increases, as does the resistance it presents to the flow of water through it.

8.3.3 In the Sand Bed

* sedimentation occurs onto the 'top' faces of the sand grains (although this is not effective for fine, colloidal material)
* particles are adsorbed onto the sand grains (by a variety of mechanisms)
* both organic and inorganic materials are adsorbed on to the sand grains. The organics become a substrate for bacteria and other microorganisms. The sand grains therefore become coated in a microscopic slimy layer to which particles and microbes from the raw water adhere
* oxidation, especially by microbes, leads to the degradation of the substances removed.

TAB. 8.1 Performance of Slow Sand Filters (after van Dijk and Oomen, 1978)

Parameter	Purification effect
Organic matter	Slow sand filters produced a clear effluent, virtually free from organic matter.
Bacteria	Between 99% and 99.99% of pathogenic bacteria may be removed to an even high degree; E.coli are reduced by 99-99.9 percent.
Viruses	In a mature slow sand filter, viruses are virtually completely removed.
Color	Color is significantly reduced.
Turbidity	Raw water turbidities of 100-200 NTU can be tolerated for a few days only; a turbidity more than 50 NTU is acceptable only for a few weeks; preferably the raw water turbidity should be less than 10 NTU. For a properly designed and operated filter the effluent turbidity will be less than 1 NTU.

8.3.4 Effluent Quality

The cumulative effect of the processes outlined above is a considerable increase in water quality. The purification processes have been outlined by van Dijk and Oomen (1978) and are summarized in table 8.1.

8.4 Advantages & Disadvantages

The greatest advantage of Slow Sand Filtration over other treatment technologies is its effectiveness in improving the microbiological and physico-chemical qualities of water. This has been stressed by many authors (see for example Huisman and Wood, 1974; Thanh and Pescod, 1976 and NEERI, 1977).

Additional advantages include ease of operation and maintenance and hygienic safety in the absence of reliable electricity or chemical supplies.

The major disadvantage of SSF is its vulnerability to clogging when influent water is of high turbidity. Where such waters are to be treated, pre-treatment is advisable. The second significant disadvantage of SSF is their greater requirement for land than other treatment options. This is especially important near densely populated areas where land values tend to be higher.

Although SSF is most commonly used for community water supplies, there have also been reports of SSF units for use in household water treatment (Morgan, 1990). These units generally operate at a variable flow rate, as draw-down occurs each time the outlet (tap) is opened.

Given the requirement for SSFs to be operated at a constant flow rate for optimal performance, it is unlikely that these units operate with the high efficiency of SSF units with a constant flow rate.

8.5 Factors Which Influence Slow Sand Filtration Efficiency

The elimination of microbes and organics in an SSF is a biological process. Factors which influence efficiency therefore include time, oxygen, temperature and the need for the biomass to develop, known as the 'ripening' or 'maturing' period.

8.5.1 Time

The time available for the reactions to take place in the filter bed is determined by sand depth and flow rate, these are discussed in greater detail below;

8.5.2 Oxygen

Microbial activity in the filter bed leads to the consumption of oxygen. If the influent oxygen concentration is low, or the water has a high organic loading such that much oxygen were consumed in the mineralization of the organic matter, then this could lead to anaerobic conditions, and subsequently both the microbiological and organoleptic quality of the effluent would be expected to deteriorate.

Aeration or pre-treatment may therefore be required for some waters. Huisman and Wood, (1974) recommended a minimum oxygen concentration at the outlet of 3 mg/l.

8.5.3 Temperature

The temperature is difficult to control, although filters may be protected by covering them in colder weather, as is sometimes practiced in northern europe.

8.5.4 Maturation

The schmutzdecke and the top layer which is especially microbiologically active in the filter bed take time to establish themselves. SSF therefore operates less efficiently immediately after commissioning, resanding or cleaning. Accordingly, short filter runs reduce efficiency.

Short filter runs may be avoided by minimizing influent water turbidity, for example by pre-treatment.

8.6 SSF Installations

Experience gained in less-developed countries, for example in the IRC programme of research into SSF in community water supply (Heijnan and White, 1981) has allowed the establishment of some general parameters for SSF design.

8.6.1 Population to be Supplied

One of the most important factors in the selection of water treatment technologies is the population to be served.

In a detailed analysis of construction costs (Galvis and Visscher, 1989), SSF were found to be more cost-effective than rapid sand filtration for flow rates of up to 6,000 m^T3^T per day (70 liters per second, corresponding to a population of 30,240 at a per capita consumption figure of 200 liters per person per day).

When operation and maintenance costs are taken into account, SSF are shown to be advantageous for even higher flow rates. Paramasivam and Sundaresan, (1982) took into account these costs and estimated that SSF are more cost-effective than other treatment options for flow rates of up to 2861 liters per second (corresponding to populations of up to 123,000 inhabitants at the same rate of per capita consumption.

Heijnan and White (1981) recommend flexibility in design such that SSF installations should lend themselves to expansion towards the end of a 10 - 15 year design period by the addition of extra filter area.

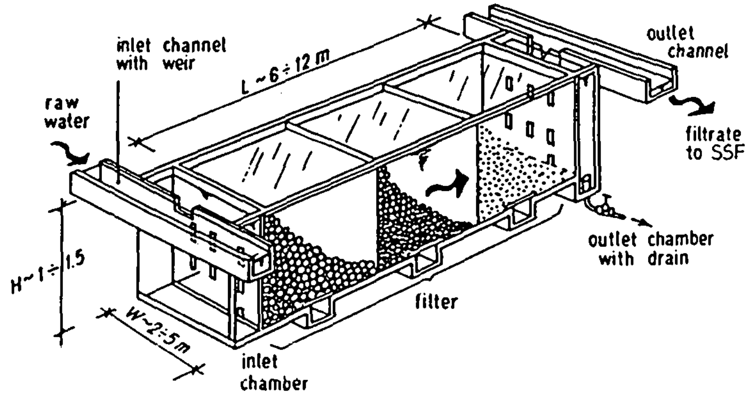


FIG. 8.3 Main Features of a Horizontal-Flow Roughing Pre-Filter. After Wegelin, 1988.

8.6.2 Raw Water Quality Requirements

SSF can be employed as the sole treatment process where raw water turbidities are not high, for example not exceeding 20 NTU (unless it is for occasional short periods). Ideally turbidity will average less than 10 NTU.

The most important raw water characteristic however is that the intake be continuous (and constant). Pumped systems therefore rely on a balancing tank. A continuous and constant intake is critical due to the biological nature of the SSF process.

Biological communities in the filter bed develop in response to nutrients (dissolved organics, incoming bacteria etc). If these parameters vary significantly, then the biological community must respond in order to adapt and this will take time. Additionally, any drying of the filter bed or surface will result in the loss of all or some of the microbiological community and result in the loss of purification efficiency.

8.6.3 Pretreatment

Where high peaks or high mean turbidities are encountered, some form of pre-treatment is required to ensure continuity of operation.

Pretreatment may be undertaken by, for example, reservoir storage, infiltration galleries, gravel pre-filtration and pumped abstraction through sand. Gravel pre-filtration appears to be particularly applicable to water treatment for small community water supply in less--developed countries (see for example Wegelin, 1988). Horizontal-flow and ascending-flow filtration are most common, see figure 8.3.

A novel pre-treatment applicable to SSF installations is that of 'protected' SSF (Lloyd, P and Wheeler, 1986). This involves placing multiple layers of fabric on a SSF. These provide an environment suitable for the growth and proliferation of beneficial microorganisms and reduce their loss during cleaning.

8.6.4 Inlet Structure

The inlet structure should be designed to enable water to enter the filter (supernatant) without disturbing the filter bed or Schmutzdecke. Typically this involves a plinth at the level of the sand to disperse the force of falling water or a dispersor.

To facilitate cleaning, one of the inlet, outlet or overflow structures should be designed to enable rapid drain - down preparatory to scraping the sand bed.

8.6.5 Filter Bed

A minimum of two filter beds should be included in any SSF installation supplying a community water supply to enable continuity of operation during cleaning.

The depth of the sand in the filter beds determines the time available for treatment. The heterotrophic zone is said to extend up to 40 cm into the sand bed, while nitrification reactions occur up to 60 cm into the sand bed. Huisman and Wood (1974) recommend a minimum sand depth of 70 cm. Cleaning is effected by removing the top layer of sand to a depth of 10-20 cm. Allowing an additional 50 cm, for example, would permit cleaning every two months for five years before re-sanding would be necessary. This implies an initial sand depth of 1.2 meter.
Such an ideal is rarely feasible however and would add considerably to construction costs due to the extra sand requirement and increased height of the overall structure. In practice, an initial sand depth of 0.8 to 1.0 m is common.

8.6.6 Supernatant

The function of the supernatant is to provide a head of water adequate to drive the water through the filter bed. Clearly, as the resistance of the filter bed increases with clogging, so the force required will be greater.

Where flow control (see below) is practiced at the inlet, clogging will cause the supernatant level to rise. An overflow is therefore necessary and when this level is reached, cleaning of the filter bed is required.

An overflow outlet which also assists in the removal of floating scum and for rapid drain-down preparatory to cleaning may take the form of a lowerable gooseneck and has been successfully employed in Colombia (Gerardo Galvis, personal communication).

8.6.7 Filter Medium

Sand is the most commonly used medium, although other granular materials, such as crushed coral and burnt rice have been employed; as have multi media filters employing gravel, sand and charcoal.

The most important characteristics of the filter medium are the diameter of the sand grains and their *uniformity*[1]. The sand should also have a low silt content and river sand is preferred as it is less likely to liberate solutes.

It has been proposed that sand size may be related to the efficiency of removal of total coliforms. Finer sands present a greater overall surface area and would therefore be expected to effect greater purification. See for example Visscher and Galvis, 1987. *The effective size*[2] of the medium should therefore lay within the range 0.15 to 0.35 mm.

It is also important that the filter material is of a uniform size, in order to ensure uniform pore size. Uniformity is measured using the *coefficient of uniformity* and should ideally lie within the range 2.0 - 3.0. Although the distribution of sand grain sizes can be calculated and expressed graphically, in many cases this is not undertaken.

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[1] *Coefficient of uniformity* is the ratio of the sieve opening through which 60 per cent of the mass of the grains will pass to the effective size (d_{60} : d_{60}).

[2] *Effective size* is the sieve opening through which 10 per cent of the mass of grains will pass (d_{10}).

8.6.8 Underdrains

The function of the underdrain system is to ensure that filtration occurs the full area of the filter.

Underdrains may comprise main and lateral drains constructed of perforated pipes or a false floor. In both cases it is covered with a layer of graded gravel to support the filter bed.

An alternative underdrain system, employed successfully in Colombia involves the use of corrugated PVC pipe intended for drainage use in agriculture. This is manufactured with slot perforations in the troughs of the corrugations and needs only to be covered by a single 10 cm layer of fine gravel. This lessens the requirements for graded gravel and reduces the height of the overall structure (and therefore construction costs). (Galvis, personal communication).

8.6.9 Outlet Structure

The main function of the outlet structure is to prevent siphonage. It may additionally be used to reaerate the water. In this case, typically a weir is incorporated and suitable ventilation provided. Such a weir should be positioned slightly above the level of the sand bed in order to prevent its drying out if the inlet flow is interrupted for any reason. Ideally, the outlet will also permit back-filling via the underdrains after commissioning or re-sanding. This is important to prevent trapping air in the sand bed.

8.6.10 Flow Rate

Widely varying flow rates have been reported as satisfactory, although the range is typically between 0.1 to 0.3 m/hour. Huisman and Wood (1974) considered flow rates of 0.1 - 0.4 meters per hour to be normal.

In work carried out by NEERI (1977), flow rates of between 0.1 and 0.3 meters per hour were observed to result in very similar bacteriological quality in treated waters. The lower flow rates however yielded waters of lowest dissolved oxygen levels (dropping to less than 1.0 mg/l on occasions with flow rates of 1 meter/hour). If this were to lead to anaerobic conditions then both the microbiological and organoleptic quality of the effluent would be expected to deteriorate.

This presumably reflects the efficiency of microbiological mineralization of organic substrates in the water. Higher flow rates will alleviate this at the cost of shorter filter runs and reduced efficiency in removal of organics; alternatively aeration may be practiced at the inlet. It should be noted that the tendency towards anaerobic conditions will be aggravated in filters with a healthy population of algae (at night) and during discontinuous operation. For example, NEERI found that bacteriological quality declined during discontinuous operation.

8.6.11 Flow Control

The maintenance of a constant filtration rate is important factor in filtration efficiency. Flow control may be practiced at either the inlet or outlet.

When flow control is practiced at the *outlet*, an outlet valve must be adjusted frequently, typically involving slight opening daily; otherwise output will fall. This ensures maximum retention of the water even at the beginning of a filter run. This method maximizes treatment efficiency, but requires greater and more frequent operator involvement.

Inlet flow control is often by gale valve plus a weir and v-notch. As the resistance of the filter bed to the flow of water increases, so the supernatant level rises. An indicator of the need for cleaning is provided by the supernatant level reaching the level of the overflow. Inlet flow control requires less operator involvement. The filtration rate is of course actually slowly declining with the clogging of the filter and a slightly decreased purification efficiency might therefore be expected at the beginning of a filter run.

8.6.12 Filter Shading

Covering a filter may influence effluent quality for a number of reasons.

The effect of algal growth on dissolved oxygen levels has been noted above and shading will minimize algal proliferation and therefore reduce fluctuations in dissolved oxygen levels. It will also reduce the proliferation of unicellular algae which are an important cause of premature filtering thereby increasing filter runs where this is a problem.

Shading may also eliminate direct contamination of the supernatant water, for instance by children or defecating birds.

In northern latitudes, covering can also be used to reduce heat loss, thereby preventing freezing and increasing microbiological activity.

TAB. 8.2 Example Schedule of Activities for SSF Caretakers

Frequency	Activity
Daily	* check the raw water intake (some intakes may be visited less frequently) * visit the slow sand filter - check and adjust the rate of filtration - check water level in the filter - check water level in the clear water well - sample and check water quality * check all pumps * keep the logbook of the plant
Weekly	* check and grease all pumps and moving parts * check the stock of fuel and order if necessary * check the distribution network and taps, repair if necessary * communicate with users * clean the site of the plant
Monthly	* scrape the filter beds * wash the scrapings and store the retained sand
Yearly	* clean the clear-water well * check the filter and clear water well for water tightness
Every two years	* re-sand the filter units

8.7 Operation and Maintenance

The ease of operation and maintenance has been noted as an important advantage of SSF. This makes the technology especially attractive for application to small community water supply.

However well-designed and constructed a plant is, effluent quality will ultimately depend on the operator. It has been shown that where support for operator training and supervision is inadequate, so SSF fails to function optimally (Robens Institute, 1990) and full consideration should be given to these aspects in any SSF project.

An example schedule of activities for SSF caretakers has been provided by Visscher (1988) and is repeated in table 8.2.

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This chapter is prepared by Jamie Bartram, Robens Institute, 1990.

9 Chlorination

9.1 Introduction

The widely spread problems related to waters with poor bacteriological conditions in the Third World rural areas, are derived from the following common situations:

* Lack of technological solutions in accordance with development and resources of the area.
* Lack of disinfection units in a great number of rural water systems.
* Discontinuity of disinfection. In places where disinfection units exist, interruptions are frequent due to:

    * feeder failures,
    * chemical run outs,
    * operational and maintenance problems.

* Lack of high level decisions to set disinfection programs.
* Lack of permanent economical resources to obtain and install disinfection units and chemical provision where necessary.
* Lack of effective drinking-water surveillance programs.
* Lack of community education and involvement. When the community gets to know the benefits of drinking disinfected water, then their support will be obtained in order to get help in operation and maintenance activity and/or pay their fees to buy disinfectants.

This module will present some ideas to cope up with the first three items already stated, based on the most up-dated information promoted and gathered by Pan American Health Organization, PAHO.

9.2 Disinfection Methods

Water treatment process, as flocculation, coagulation, sedimentation and filtration can reduce the bacteriological content up to 90%.
To achieve the 100% effective kill, a complete disinfection should be done.

Numerous are the conditions that will influence the effective killing: the kind and number of organisms to be destroyed, the kind and concentration of the disinfectant, the water temperature, the contact time, the nature of the water to be treated (e.g.: presence of turbidity), the pH, the mixing, etc.
The methods of disinfection can be divided into two main categories:

9.2.1 Physical Methods

There are a good number of physical method: sound waves, light, ultra violet light, electricity, radioactivity, filtration through special beds, violent shaking, use of CO_2 under pressure, heat etc.

Of all of these, the best known is the last one, but even its excellent bactericidal capacity, it is not good enough (as not good are any of the other ones) to treat but little quantities of water, and no one can be used in an extended scale for community water treatment.

9.2.2 Chemical Methods

Several chemicals, acting just as strong oxidizers or as poisons can destroy bacteria.
Hydrogen and some metallic peroxides, lime, potassium and calcium permanganate, iodine, pure metals as copper, silver or zinc, ozone and chlorine derivates are among this category.
Of these methods, the most spread one is chlorination, and the one with excellent future possibilities is the use of ozone.

9.3 Chlorination

The adding of chlorine derivates to water is performed through the bubbling of chlorine gas in the water or through the dissolution of hypochlorite or organic-chloride powders.
In both cases the reactions taking place is:

$$Cl_2 + H_2O <===> HCl + HClO$$

The hypochlorous acid is dissociated in ions Cl^- and H^+ and does not take part in the disinfection.

The reaction is a reversible one, but can continue through a further step:

$$HClO <===> ClO^- + H^+$$

Summing up both reactions we'll have:

$$Cl_2 + H_2O <===> HClO <===> ClO^- + H^+$$

The water pH will be responsible for the relative quantities of Cl_2, HClO and ClO^- and so will be the relative bactericidal power as the different compounds have different powers (the greatest is that of HClO).
Several compounds having different chlorine concentration can be used in the chlorine disinfection.

Active Chlorine is the weight of molecular chlorine that will be rendered by one molecule of the compound. If a certain hypochlorite has 10% active chlorine, it means that 10 g of the chlorine gas were bubbled in 100 ml (100 g) of water.
The chlorine derivates more used in water treatment and their characteristics are presented in the Table 9.2.

When one of the mentioned compounds is added to a water, a certain time is needed for it to diffuse and to destroy (oxidize) the organic matter. This needed time is the *Contact time.*

The chlorine that is added is the *Dose*, and what remains after a selected contact time (usually 30 minutes) is known as *Residual Chlorine*.

The quality of chlorine needed for a complete oxidation of the organic matter is called *Demand*.

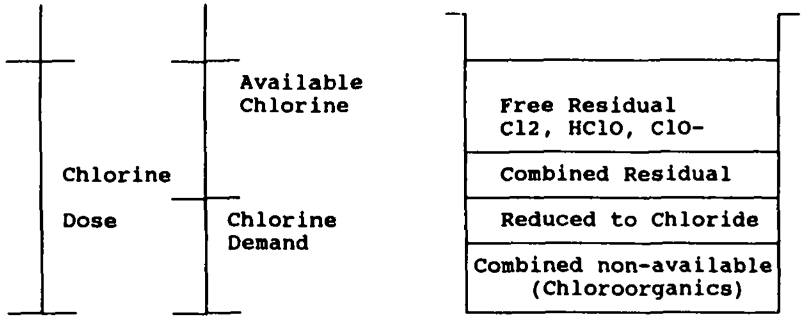


FIG. 9.1 Qualitative illustration of the different fractions of chlorine components in water.

It is important to note that there should be a residual that may cope up with any eventual future contamination (e.g.: in a distribution system). For this reason the demand should be known through an appropriate analysis.

If this analysis cannot be done, the way of proceeding is to fix an approximate dose and then determine the chlorine residual.

TAB. 9.1 Compound Characteristics

Compound	Formula	Produced as	Fed as	Active chlorine
Sodium hypochlorite	NaClO	Liquid	Solution	10 %
Chlorinated lime*	CaClOCl	Solid	Solution	35 %
Calcium hypochlorite	$(ClO)_2Ca$	Solid	Solution	30-70 %
Organic Chlorides, e.g.	$NaOOCC_6H_4SO_2NCl_2$	Solid	Powd./Sol.	60-90 %
Chlorine	Cl_2	Gas	Gas	100%

* Also called "bleaching powder"

Calculations:

To preform a disinfection calculation it is needed to know:

1) Water volume (or flow) to be treated.
2) Dose of disinfectant.
3) Active chlorine in the disinfectant.

Example 1:

50 liters of water. We want to add a 2 ppm (mg/l) dose of active chlorine and we have NaClO 8 %.

1 litre	≈ 2 mg active chlorine
50 litre	≈ x = 100 mg active chlorine
8 mg a.c.	≈ 100 ml NaClO
100mg a.c.	≈ x = 1250 ml NaClO

Example 2:

Let it be a flow of 5 l/s. We add a dose of 3 ppm of active chlorine, using an organic compound with 70% of active chlorine. How much of that compound should be added per hour?

$5\ l/s \cdot 1\ m^3/1000\ l \cdot 3600\ sec/h = 18\ m^3/h$

3 ppm = 3 mg/l = 3 g active chlorine

$1\ m^3$	≈ 3 g active chlorine
$18\ m^3$	≈ x = 54 g active chlorine
70 g a.c.	≈ x = 77 g compound

The dose will be: 77 g of the compound/ hour.

9.3.1 Selection of Chlorine Compound

On the basis of the previous examples it can be known how much chlorine should be needed, but it is not always easy to define what compound should be used, as many conditions should be considered in the selection (the type of feeder, the control means, operation and maintenance requirements and possibilities, the operator training level, cost of the compound, etc).

Nevertheless, as a very general rule the selection can be done as suggested in the following table:

TABLE 9.2 Selection of chlorine compound.

Population	Daily Personal Consumption (m^3/inhab·day)	Total Daily Consumption (m^3/day)	Chlorine Quantity (kg Cl/day)	Compound
< 1000	< 0.1	100	0.5	Sodium hypochlorite
1000-5000	0.1-0.3	1500	0.5-7.5	Chl.lime, calc. hypochl. Organic chlorine
> 5000	> 0.3	>1500	>7.5	chlorine gas

In the following, different types of diffusor feeders and solution feeders will be described.

As we are dealing with small rural communities, the use of gas chlorine will not be discussed here, as this method is generally used in great cities.

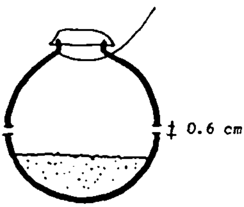
9.4 Stationary Diffusor Feeders

The use of gravimetric or volumetric feeders are only useful in big treatment plants. For small villages the chlorine powders are used in tanks and/or dug wells as diffusion feeders.

The best of these are the following:

9.4.1 Closed Pot With Holes

This pot, submerged in wells or in flowing water will render chlorine from a powdered compound placed in its interior. See figure 9.2.



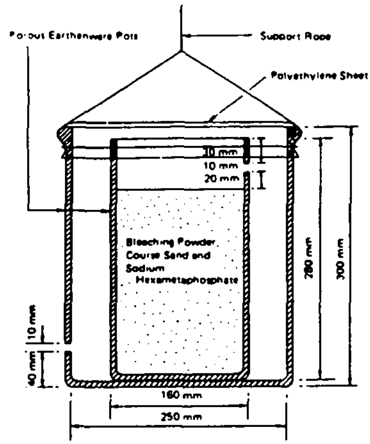


FIG. 9.2 Single and double pot chlorinator.

The pot can be of any kind of material (clay, plastic, glass). With a 12 -15 liters volume, and containing a mixture of:

1.5 kg chlorinated lime and
3.0 kg of gross sand.

The pot is lowered about 1 m below the water surface. It can chlorinate wells of 9 -13 m^3 of water with an extraction rate of 900 - 1300 liters/day.

9.4.2 Plastic Bag

This is a very extended method in China for dug wells disinfection. See figure 9.3. The feeder is made out os a plastic bag with several holes 1 - 2 inches in diameter, set in two rows. The upper row is over the chlorinated compound level, and the number of holes depend on the well water volume.

1 - 2 m^3	≈ 12 holes
3 - 5 m^3	≈ 13 - 18 holes.

9.4.3 Porous Clay Pot

A porous pot made out of clay. Its volume is around 15 liters (0.20 m in diameter and 0.50 m in height). It contains between 0.2 and 10 kg of chlorinated lime.See figure 9.4.

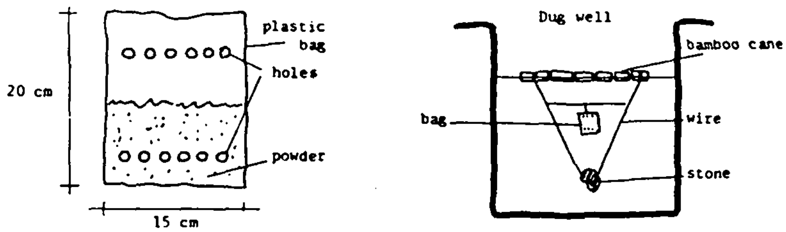


FIG: 9.3 Illustration of dimension and use of the plastic bag chlorinator.

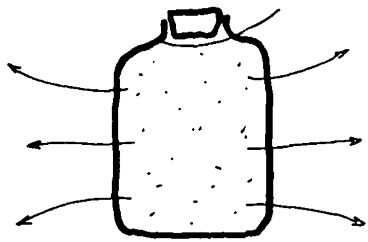


FIG. 9.4 Porous clay pot chlorinator.

9.4.4 PVC Concentric Tubes

It is a similar system to the pots. Made out of two PVC concentric tubes, having the inner one a slot that connect the chlorine powder (mixed with coarse sand) with the water to be disinfected. The bigger the slot exposure, the higher the dose. See figure 9.5.

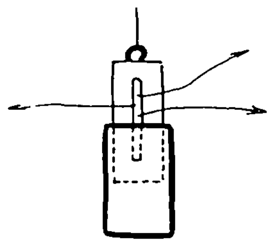


FIG 9.5 The concentric tubes chlorinator.

9.5 Continuous Flow Diffusor Feeders

The Costa Rica Institute for Water and Sanitation developed the following system. See figure 9.6 & 9.7.

Two recipients: one contains an organic chloride compound in tablets and the second being the diffusion chamber. The feeder is placed in the water outlet to a water storage tank.

The tablets can be made out of powdered compound (70% active chlorine) by means of a car jack. This lowers costs. The tablets characteristics are:

Diameter:	25 mm
Height:	10 mm
Weight:	12 g.

9.6 Solution Feeders

The diaphragm pump, one of the best systems for feeding chlorine solutions, will not be described here due to its cost and the operation and maintenance needs.

Two possibilities arise in solution feeding:

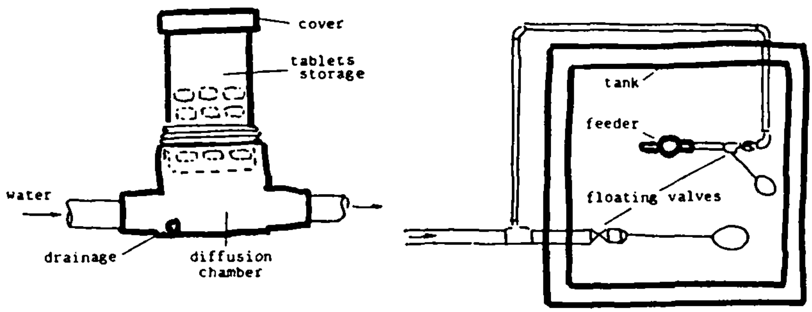


FIG 9.6 A simple tablet compressor.

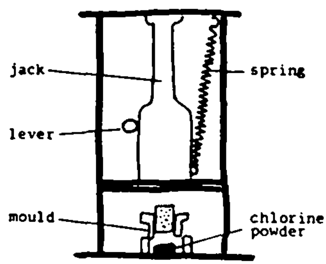


FIG 9.7 A tablet diffusion chamber and a chlorine solution feeder.

* Atmospheric pressure feeding
* Feeding under pressure (in a main).

Under atmospheric pressure there are also several possibilities:

* constant head systems
* wheel feeders.

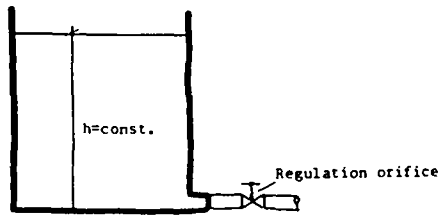


FIG 9.8 A constant head chamber with regulation orifice.

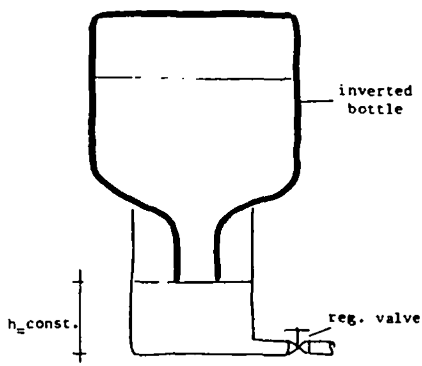


FIG. 9.9 An inverted bottle constant head feeder.

9.6.1 Constant Head System

These systems are composed by two elements: a constant head and a regulation orifice. See figure 9.8.

9.6.2 Inverted Bottle

An inverted bottle containing chloride compound solution is placed over a tube or container having an outlet with a regulation valve. See figure 9.9

This is one of the simplest methods, although it is affected with a considerable error.

9.6.3 Floating Valve

This system uses as a basic element, a floating valve, such as those used in the water-closet tanks.

One or two tanks hold the solution to be fed, while a small container having the floating valve can be considered the feeding element.

One of the many possible arrays is shown in the figure 9.10.

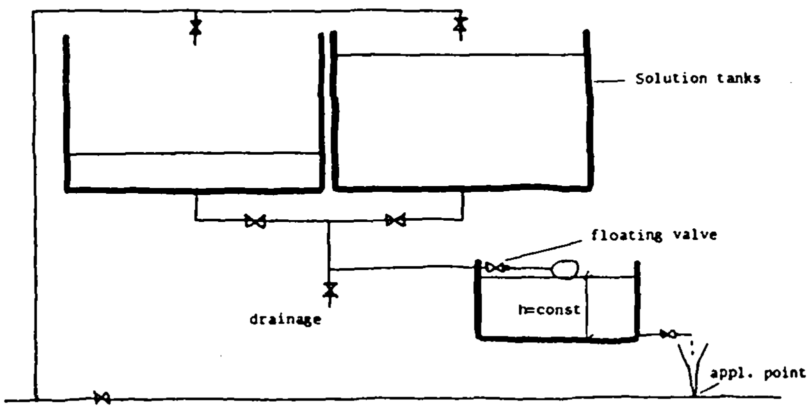


FIG. 9.10 Alternative fill and withdraw tanks with floating valve.

9.6.4 Floating Tube With Hole

This system also accepts different design, being the basic element a PVC tube (also a cane can be used) with one or more holes. See figure 9.11.

The tube is attached to any float, and the hole(s) remain some inches below the chlorine solution level. This solution enters through the hole(s) and is conducted by a small plastic tube to the outside of the tank.

The flow is regulated by

a) lowering or raising the tube with respect to the solution level varying in such way the head (the greater the head, the greater the flow), or
b) by means of a small valve in the outlet.

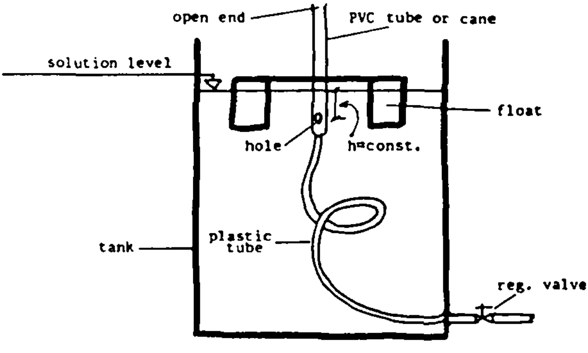


FIG. 9.11 Float and flexible tube controlled constant head feeder.

9.6.5 Beer Can And Plastic Bottle Feeders

These two systems were designed be Eng. F. Solsona from Argentina.

The first one is made out of used beer and spray cans.
The beer can has a cover (plastic , wood) through which passes a small tube (a piece of plastic pen can do) and a small vent hole. Another similar tube is placed in one wall for the outlet.

The spray can has no valve (it is easy to take off) and in its place a thick (1 cm) and soft rubber is glued. This second can act as a float inside the first one, and there, a constant head is formed, thanks to the action of the spray can.

The regulation is done be means of a hinge-valve. See figure 9.13.

The tank with the chlorine solution should be placed one meter above the feeder to diminish errors, and this tank has a filter inside to prevent the insoluble to clog the system. The filter can be the one used in motor-car for gasoline filtering or made out of a small plastic container.

Both cans should be convenient painted with resistent (epoxy) paint. See figure 9.12 and 9.13.

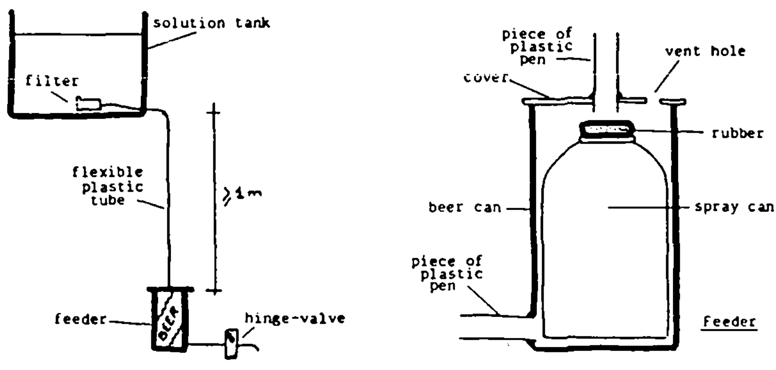


FIG. 9.12 Beer can feeder (left), and spray can feeders (right).

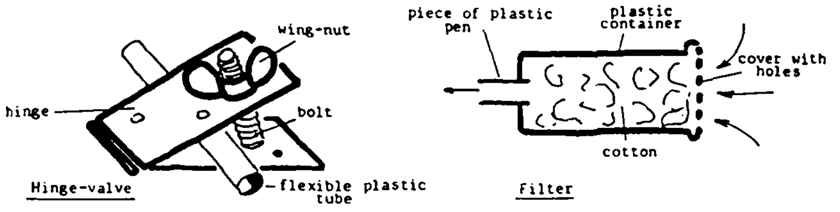


FIG. 9.13 Hinge-valve (left) and Filter (right).

The second system works under the same hydraulic principle. The difference consist in the use of different elements less vulnerable to the oxidizing power of the chlorine.
These elements are a plastic bottle and an inverted plastic beaker or glass. The bottle has no bottom and in its place a cover similar to the one used in the beer can system is placed.See figure 9.14.

The equipment operated exactly as the previous one.

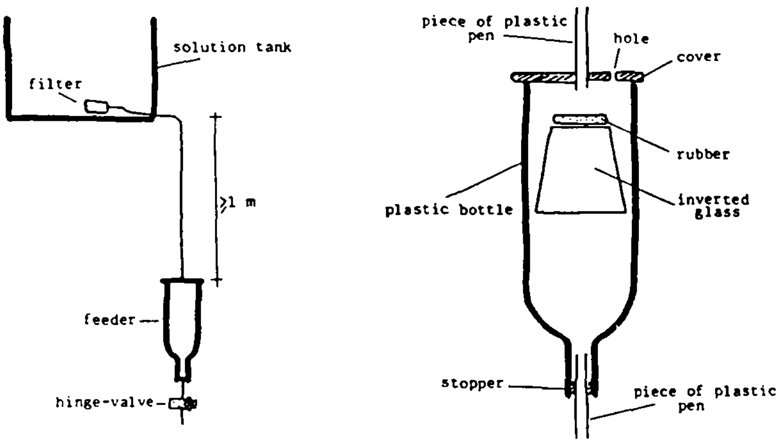


FIG. 9.14 Hinge-valve (left) and rubber/plastic pen controlled feeders (right).

9.6.6 Archimedes Wheel

It is a wheel that should be rotating by any means. The wheel has arms with pots, cans or glasses attached to their ends. These small containers raise up chlorine solution. The feeding flow is regulated with the variation of the wheel speed. See figure 9.15.

9.6.7 Paddles in Channels

This is an interesting system developed in Colombia by the National Health Institute. Where there is a channel with flowing water, a set of paddles will turn around an axis having three or more tubes with holes, that, when immersed in a tank with chlorine solution will raise portions of this one. The solution will pass through the interior of the tube to a discharge

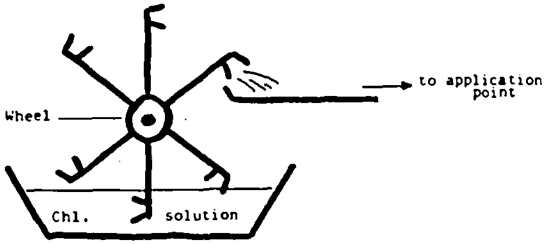


FIG. 9.15 The principle of archimedes wheel for solution feeding.

hole, over the channel.

The system is very interesting as it is proportional to the flow in the channel (the more flow, the quicker the paddles turn, the more solution the tubes gather). See figure 9.16.

9.7 Feeding Under Pressure

9.7.1 Venturi System

A venturi tube produces a partial vacuum, that can raise up solutions from a container. If this container has a constant level (by means e.g. of a floating valve) the feeding flow will be also constant. See figure 9.17.

9.7.2 Venturi With Rotameter

A loop around a pump, conducts water through a small venturi connected to a rotameter. The action of the venturi sucks the solution out of a tank. The rotameter, has a screw that allows the flow to be regulated. See figure 9.18.

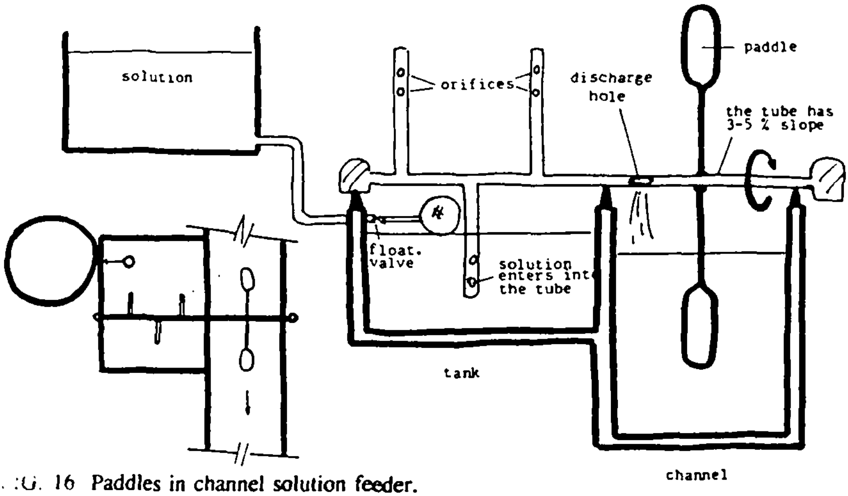


FIG. 16 Paddles in channel solution feeder.

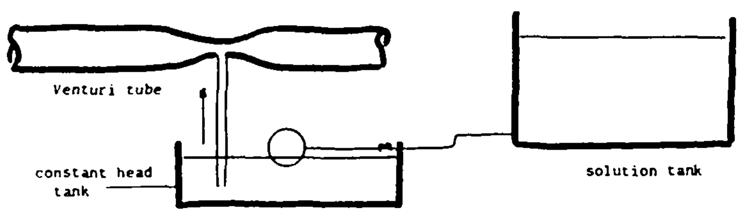


FIG. 9.17 The venturi tube feeder.

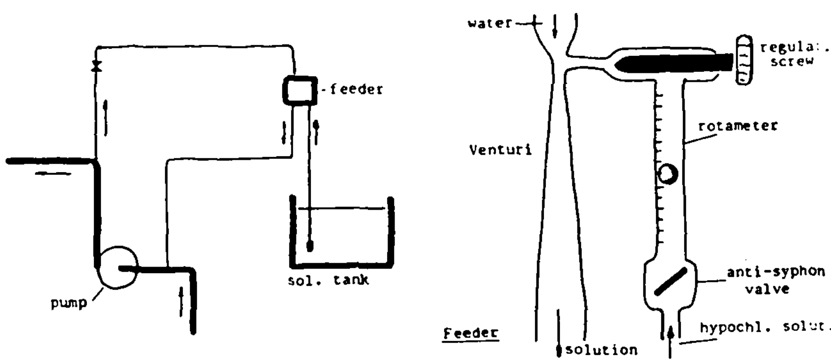


FIG. 9.18 Venturi valve rotameter for solution feeding.

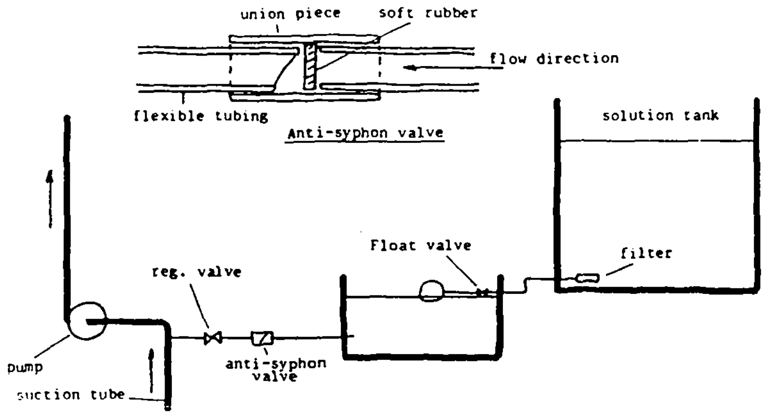


FIG. 9.19 Valve suction feeder.

9.7.3 Suction With Valve

When having a system with a pump, a small tube can be connected to the suction of the pump. A regulation valve, an anti-syphon valve, a constant head container and a big tank complete the equipment. The anti-syphon valve can easily be produced with a piece of thin rubber as described in the following design, see figure 9.19.

9.8 References:

1 Research on water disinfection in rural supplies. CEPIS - PAHO (1983) (Spanish)
2 Handbook of Chlorination. G.C: White
3 Manual on water disinfection. (Mexican water disinfection courses) -F. Solsona (1984)(Spanish)
4 Low cost chlorine feeder. Booklet - F. Solsona (1984).

This chapter is based on a paper given by F. Solsona.

10 Village Iron Removal

10.1 Introduction

Presence of iron in drinking water is often considered as an easy problem of aesthetic and technical nature. Yet in rural areas of developing countries, people may resist to drink and to use water with high iron content. Instead, they prefer surface water, which may look clear and taste nice, but which may contain pathogens. At such areas, iron removal is a severe problem of significant health dimension.

Comprehensive literature and good technology of iron removal has been available for decades. Much of it however has been innovated with relevance to urban conditions, i.e.:

A) Waterworks costs of traditional treatments are affordable.
B) Water source is often selected so that raw water with very high iron contents are avoided.
C) Pumping of water is based on fuel or electricity. Thus sufficient volumes of high pressure water with or without pressurized air are available for backwashing of filters.
D) Remote waterworks make it possible to find sufficient space for treatment plants.
E) Plants are operated by skilled operators.
F) Maintenance and repair are carried out by skilled manpower.
G) It is possible to provide indoors or at least enclosure protection of plants and equipments.
H) The operation implies continuous flow of water.
I) The scales of water consumption and plant constructions are large.
J) Water treatment is independent of community collaboration.
K) High removal efficiency is required.

In most villages, where water supply is based on hand pumps, the situation is completely different in respect of all these conditions. As a consequence, the conventional techniques of iron removal from ground water are of no direct use in major parts of the world, where iron removal from ground water is badly required.

10.2 Innovated Plants

Pioneer research and development on iron removal on small scale has been carried out by National Environmental Engineering Research Institute (NEERI), Nagpur (India). As a result, a Domestic Iron Removal unit called DIRU was patented, figure 10.1 (Dixit & Pathak, 1971). This plant is based on trickling aeration and down flow filtration mainly through the same unsaturated coarse media. Maintenance of filter is carried out by manual wash and rejuvenation of filter beds.

Richardson & Cruddas Ltd., an Indian governmental undertaking in Madras has developed DIRU, and introduced on commercial basis a package plant, RC-I for hand pump connection, figure 10.2. R & C thus introduced filtration through sand and the special arrangement of drain of clean water through patented permeable capsules. Operation and maintenance is similar to DIRU.

Furthermore, the Richardson and Cruddas developed a new plant, the RC-II for small power pump connection, figure 10.3. This plant is based on trickling aeration, down flow filtration and retention of water in a clean water compartment, from which water can be used for upward backwashing. It may be used for hand pump connections as well (Krishnaswamy & Alagarsamy, 1972) (Alagarsamy & Grandhirajan, 1981).

In Bangladesh the "UNICEF plant" was developed, based on trickling aeration, sedimentation and successive double filtration figure 10.4. Cleaning of filter media as for the DIRU plant. This plant has been constructed both as a prefabricated package unit, using mild steel, and as an on site built plant, using durable and locally available materials (Ahmed, 1982).

The Technical University of Denmark, in collaboration with the Drinking Water Project in Orissa, developed two iron removal plants, the DANIDA Mark I & II, for hand pump connections, figure 10.5 and 10.6. The DANIDA Mark I is similar to RC-I. It is however, constructed using locally available durable materials and of larger size, which allow scraping of filter sand without disconnecting any parts of the plant (Dahi, 1984).

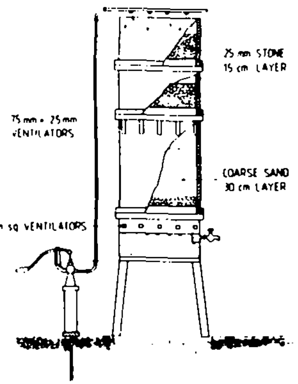


FIG. 10.1 The Domestic Iron Removal Plant DIRU, developed and patented by NEERI.

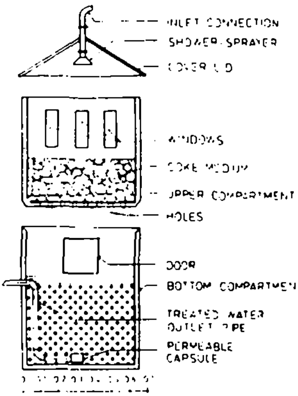


FIG. 10.2 The RC-I plant developed, patented and commercially introduced by Richardson and Cruddas LTD.

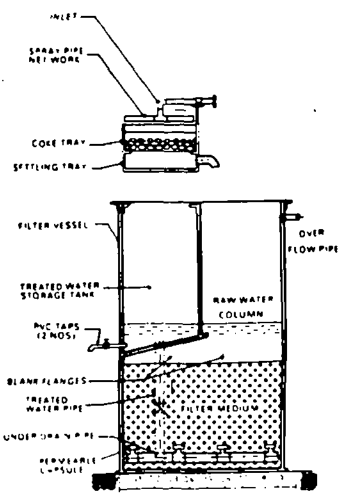


FIG. 10.3 The RC-II plant developed and commercially introduced by Richardson and Cruddas LTD for power pump connections.

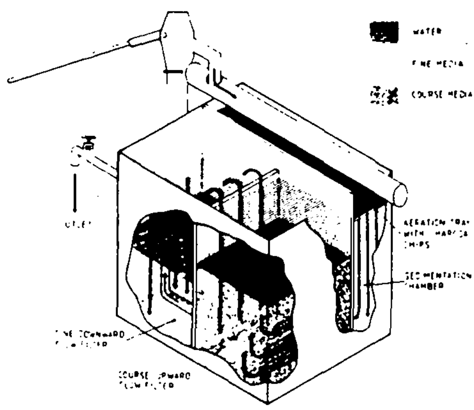


FIG. 10.4 The "UNICEF Plant" introduced in both Bangladesh and Sri Lanka as a prefabricated and an on site built unit.

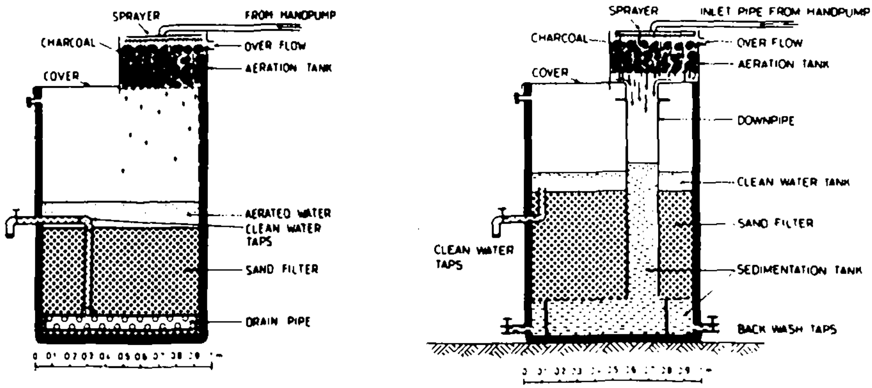


FIG. 10.5 The DANIDA Mark I (left) and II (right) designed and introduced for preliminary testing by the author in collaboration with the DANIDA Directorate in Orissa.

a: Elevated suck pump.
b: Perforated gutter.
c: Aeration chamber.
d: Filter tank.
e: 20 cm gravel 3-5 mm.
f: 20 cm pebbles 10-15 mm.
g: 20 cm stones 25-30 mm.
h: Down pipe .
i: Backwashing outlet.
j: Sedimentation chamber.
k: Clean water taps.
l: Overflow socket.
m: Clean water tank.

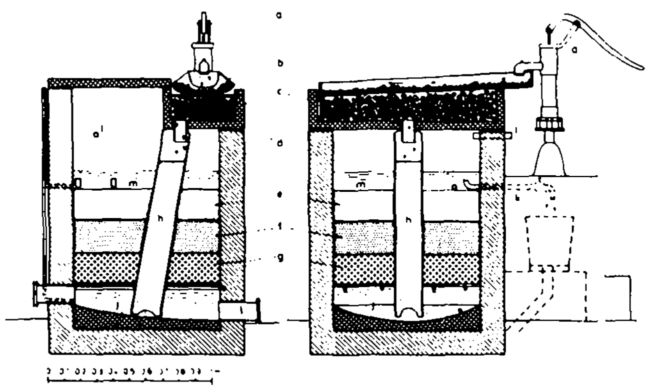


FIG. 10.6 The DANIDA MARK II plant designed by and introduced by the author in collaboration with the DANIDA Directorate for secondary long term field testing in Orissa.

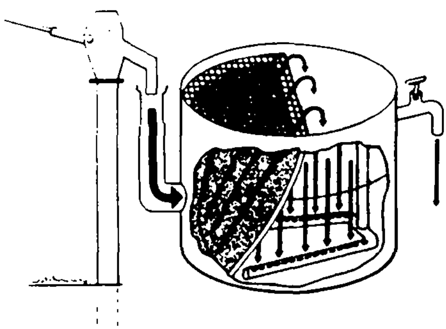


FIG. 10.7 Recent version of the Finnish iron removal plant utilizing venturi aeration, sloping edge filters and floating cement covered polystyrene balls in the first upflow filter.

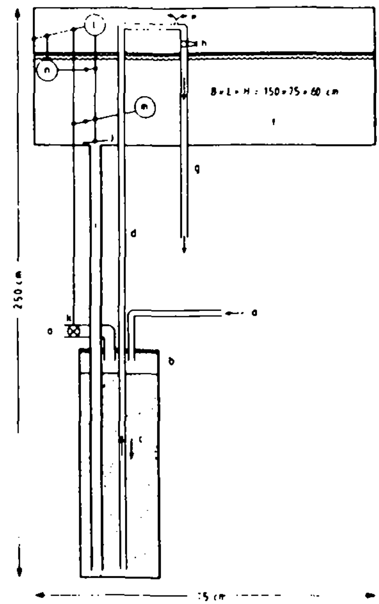


FIG. 10.8 The Pure Water System LTD plant utilizing elevated clean water tank for automatic backwash of filter.

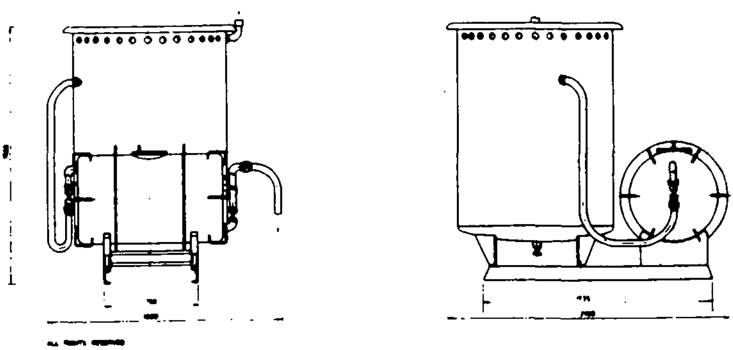


FIG. 10.9 The Kruger LTD plant utilizing filtration in air tight drum which is rotated on special wheels and stand for agitation of sand before flush wash.

The DANIDA Mark II, figure 10.6, is based on trickling aeration, sedimentation, upflow filtration and retention of treated water in a clean water compartment. It is constructed using durable local materials. Cleaning of filter bed is carried out by downward backwashing and occasionally rejuvenation of filter bed.

Another approach has been introduced in Sri Lanka by a FINNIDA project, figure 10.7. The "Finnish Plant" is based on venturi aeration through a down pipe, and dual filtration, first upwards through coarse media of floating polystyrene balls, then down flow filtration through a fine sand medium. The plant is prefabricated in mild steel.

Recently two private firms have been paying attention to the problems of iron removal in hand pump connections. Two different plants have been developed and patented. The English Pure Water Systems Limited plant is based on double or multiple media filtration, figure 10.8. So far no information has been given, neither about the composition of the filter media, nor about the aeration technique. It is however believed that the filter media consist of anthracite, sand and marble for acid neutralization. The aeration is probably obtained by a venturi arrangement. The interesting part of the plant is the automatic self-cleaning system; Part of the water pumped through the filters is retained in an overhead tank. When the tank is full it will automatically discharge in the reverse direction for backwashing the media (Dahi, Pani and Mishra, 1985).

The second plant is patented by the Danish firm Kruger, figure 10.9. This plant is based on trickling aeration and single down flow filtration through ungraded sand bed. The interesting issue of this plant concerns the aseptic sand cleaning. When cleaning is required, the filter drum is disconnected from the inlet and the outlet pipes and rotated on special bearing wheels. This agitate the sand media and loosen the adsorbed iron particles which then are suspended. Particles are then removed by discharging the suspension. Complete cleaning is achieved by repeating this procedure few more times (Carl Bro, 1986).

10.3 Filtration Kinetics

Kinetics of iron removing filters have been expressed using three simple equations (Dahi, Joshi, Vaidya and Viegand 1985):

Darcy Law:	$q/A = H \cdot K/L$	eq.1
Filtration Kinetics:	$L/K = L/K_o + \alpha \cdot M^a$	eq.2
Removal Balance:	$M \cdot A = Q \cdot (C_i - C_o) \cdot t$	eq.3

Where:

q	is hand pumping rate, $m \cdot s^{-1}$.
A	is filter cross sectional area, m^3.
H	is headloss, m.
K	is filter specific permeability, $m \cdot s^{-1}$.
L	is depth of filter bed, m^3.
M	is totally removed iron per c.s.area, $gFe \cdot m^{-2}$.
Q	is water consumption, $m^3 \cdot d^{-1}$.
t	is filter operation period (not time), d.
C_i	is iron concentration in filter influent, $g \cdot m^{-3}$.
C_o	is iron concentration in filter effluent, $g \cdot m^{-3}$.
α, β	are proportion and exponent coefficients, -.

Above mentioned modelling is useful for making field and laboratory observations. It also seems impossible to perform rational design of any iron removal plant, unless kinetics of iron removal is estimated properly. As such kinetics have not been reported, it is assumed that most plant development work carried out so far has been empirical.

10.4 Laboratory Testing

Apart from the DANIDA Mark plant I & II, which were "borne in the field", all the plants mentioned above have been tested in laboratory; at least during development of the constructions. Though laboratory testing may have been most useful for development of the plants, it may be useless or even misleading for evaluation of the applicability of the plants. As a matter of fact, the DIRU plant, which has been tested carefully by NEERI, and reported by prominent authors in textbooks on appropriate technology, has, to the authors knowledge, so far not been implemented any where in field.

10.5 Up- & Down Flow Studies

As seen in figure 10.1-10.9, both up and down flow filtration are utilized in several plants either as alternatives or in combination. Thus comparison of these techniques is of major importance for plant development.

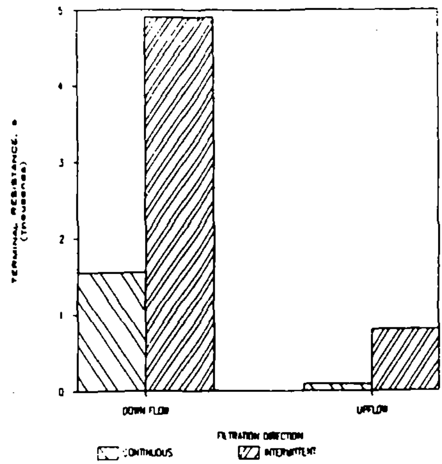


FIG. 10.10 Terminal filter resistance, L/K in s, obtained after one filter run where 350 g/m2 of iron removed in up and down flow filters operated continuously and intermittent (Andersen, 1986).

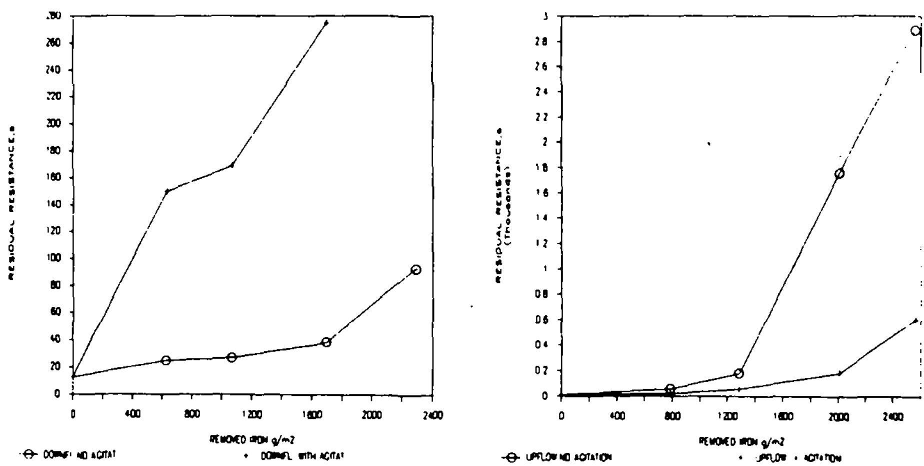


FIG. 10.11 Residual filter resistance after backwashing of up- and down flow filters with and without using manual agitation of sand (Andersen, 1986).

10.5.1 Filter Periods

Both laboratory column studies and field experiences seem to confirm that filter resistance, L/K, increases at faster rate in down flow than in upflow filtration, (Viegand,1984; Joshi, Vaidya and Dahi,1987; Andersen,1986) see also figure 10.10. Thus, longer filter runs would be expected in upflow filters.

10.5.2 Backwash Efficiency

On the other hand, upwards backwashing of down flow filters, using small amount (one bed volume) of water, is more efficient than down wards backwashing of upflow filters (Andersen, 1986; Joshi,Vaidya and Dahi, 1987). Figure 10.10 indicates that even recovery of permeability of down flow filters, though better than in upflow filters, may still be incomplete. Thus, simple backwashing of especially upflow filters, using one bed volume of water, would result in insufficient recovery of filter permeability.
After some filter runs rejuvenation of filter will be required. This is at least valid in laboratory column experiments. Down ward flush of down flow filters and up ward flush of upflow filters are yet to be investigated.

10.5.3 Agitation of Sand

Agitation of sand prior to backwashing is demonstrated by Andersen (1986) to have different effects on up and down flow filters, figure 10.11. This is at least valid for filter bed gradation as shown in figure 10.6. Obviously, agitation of upflow filter beds would help making the flush of precipitated iron more complete. On the contrary in down flow filters, precipitated iron is transferred to the deeper layer, from where it becomes more difficult to elevate and flush upward.

Backwashing (and thus re-operation) of filter beds having normal cross sectional areas, e.g. 0.8 m^2, may deviate from small sectional columns. Especially up ward flush may lead to local fluidization of a part of the filter bed. In such cases agitation of sand during backwashing may be beneficial for recovery of filter permeability. This effect has been observed by Viegand (1984) in the R&C-II plant.

10.5.4 Intermittent Flow

Laboratory studies carried out by Andersen (1986) show that kinetics of iron removing filters, both the upflow and the down flow version, is dependent on whether the flow of the water is continuous or intermittent, figure 10.10. More surface filtration is achieved by intermittent pumping. More depth filtration is achieved by continuous pumping. This is at least valid for filter bed gradation as shown in figure 10.6. Most laboratory testing of iron removal plants are carried out using continuous flow of raw water from a reservoir or by an electric pump, while hand pumping is discontinuous by nature. This is due to the pulsatory current of the pump strokes as well as to the interrupted pumping during the day and the night time.

On the background of these findings, it is expected that field experiences may show shorter filter runs and easer backwash than expected from continuous flow laboratory testing.

The intermittent flow of the hand pump, the possibility of agitation sand and the pattern of water consumption are among the several reasons, why some constructions may look promising in laboratory experiments but not in field work. Laboratory experiments on "hand pump connected plants" should therefore be planned and elaborated very carefully. Still, laboratory experiments alone can not show whether a plant is worth implementation in field.

10.6 Field Testing

In a study carried out in collaboration with the DANIDA Directorate in Orissa and reported by Dahi and Viegand (1985), the Richardson and Cruddas I, the Richardson and Cruddas II, the DANIDA-I and the DANIDA-II were installed and studies in selected villages in Orissa, India. This study showed, that the iron removal efficiency is very high, between 97 and 99.9 % in all tested plants. However, taking into account the length of filter runs, the corrosion problems of mild steel constructions, the breakage problems of the glass fiber reinforced plastic and the problem of pumping of backwash water, it was concluded that at least three of the four types of plant were of no use for the Orissa Drinking Water Project.

TABLE 10.1 Summary of evaluation of four iron removal plants on the background of field testing in Orissa villages.

PROBLEMS IDENTIFIED	RC-I	RC-II	DM-I	DM-II
Construction Break	High	Medium	Low	Low
Corrosion Problems	Low	High	Low	Low
Frequency of wash/scrap	High	Medium	Medium	Low
Burden of backwash pump	Nil	High	Nil	Medium
Burden of rejuvenation	High	Low	Medium	Medium
Burden of scraping sand	High	Nil	Medium	Nil
Costs	Medium	High	Low	Low
Community involvement problem	Medium	Medium	Medium	Low

TABLE 10.2 Experiences on iron removal plants as summarized by a DANIDA sponsored Mission from the Carl Bro International (1986).

COUNTRY	PLANT	EXPERIENCES
SRI LANKA	UNICEF	Initially not positive. Recently more promising. Yet not proven over long term field trials.
BANGLADESH	UNICEF	Completely unacceptable high failure. Some plant have been operating successfully for 2-3 years.
ORISSA	DANIDA Mark II	Well designed and constructed on correct basic principle. Yet to be field tested and optimized.

The DANIDA Mark II seemed to be superior to the other plants tested. Long term field testing should show whether this plant or an improved version of this plant may fulfill the expectations in the project.

10.7 Evaluation Studies

Danish International Development Agency, DANIDA, conducted a mission (Carl Bro, 1986) to assess iron removal technology at hand pump level. The mission reviewed available literature on the subject, interviewed project workers and inspected selected units in Orissa, Sri Lanka, Bangladesh. The Mission also inspected the Kruger plant in Copenhagen. Some of the main conclusions are shown in table 10.2.

The Mission concluded that the situation in respect of iron removal is different in each country visited, and these differences must be considered in evaluation of solutions to be applied. It is remarkable that non of the inspected plants were directly rejected by the Mission. F. ex. the Mission described the Kruger plant as "strong objected in Bangladesh", but recommended testing the plant in Orissa. In general, the mission recommended more scientific research and re-design of some unit defects and further testing of the more promising plants.

In April 1985 another group inspected the 17 DANIDA Mark II plants which were installed 9 months before in remote Orissa villages. The group made following observations:

A) Two identical plants installed in two apparently similar villages in the same district were having entirely different degrees of success.

B) Backwashing of filters, which should be carried out by project junior engineers, was neither conducted regularly nor properly. Because of slowly opening of the flange in the bottom of the plant, only the sedimentation chambers and not the filter beds were flushed. Like that several, even very important concepts were not understood by the juniors, who have never been trained in identifying plant failures or in measurement of water consumption or filter resistance.

C) Implementation defects were identified in most of the plants.

D) Design defects were identified. Especially the delicate point of connection of down pipe and aeration chamber seems difficult to get tight, and the flange of backwash seems difficult to get open suddenly.

On this background the group suggested:

A) Establishment of a specialized group or cell responsible on iron removal.

B) Updating of plant constructions.

C) Conducting training of trainers and of maintenance staff.

D) Conducting sociological studies to explain the different villagers attitude.

So far the field control program has been carried out. The proposed suggestions are yet to be considered. Presumably this is not unique for the Orissa Project. Often it is easier to make suggestions and to initiate more evaluation and reporting in city offices, than to conduct field work in remote villages in developing countries.

10.8 Design Criteria

As most development work conducted so far is empirical in nature, generally accepted design criteria have not been established. Comprehensive discussion of the design criteria is out of the scope of this paper. Yet it has to be stressed that field experiences, gained in Orissa and Bangladesh, indicate that the entire background for the main design and construction criteria is socio-economical rather than technical.

When villager reject a plant as "not working" it often because of:

A) Break down of some essential parts of the pump or plant.
B) Too slow discharge even after 1-3 minutes of pumping at a time where the plant have just been backwashed or rejuvenated.
C) In some cases because of long term break through of iron.

This means that major emphasis should be given to:

I The robustness and the possibility of local community repair of the plant.
II It must be possible, at the end of any filter run period, to establish the head loss required for satisfactory water discharge, say 10 l/min, within say 2 minutes of hand pumping from a start condition where the plant is "empty".

Two minutes of hand pumping, i.e. about 30 l of water, is corresponding to 0.05 m of head in the R&C-II plant, but to 1.5 m in the DM-II plant. In other words, if the head required in both plants is 0.2 m, then the initial pumping required my be 8 minutes in the R&C-II plant, but only 16 sec. in the DANIDA Mark II plant. This is of course because of the 30 times difference in the areas in the head chamber upstream the filter. Unfortunately this issue of up- and down flow filters, though extremely important, seems not to be acknowledged by many desk officers and even many professionals in the field.

The initial pumping time, where water is accumulated in the plant until satisfactorily discharge is reached, and the attended degree of prefabrication and off site built, are assumed to be basic design and construction criteria for hand pump connected iron removal plants.

10.9 Literature

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This chapter is based on a paper given by Eli Dahi 1987.

11 Defluoridation

11.1 Health Aspects

Traces of fluoride occur in many waters, and higher concentrations are often associate with underground sources.

Most waters contain below 1 mg of fluoride per litre (1 mg/l), but in several areas scattered all around the world in which fluoride containing minerals are common, waters may have up to 10 mg/l and even higher.

There are other routes of exposure, but comparing the contribution in fluoride of food, air and water, depending the concentration of this ion in water, the contribution percentage is shown in table 11.1.

TABLE 11.1 The exposure to fluoride through water.

Fluoride conc. in water (mg/l)	Total water contribution (%)
0.5	50
1.0	67
1.5	75

So, it is seen that when consuming waters with high fluoride levels, the dietary contribution arises, and as the fluoride ingested with water is almost completely absorbed (better than the ones from the air or food), the people drinking fluoridated water will be easily susceptible to the health related effects.

Absorbed fluoride is distributed rapidly throughout the body. It is retrained en the skeleton, and a small portion is retrained in the teeth. Fluoride is essential for human beings, in particular fertility and growth are improved as a result of relatively small doses of fluoride. When drinking waters with around 1 mg/l F^-, there is a substantial reduction of dental caries in both children and adults.

For this reason in many cities of the world it is a common practice to add fluoride to the distributed water as a means to reduce that illness in the population. This is known as "water fluoridation" and some international organizations like WHO have or have had at certain times fluoridation programs.
Nevertheless if the waters contains far more than 1 mg/l different health problems may appear.

When the F^- level raises from 1.5-2.0 mg/l on, people consuming these waters for many years may develop "dental fluorosis" a white-yellow-brownish mottling that affects the aesthetics of the teeth and that at high level may turn them considerably brittle. Skeleton fluorosis has been observed in persons when water contains more than 3-6 mg/l. Intake of 20-40 mg of fluoride per day (or more) where water contained in excess of 10 mg/l over a long periods have resulted in crippling skeletal fluorosis.

At high doses, fluoride can interfere with carbohydrate, lipid, protein, vitamin, enzyme and mineral metabolism being the symptoms of intoxication, the binding of this ion with calcium.

In very high doses fluoride id acutely toxic to man. Pathological changes include hemorrhagic gastroenteritis, acute toxic nephritis, and various degrees of injury to the liver and heart muscle.

The acute lethal dose is about 2 g of fluoride ion for a human being.

11.2 Control Options

There are a great number of methods and/or substances that can be used for the fluoride removal from drinking water.

Here it will not be listed all possible methods, but rather the most effective ones presenting them in a simplified division:

	Precipitation.
Methods	Adsorption and ion exchange.
	Special methods.

Precipitation

1.-Aluminum sulphate
2.-Lime softening
3.-Alum and lime

Adsorption and ion exchange

1.-Activated carbon
2.-Plant carbon
3.-Zeolites
4.-Defluoron 2
5.-Clay pots
6.-Activated alumina
7.-Bone meal
8.-Bone char

Special

1.-Blending
2.-Electrodialysis
3.-Reverse osmosis

11.2.1 Aluminum sulphate (alum)

Alum treatment to remove fluoride is similar to alum treatment for turbidity removal, except that the required dose is larger.
The equipment needed is similar to that normally used for chemical precipitation: dosing system, flocculation tank, sedimentation tank and possible a filter.

Expected problems with the use of this method include the large amount of alum required (residual aluminum levels may exceed recommended limits for drinking water), large amount of sludge produced and the low pH of the effluent. The method is rather uneconomic.

11.2.2 Lime softening

Under certain conditions it is possible to remove fluoride as a side reaction in lime softening.

During the softening, fluoride coprecipitates with magnesium hydroxide. The amount of fluoride removed depends on the amount of magnesium removed. The residual fluoride can be calculated from the following formula:

$F_r = F_i - (0.07 \cdot F_i \cdot Mg^{0.5})$
F_r = Residual Fluoride
F_i = Initial Fluoride
Mg = Mg removed (in mg/l)

If the amount of magnesium in the water is not sufficient for the desired fluoride removal, more Mg must be added.

Expected problems include sludge disposal, the high pH of the treated water and the need for eventual magnesium adding. Trained operators are also needed.
This method should be suitable for low fluoride, high magnesium water which needs softening before use.

11.2.3 Alum and Lime

In this method, often called the Nalgonda method, lime is added first, followed by aluminum sulphate. the use of lime, about 1/20 of the alum dose reduces the amount of alum needed.

The advantages of the method are the possibility of being used in rural areas, an easy operation and an easily performed equipment.

The disadvantages are: It does not have as much high fluoride retention as other techniques have. it produces great quantities of sludge. With water with F higher than 10 mg/l a two stages treatment is recommended, and in some rural areas it is not easy to obtain the chemicals involved.

11.2.4 Activated Carbon

Although the fluoride removal efficiency can be high, the process is pH dependent. The best removal rate is at pH 3 or less. Many activated carbons have a very narrow optimal pH range and their effectiveness can be modified by other substances in water.

This method is expensive and not very practical because of the large change in pH required before and after treatment.

11.2.5 Plant carbon

Treatment of paddy husks by digestion in 1 % potassium hydroxide followed by soaking in 2 % alum produces a media which will remove fluoride.
The material may be regenerated using 2 % alum.

Optimal influent pH is 7.0. The removal capacity is reported to be 320 mg F/Kg, at pH 7.0. Although other plant wastes may also be suitable, there is no evidence that such tests were held.

Disadvantages include disposal of waste regenerant.

11.2.6 Zeolites

Zeolites have certain limitations, and in addition they can also be relatively expensive. One problem is the competition between the removal of fluoride and other anions which may be present in the water.

Natural zeolites seems to have small fluoride removal capacity and besides they have little resistance to abrasion, which may cause excessive media losses.

11.2.7 Defluoron 2

Successfully used in India, the Defluoron 2 is a sulphonated coal regenerated with alum. hydraulic properties are said to be good, capacity decreases with increasing alkalinity and low initial fluoride concentration.

In relation to other techniques used in India, the use of Defluoron 2 has been regarded as cumbersome in operation and regeneration. It is reported that skilled operators are needed to obtain effective control.

11.2.8 Clay Pots

The passage of water through clay pot walls for removing turbidity is a technique in use in some areas in different countries. reports are also available that these elements can remove up to some extent fluoride ion as well as turbidity.

The capacity probably varies with the type of clay used, and so will passage time estimated in general as very long.
The method (tested in some African communities) seems to be not very efficient although an advantage is its simplicity.

11.2.9 Activated Alumina

This method is one of the most widely used and favored. There is good experience on the subject and large bibliography available.

Activated alumina is a special form of acid treated alumina (possibly: $(Al_2O_3)_n 2AlO_3H_3$)

The affinity for fluoride is very high, but as so its affinity for OH^-, the water to be treated should be acid, being the best range between ph 5 and 6.

The exchange capacity is high, and the method can also be used in presence of water with fluoride plus arsenic, a situation that in some areas is found. The media is used and regenerated with sodium hydroxide solution followed by a neutralization with sulfuric acid.

Although its use will demand well trained operators for a good plant treatment control, and although it is a relatively costly method, activated alumina is an excellent media for fluoride removal.

11.2.10 Bone Meal

Since many years ago, the use of bone meal for fluoride removal has been used in central areas of the Argentine Republic. The bone meal is a degreased bone with a content of about 70% of tricalcium phosphate which retrains the fluoride ions showing high capacity. The media is obtained from animals, specially cows, being the best ones, the limb bones.
The media acts as an ion exchange media and is regenerated with sodium hydroxide solution and consequent neutralization.

The low cost, the possibility of finding bone in any country and the high retention capacity makes this to be a good method. The disadvantages are (as with other methods) the need of an ion exchange treatment plant and the necessity of well trained operators. In some cases, if the bone is not well prepared, and/or the plant stops for several days, some "soup" taste may be given to the water.

The media usually suffers loses of around 10-20 % per year, and if the raw water has high arsenic content, it can be poisoned and not be able to generate.

11.2.11 Bone Char

Bone char is quite similar to bone meal, its preparation needs one more step, the burning of the bone. This is important to eliminate the organic matter left in the bone after the degreasing treatment. Thanks to this, the soup taste problem is less feasible to occur. A slight color can be given to the water when the first runs take place.

11.2.12 Blending

Blending with an alternative source of water of low fluoride content can be a very appropriate option as long as problems of physical or chemical reactions do not occur between the blending waters.

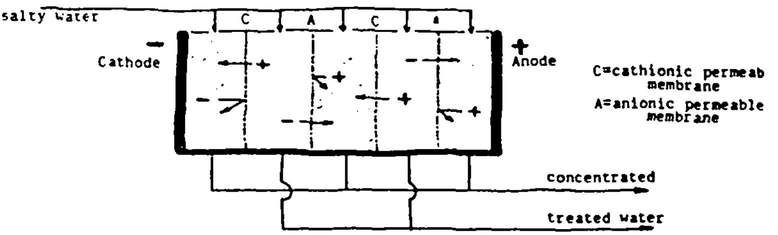

FIG. 11.1 Electrodialysis Equipment

11.2.13 Electrodialysis

This is not specific for fluoride, but for salinity in general. The water ions, under an electrical field are diffused, through special membranes, placed in ad-hoc chambers. See figure 11.1.

The membrane are alternative anion and cation permeable, and so, a set of chambers ones concentrating salinity and the other deconcentrating it,, produces two outlets. one with the concentrated, and one with desalinized (defluoridated) water.

The removal capacity is very high, but also high are the unit price and electricity requirement for the operation.
Turbidity may affect negatively the process. This method is not recommended for the Third World countries.

11.2.14 Reverse Osmosis

Reverse osmosis is a desalinization method that changes the direction of the natural osmosis flow. This is done by means of employing over a saline solution a pressure superior to that of the osmotic one, obliging the solvent by this way, to pass through a semipermeable membrane.

The membranes are placed inside some molecules, that helps to support the imposed pressure. There are a lot of different kinds of membranes, being the most common the cellulose acetate and the polyamide derivates. These membranes retrain between 90-99 % of all dissolved salts, 95-99 % of most organic compounds and 100 % of colloidal matter.

This means an excellent possibility for reducing high levels of fluoride in water, even excellent when having also arsenic that may poison bone media if using these.
The raw water to be treated should be free of turbidity, so a microfilter is placed before the pressure modules. A pre pH adjustment is also needed.

The disadvantages of this method are the cost of the system and the operational cost, the need of well trained operators and the highly concentrated effluent produced.

11.3 Bone Meal & Bone Char Techniques

There are two possibilities when using these media:

a) treatment plant (normally the treatment of water after being pumped from a drilled well), and
b) the bucket technique for isolated families with low water consumption.

11.3.1 Principle

The principle of this method is the fluoride adsorption by bone meal or bone char.
Raw water passes through the media placed as in a filter, leaving its fluoride in accordance to the following reaction:

$$F^{-} + \text{bone} \xrightarrow{\text{Adsorption}} \text{F-bone}^{-}$$

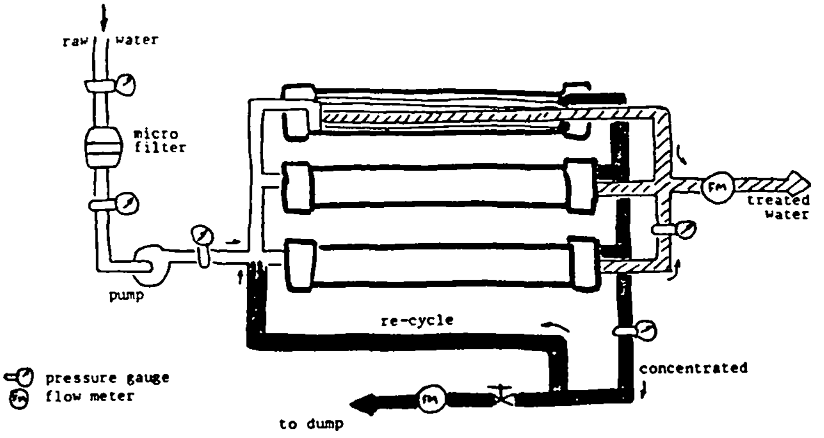

FIG. 11.2 Reverse Osmosis

When the media has become saturated with fluoride; in the case of the bucket technique, the media is discarded; but in the case of using it in a treatment plant, it is regenerated with a diluted solution of sodium hydroxide in accordance to:

Desorption

$$\text{F-bone}^- + Na^+ \;\text{----->}\; FNa + \text{bone}$$

Once this has been done, the filtering media needs to neutralized with acid water prepared with sulfuric acid, being now ready to begin a new cycle.

$$SO_4H_2 + HONa \;\text{----->}\; SO_4NA_2 + H_2O$$

11.3.2 Exchange media

In some places the bone media can de readily available from local slaughter houses.
One of the criticism to this technique is that if the bone is not well treated, it give the water a soup taste.

There are two ways of treating the bone. The traditional is the following:

Let the bone be clean. Ideal is the bone that has been exposed for a long period of time to the sun and atmosphere. This bone is degreased by means of a prolonged boiling in water (For a better degreasing the boiling can be done in a caustic solution of sodium hydroxide 30 %, not less than several hours). After this, the bone is dried in a stove or directly by exposure to the sun. Then the bone is crushed and sieved.

The second procedure is the pressure one. The bone is introduced in a steel pressure chamber with water and set with 2 kg/cm^2 pressure for one hour. A second hour passes by while the pressure is lowered down to 0 kg/cm^2; and a third hour is needed for settling. The bone; in this way degreased, is washed with cold water and then put under sunlight or in stove to get a complete drying. The bone is now ready for grinding.

At the end of these treatments the bone should complain with the following specifications:

Phosphate tricalcium	70%
Moisture (maximum)	5%
Grease (maximum)	5%
Apparent specific weight (approx)	0.8 Tn/m^3
Absolute specific weight	1.4 "
Effective size	0.5-1.5 mm
Uniformity coefficient	2.35
Void percentage	50 %

Bone char is obtained in the same way, but with further steps: a burning of the media over a steel plate or in an oven to get a brownish-black compound.

11.3.3 Treatment plant technique

The basic design is that of a system in which raw water is passed through an exchange filtering media in an ad-hoc container. This container inlets, and outlets as in a pressure filter. Two tanks contain sodium hydroxide solution and another one sulfuric acid, with its corresponding feeding pumps. See figure 11.3.

For the design of a treatment plant, the first step is to know the exact exchange capacity of the media. The exchange capacity is the quantity of fluoride ion that the media volume unit is able to retain allowing the treated water with the optimal residual along a working cycle.

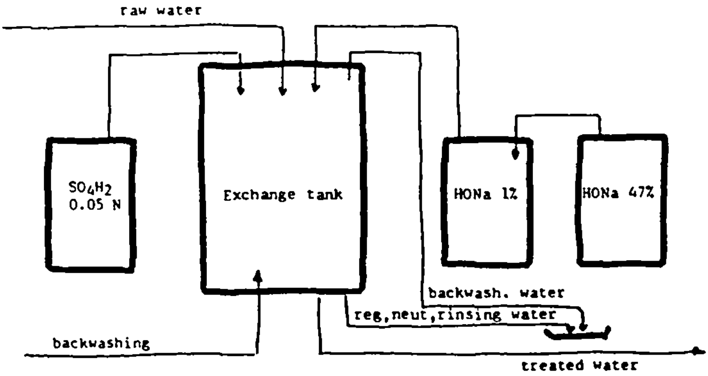

FIG. 11.3 Exchange filtering treatment plant

It is expressed as grams of F- ion retained/m3 of media. The optimal residual is obtained from the Gallaghan-Vermillion table, which entails maximum Mean Temperatures with the mean dose to be supplied.

T 1/2 Max (°C)	F^- (mg/l)
10.0 - 12.1	1.2
12.2 - 14.6	1.1
14.7 - 17.7	1.0
17.8 - 21.4	0.9
21.5 - 26.3	0.8
26.4 - 32.5	0.7
32.6 - 37.5	0.6

The obtention of the exchange capacity is important to calculate the volume of media to be used in the treatment plant.

The correct way of measuring this capacity is making a column filled with the media; run the water through it and measure the volumes and the fluoride content of the inlet and the outlet.

When designing a treatment plant, there are several figures corresponding to the most important parameters, obtained through a good experience in many operating plants.

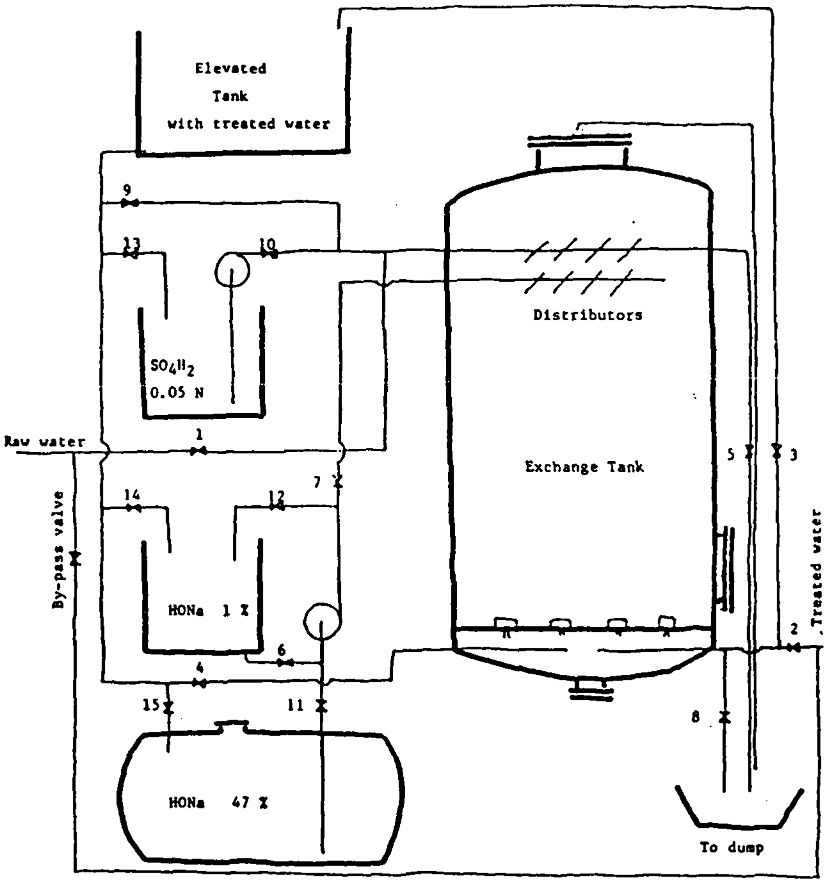

FIG. 11.4 Equipment and valve design using treated water

Among others these are: water flow, backwashing, regeneration and neutralization rates; regeneration and neutralization levels; regenerant and neutralizer concentration; backwashing duration and bone media height in the tanks; maximum tank diameter, water rate in tubing etc.

With the figure 11.4 and the aid of a plant design manual (e.g. /6/), a treatment plant as the diagramed can be designed.

11.3.4 Bucket technique

This technique is good for isolated families or group of families.
Prepared in central agencies, the buckets with the bone (meal or char) can be delivered to country families for their use.

A simple calculation will yield these results:

No of components/family	5	
Drinking needs/capita	3	l
Liters to be treated/family x day)	15	l
F- conc in raw water (supposed)	7	mg/l
Capacity of bone (approx)	900	gF^-/m^3 bone
Volume of bone/bucket	20	l
Capacity of 20 l of bone	18	gF^-
Liters of raw water to be treated with 20 l of bone	2571	l
Days of treatment with one bucket	172	days

The bucket is a very simple device. Nothing else but a filter with the exchange media, that can be easily built with a bucket of any origin of 25-30 liters of volume.

On one side, and near the bottom, a 1/2 inch hole is drilled and through it, it is placed any kind of rigid tube, and then, it is sealed. The tube needs a valve or any device that may serve as a valve (e.g.: hinge-valve).

The bucket is filled with 20 liters of media (bone meal or bone char) and is ready for use.

The operation is very simple: 1) fill the bucket with raw water, 2) open the outlet and let the water flow very slowly (about 35 ml/minute) and 3) continue filling the bucket with water.

Note: specially while using bone meal, it is wise not to let the unit without using for more than two days. If so, the first new portions will have soup taste and odour.

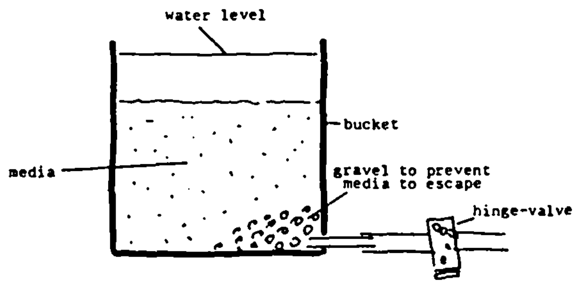

FIG. 11.5 The Bucket Technique

11.4 Activated Alumina Technique

The principle of this method is that of the fluoride ion adsorption by the activated alumina.

The media, activated alumina, is hydrated aluminum oxide that after a convenient treatment (heat) is converted to granules of $(Al_2O_3)n \cdot Al_2O_3$

The advantage of this defluoridation method is that it may be perhaps the most known technology; it does not give taste or odour to the treated waters and it is not "poisoned" as bone is when treating water with arsenic.

The disadvantages are the need of a well operated process, acidification of the inlet water, and its costs, roughly ten times that costs of bone meal.

The chemical, physical operational characteristics, as well as those of equipment and even employed solutions, are practically the same as the ones for bone meal, or bone char, so the reader will be sent for the plant to design to some of the recorded bibliography (e.g. /6/; /7/).

There are, nevertheless, some differences when using activated alumina.

First: the most widely used a.a. is the Alcoa-grade F-1, mesh 28 x 48, and although in order to know its exact exchange capacity a column test should be run, it is already known that this capacity ranges from 1000 to 5000 g F/m^3, depending the exact figure on many conditions, but being the most important the water pH.
The operational pH (of inlet water) should be between 5 and 6 being the optimum 5.5-
So, if the raw water is not so acid, it will be acidified by dosing sulfuric acid 0.05 N, before entering the exchange tank.

Second: the operational sequence when using this technique is also a bit different, as it needs to follow the next steps:

Normal operation	down flow
backwashing	up flow
regeneration 1	up flow
rinsing	up flow
regeneration 2	down flow
neutralization	down flow
normal operation	down flow

With cautious operation, this method is excellent, but from the stated condition it is clear that there is a great need of well trained personnel to deal with the whole process.

11.5 Nalgonda Technique

This method mostly developed in India, and known as the Nalgonda Technique, is based on the treatment of raw water with high fluoride content, first with lime and then with alum (aluminum sulphate).

The treatment is performed in specially designed tanks, but for rural areas or even for economic reasons it can be used with tanks or containers of different volumes or types.

This method is ideal when dealing with highly turbid waters, due to the fact that alum is the chemical most used for turbidity reducing.

The quantity of chemicals to be fed should be determined for every type of water, because doses depend on fluorides, alkalinity and dissolved solids present in the water. The authors

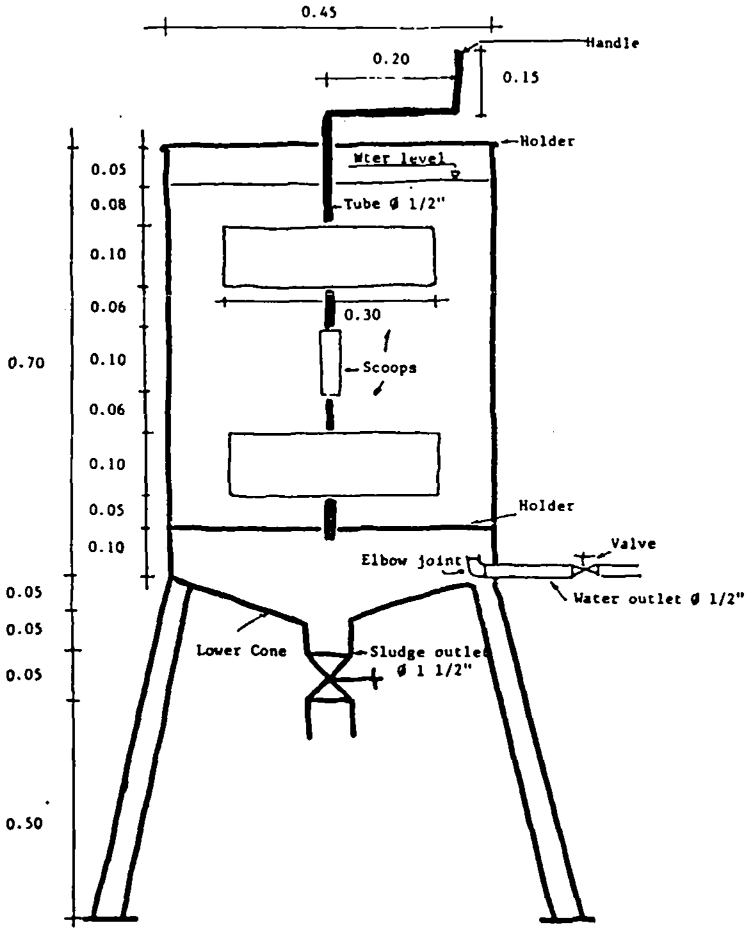

FIG. 11.6 The Nalgonda Unit

of the method recommend the use of disinfectant (e.g.: calcium hypochlorite) at the same moment that other chemicals are fed.

11.5.1 Equipment

Size of equipment will depend upon the quantity of water to be treated in each batch.

As the process is discontinuous, it will treat only the water for drinking and food preparing (it will be considered 5 liters/person x day).

A basis equipment as proposed by the National Environmental Engineering Research Institute - NEERI - Nagpur (India) (bibliography /8/ and /9/) should have the following characteristics:

Diameter	0.45	m
Cylinder height	0.70	m
Lower cone height	0.05	m
Sludge outlet length	0.05	m
Sludge outlet diameter	1.5	inches
Supporting basis height	0.65	m
Total height	1.35	m
Water outlet diameter	0.5	inches
Number of scoops	3	
Scoop width	0.10	m
Scoop length	0.30	m
Water outlet valve diameter	0.5	inches
Sludge outlet valve diameter	1.5	inches
Total volume	115	liters
Sludge volume	4	liters
Net volume for water	100	liters

With the noted volume of 100 liters/batch, and with a daily intake of 5 liters/person·day, with each batch there can be treated water for 20 people, or the water for one family (5 people) for four days.

To treat greater quantities of water, greater tanks can be designed, but being respectful to the following conditions:

TABLE 11.1 Characteristics of defluoridation methods.

Method	Capacity or Dose	Appr. pH	Interferences	Estimated Cost
Aluminum Sulfate	150 mg/mg F	Ambient	-	H-M
Lime softening	30 mg/mg F	-	-	M-H
Alum + Lime	150 mg alum/mg F 7 mg lime/mg F	-	-	M-H
Activated Carbon	Variable	< 3	many	H
Plant Carbon	300 mg F/kg	7	-	L-M
Zeolites	100 mg F/kg	ambient	-	H
Defluoron 2	360 g F/m^3	ambient	Alkalinity	M
Clay pots	80 mg F/kg	ambient	-	L
Activated Alumina	1200 g F/m^3	5-6	Alkalinity	M
Bone	900 g F/m^3	ambient	As	L
Bone Char	1000 g F/m^3	ambient	As	L
Electrodialysis	High	ambient	Turbidity	Very high
Reverse Osmosis	High	ambient	Turbidity	Very high

* Tank height $\geq$ 1 m
* Diameter depending on volume and adopted height
* Lower cone height diameter/10
* Scoop length 2/3 x diameter
* Scoop width 0.10 m
* Water outlet diameter 0.5 - 1.0 inches
* Sludge outlet diameter 1.5 - 2.0 inches

Equipment of big capacity may have mechanical mixing, with a rate of 60 - 80 rpm. A far more cheaper unit can be prepared by using a 200 litre drum.

TABLE 11.1 (continued).

Method	Advantages	Disadvantages
Aluminum Sulfate	Well known process	Sludge product; Low pH of treat. water
Lime softening	Well known process	Sludge product; High pH of treat. water
Alum + Lime	Can use batch Low technology	Sludge product, High chemical dose.
Activated Carbon	-	Large pH change after treatment.
Plant Carbon	Locally available	Requires soaking in KOH
Zeolites	-	Poor capacity.
Defluoron 2	-	Regenerant disposal
Clay pots	Locally available	Lower capacity - very slow
Activated Alumina	Effective, much	Requires skilled staff. Non available media
Bone	Locally available	10-20% loss/year. May give taste
Bone Char	Locally available	10% loss/year
Electrodialysis	Can remove other ions Used with high salinity	Skilled operators. Costly Not much used
Reverse Osmosis	Can remove other ions Used with high salinity	Skilled operators. Costly Not much used

The bottom should be conical (by hammering) with a sludge outlet on the lowest part, and a treated water outlet about 5 cm from the bottom.

The mixing can be done simply by means of a wooden paddle.

11.5.2 Chemical Dosing

The technique consists in the sequenced adding of lime and alum.
As the floc formation using alum depends on the water pH and alkalinity, at least the latest should be taken into account.

The indian studies present a table relating alum doses with alkalinity and fluoride concentration. See table 11.2.

TABLE 11.2 Alum dose in mg/l

F^- conc. in raw water (mg/l)	Alkalinity in mg CO_3Ca/l 80	125	200	310	400	510	600	820	1070
2	100	140	220	270	310	350	400	470	520
3	150	220	300	350	400	510	520	580	770
4	270	370	400	420	470	560	600	690	940
5	420	470	540	510	600	690	710	880	1010
6	570	690	770	610	710	780	940	1070	1200
8	750	800	860	900	960	1000	1120	1300	1430
10	820	850	890	930	990	1100	1250	1500	1700

The dose for lime is 1/20 the dose for alum

Example:

Volume of water to be treated	100	liters
Fluoride concentration (e.g.)	4	mg/l
Alkalinity	90	mg/l

From the table it can be seen that the approximate value for alum dose:

Alum dose	290	mg/l
Alum to add in 100 liters	29	g
Lime dose (1/20 alum dose)	1.5	g

Operation:

The operation of the equipment follows the next sequence:

1. Fill the tank with raw water
2. Add lime
3. Mix quick for one minute
4. Add alum
5. Mix gently for 10 minutes
6. Allow sedimentation for 1 - 2 hours
7. From the treated water outlet obtain defluoridated water
8. When tank is empty, open sludge outlet valve and discard sludge

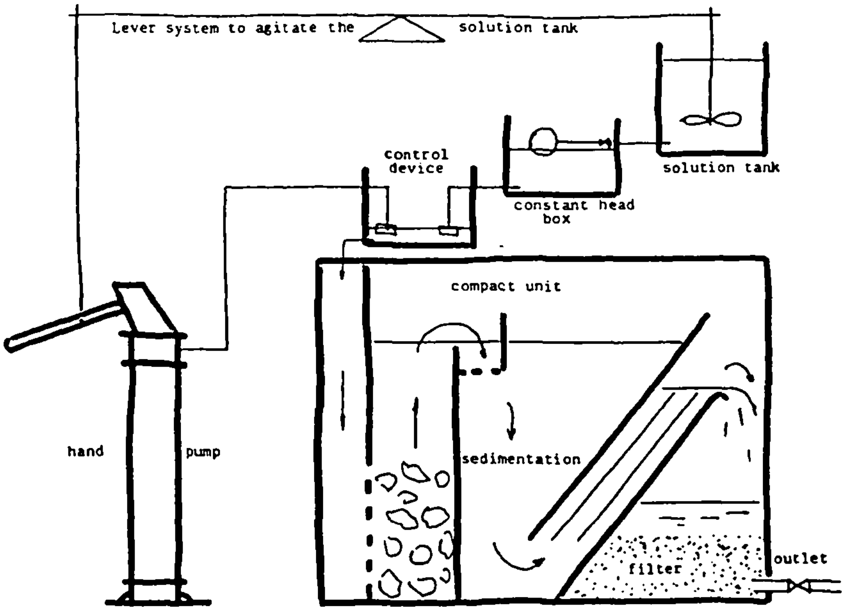

FIG. 11.7 Package Defluoridation Unit

11.5.3 Package Defluoridation Plant

An intermediate solution between family use and water treatment plant production is a package defluoridation unit proposed by Richardson and Cruddas (India). The unit is a kind of compact complete treatment plant fed by a hand pump, and using the alum plus lime technique. See figure 11.7.

The components of the package plant include chemical (alum and lime) solution tanks and feeding systems, flocculation compartment, settling tank and filtration unit.

It is interesting to note that there is a synchronization between the chemical dosing and the pump operation. An agitating arrangement is incorporated in the lime solution tank to prevent its sedimentation there and in the feeding box.

The data at hand shows that the package unit seems to work fairly well with waters with up to 3 mg/l F^-, roughly reducing that content up yo a 50 %, and from the information provided by the company, a plant of this type has been operating since 1983.

11.6 Literature

1 Fluorides and Human health, WHO monography no.59 (1972).

2 Guidelines for Drinking Water Quality, Vols I and II, WHO.

3 Adsorption in water treatment, Hendrikson, Arctander Vik - Norwegian Inst for Water.

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5 Final report on Water defluoridation in Durango, Mexico. F. Solsona - WHO report (1985, Spanish).

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7 The removal of excess fluoride from drinking water by activated alumina. Rubel-Woosley, Awwa Journal Vol 71 no.1 (1979).

8 Fluoride in water. Defluoridation technique and their limitations. Bulusu et al. Journal of the institute of engineers (India) Vol 60 (1979).

10 Package defluoridation plant for hand pump water supply schemes. Leaflet - Richardson and Cruddas - Madras, India.

11 Standard Methods. 15th Edition.

12 Manual on Water fluoridation. F.Solsona (1973, Spanish)

12 Preventive Maintenance in Waterworks

12.1 Introduction

The nature and the scope of the operation and maintenance required will vary with the type of system and also the elements that comprise the scheme. Generally water which requires no treatment to meet bacteriological, physical and chemical requirements and which can be delivered to the consumer by a gravity system is given first consideration. Rural water supplies presently being installed fall under this category. However, there are a few systems with simple treatment facilities; treatment process being limited to one or more of the following:

* Sand trap.
* Storage which would provide plain sedimentation.
* Chlorination.

This guide has been designed to serve rural gravity pipe water supply schemes. Depending upon the particular situation, the operator's work may include:

A) Spring, Stream and/ or drainage basin inspection and maintenance.
B) Dam or weir maintenance.
C) Intake structure and/or appurtenance maintenance.
D) Operation and maintenance of simple treatment facilities.
E) Operation and maintenance of gravity supply pipe including appurtenances such as valves, airvalves, washouts, break pressure tanks special crossings etc.
F) Service reservoir operation and maintenance.
G) Distribution system operation and maintenance.
H) Operation in emergencies.

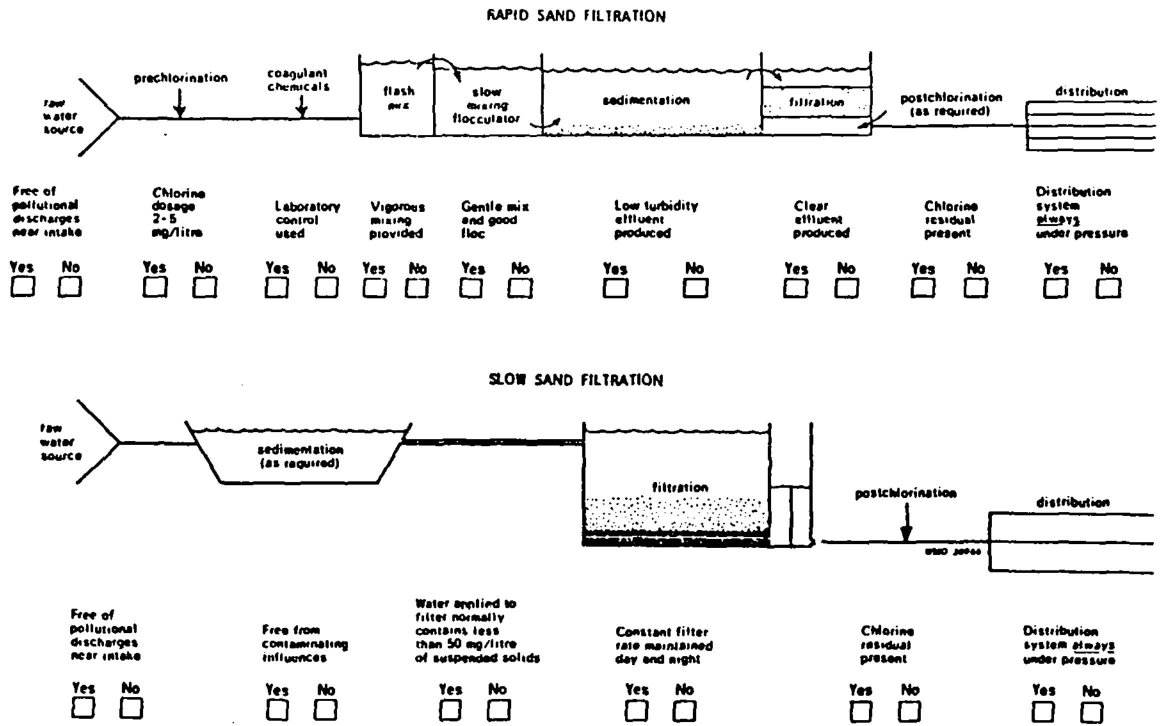

FIG. 12.1 Checklist for surface water treatment plants. See also section 12.20.

The guide describes in brief the different components of the system and the care that would need to be taken by the operator of the system. Figure 12.1 and section 12.20 give the works to be carried out at fixed intervals of time in the form of an Operation and Maintenance Schedule and Check List.

12.2 Spring and Stream

During the design and implementation phases great care is taken in respect of those major components with regard to their location and design so as to afford natural protection later against outside contamination. It is imperative that routine inspection should be carried out to check whether the protective measures provided are in fact in good condition and are continuing to provide the protection intended.

Some of the protective measures taken with respect to spring sources are:

* Diversion ditch above and around the collection chamber to intercept surface run-off and divert it away from the ground-water collection zone.

* Fencing to prevent animals and habitation from a substantial area (say 30 to 90 meters) around the collection chamber.

Generally it will not be necessary to carry out sanitary inspection of the spring source intake works site any more often than say half yearly except in those cases where the spring water is led into the collection chamber via a built up channel or natural water course. The latter method is generally not adopted except under special circumstances for technical or economic reasons. Moreover this latter method is adopted where there is no habitation. In such cases it will be necessary to inspect and clean the channel or water-course by removing the obstructions, if any, say once in 3 months. In the case of natural water courses, trimming the overgrown vegetation on the banks may also be necessary. Structural stability of the channel should be examined, viz.:

* Whether there are any signs of erosion of the embankment or the foundation under the built up channel,

* Whether there are any signs of earth slips which might endanger the functioning of the channel or natural water course, and corrective measures taken.

Corrective measures would include strengthening of the bund or trimming the sides to a stable slope and also taking protective measures to prevent earth slips and/or erosion of foundation under the built up channel.

In the case of stream intake work sites, regular sanitary inspection, say half yearly, should be carried out and preventive measures taken to protect the stream from being polluted upstream of the intake works through:

* Discharge of foul or contaminated water.
* Habitation living nearby using the stream for bathing, washing of animals, clothes etc.
* The habitation using the banks of the stream/immediate drainage area as defecation grounds.
* *New unauthorized settlement of people in the near vicinity of the stream, especially* upstream, and using the stream for all purposes.

In addition to the sanitary inspection the operator should check to see whether there is any temporary or permanent part-diversion of the flow upstream for other purposes without prior approval; if so, he should block the diversion and bring it to the notice of the Department.

12.3 Dam or Weir

In the case of stream source supplies, the water is generally abstracted in one of the following ways:

* By diverting the flow in full or in part to the intake chamber by the construction of a dam or weir across the width of the stream.
* By impounding water behind a small dam or weir built across the stream and draw water through an intake pipe.
* Collection of water through infiltration pipes laid under the bed of the stream. Here again, sometimes a dam or weir is constructed to pond the water above the area where the infiltration pipes are laid.
* Abstract directly water from the stream by locating the collection chamber/intake structure on the bank of the river.

The weirs and dams are generally of random rubble masonry. These structures are subject to damage by:

* Boulders rolling down the river during flood periods.
* Scouring underneath the foundation due to seepage.

The operator should inspect the structures from time to time, especially during and after floods, and effect the needed immediate repairs promptly. If the situation demands closer inspection and major repairs it should be brought to the notice of the Department.

If the stream bed where the water is ponded gets silted, this should be cleaned. This would normally become necessary after the rainy season. Generally facilities are provided for draining by the provision of a washout valve/penstock and a diversion channel. The stream flow will be diverted in the first instance and then the ponded water emptied via the washout/penstock. Where such facilities are not provided temporary measures should be taken to desilt the basin.

12.4 Intake Structures

12.4.1 Spring Intake Chambers

Generally water from the spring is collected through the spring intake chamber, constructed at the source. The structure would generally be of rubble masonry, with a concrete slab cover. Wherever feasible even dressed rook slab cover is used. The pipe work would comprise an outlet pipe generally fitted with a strainer, over-flow pipe and washout pipe fitted with a valve or screwed cap.

Spring water is generally free of turbidity as it emerges from source. Where the water becomes turbid during the rainy season, a sedimentation tank is provided to allow sand, grit and silt to settle. If the spring water is clear all round the year, a silt and grit collection tank is not provided.

The maintenance of the spring collection chamber and the sedimentation tank, when provided, will include the following:

* Inspect at least once a quarter and clean the surrounding area and check whether the protective measures provided are in fact in good order; if not take corrective measures.

* Check once a quarter (and say once a month in the rainy season) the inside of the collection chamber and if there is accumulation of silt, sand or pebbles proceed to clean the chamber as follows: Close the outlet valve and flush out the contents of the chamber through the washout; if needed, use a long-handled brush. If necessary clean the inside of the chamber including the outlet strainer.

  Fill up the chamber, flush again and close the washout valve. Then let the fresh water collect in the chamber till it reaches the top water level mark; open the outlet valve gradually till the outflow balances the inflow and close the chamber with cover provided.

* Check half yearly the overflow pipe to see whether it is functioning by closing the outlet valve and clean the overflow pipe if necessary. Also check the overflow leadaway arrangement and ensure that it works satisfactorily without eroding the soil around the chamber and thus weakening the stability of the structure.

* Once a quarter (and say once a month in the rainy season) inspect the sedimentation tank and if there is accumulation of silt, sand and pebbles proceed to clean it as follows: close outlet valve then the inlet valve, open washout valves and, while the water is being let out, flush out the silt, sand etc. collected in the tank through the washout provided. If the quantity of silt, sand etc. is large and also well set remove manually with shovels or other similar implements.

  After removing the silt and foreign matter, open the inlet valve for water to flow in. Wash the sedimentation tank thoroughly by repeatedly flushing and letting in fresh water. A long-handled brush may be used to scrub the side walls and the base. Clean the pipe fittings as well and check that they are functioning satisfactorily.

When all the cleaning work is over, see that the cover slab is put back correctly in position and locked wherever locking device is provided. Very often the cover slabs which are heavy get damaged especially along the edges if the provision made for lifting is not used properly. Many of these slabs are damaged by levering them out of position by using a crow-bar.

Adequate labor must be employed to lift the slabs and put them back in position so that they completely close the opening and prevent any foreign matter gaining entrance.

The valves in the two structures should be operated a few time by opening and closing to see that they do not become rusty and get jammed or stuck in one setting due to non-use. If any valves are found to leak through the glands, they should be repaired.

* Wherever the water is led into the spring collection chamber or the sedimentation tank via a natural water course or built up channel, the intake chamber would be provided with a grating and in some cases with a removable screen to prevent floating and other foreign matter entering the chamber. In such cases the screen should be lifted out, cleaned and put back in position.

  Very often the screen is damaged from bad handling, long use or general wear and tear. Cleaning of the screen should be done with care, preferably with a soft brush. If the screen netting is damaged it should be mended or replaced promptly. Similarly, handles are generally provided for the lifting of the screens and these tends to become loose, bent or damaged due to rough handling or wear and tear; these too should be mended and kept in good order to facilitate easy lifting and replacing the screen in position.

In the operation of this intake the operator should set the opening in the outlet valve both in the spring intake chamber and the sedimentation tank so that the water level in the respective chambers completely submerges the outlet and thus no air gets into the system. If the rate of outflow from the chambers is more than the rate of inflow, the water level will fall to the level of the strainer or bellmouth and will only be partially submerged in water. In this situation thee will be a continuous suction of water and air.

12.4.2 Stream Intake

Diversion of part or full flow in the stream:
This is one convenient way of drawing water from the stream. This would generally involve the construction of a dam or weir across the stream, a diversion channel, raw water channel or a draw off pipe and a sedimentation tank. Stream water will generally contain silt and sand and floating matter during the rainy season. Ponding of the water behind the weir will, to a certain extent, facilitate settling of suspended matter, thereby reducing the turbidity of

the water. Very often a grating in addition to a screen is placed at the entry to the diversion channel. This helps to arrest the floating matter.

The maintenance of this type of intake would include regular cleaning of the floating matter lodged at the grating and also cleaning the screen which might have collected a lot of silt. Wherever facility is provided for draining the ponded water this should be done and the basin cleaned. The dam or weir should be brushed and cleaned especially if the surface is dirty and there is growth of moss and/or algae. With the above type of intake it is customary to provide a sedimentation tank. The maintenance of this would be carried out in the manner described earlier.

Here again all the valves and fittings where there are moving parts should be checked to see that they continue to function satisfactorily.

Collection of water through an intake pipe:
Here again the provision consists of a small dam or weir across the stream plus a submerged pipe line with a submerged crib or a screened bellmouth at the open end. The water is generally led into a collection chamber or sedimentation tank downstream. It would be necessary to remove the floating or suspended matter which will otherwise block the entry of water into the intake pipe.

The maintenance of the collection chamber or the sedimentation tank would need to be carried out in the manner described under the earlier sections.

Collection through infiltration pipes:
In this type of intake the perforated pipes laid in the river bed of the stream are connected to an intake chamber generally located on the bank. Water after percolation flows into the intake chamber. To facilitate better infiltration the slotted collection pipe(s) is covered with graded gravel and sand. If these pipes get blocked it would become necessary to divert the flow in the stream, remove the packed filter media, clean and refill the trench with clean filter media.

The intake chamber also may need cleaning by removal of sand accumulated over a period of time. Among the type of stream intakes described, this has the definite advantage that this system provides clearer water during most of the year, if not at all times.

Generally the infiltration pipe(s) is provided with valves and these valves are located in the collection chamber. These valves should be set or adjusted from time to time to give the desired rate of infiltration. When the level of stream water above the infiltration pipe is high, the rate of infiltration would be high and it is possible that the quality of the water collected would not be that good. This could be partially corrected by trotting the inflow from the infiltration pipes.

Generally the collection chamber would be located on the bank and built up so that the chamber mouth is above flood level and covered with concrete slab covers with lifting handles. Very often provision is also made to lock the cover slab in position. Particular care should be taken to se that the mouth of the collection chamber is well covered.

12.5 Presedimentation

These basins should deliver clear effluent. The overflow rate and weir loading should be checked. Sludge accumulations and decrease in quality of the passing water are the usual defects to be looked for. Algal contamination can be decreased by prechlorination, if such contamination persists the quality and turbidity of the influent raw water should be examined with a view to more radical measures; sometimes the basins can be bypassed. Increased loading is possible in the clear water season.

12.6 Chemical Dosing

It is useful to check whether the dosage is in accordance with laboratory test, and to carry out a simple jar test on the spot for confirmation. The check should also ensure that solution preparation and storage, and chemical feeding conform to the standards directions, and that no improvisations have been adopted to cover stock deficiency or plant disorder. Such deficiencies should be corrected immediately.

12.7 Coagulation and Flocculation

Flash mixers and flocculators should be checked and repairs should be carried out without delay. Dosing efficiency, flash mixing, paddle efficiency, and floc formation should all be verified. The character of the water also has a considerable influence on the pH at which satisfactory floc is formed.

Suitable adjustment of the pH makes it possible, with any kind of water, to achieve good flocculation with a minimum quantity of coagulant. Points of excessively high or low velocity in the flocculation chambers and bad short-circuiting should be investigated.

12.8 Sedimentation

The characteristic and functional efficiency of sedimentation basins are influent by their shape and size, the method of influent entry, the range of diffusion, eddy and current zones; effluent weir location and sludge removal arrangements. In addition to the usual design norms for surface loading and weir overflow rates, the displacement efficiency as between theoretical detention period and actual flow-through period should be a reliable parameter for a well-designed basin.

The degree of effluent clarity and its uniformity are good indications of the soundness of the design. Normally, a displacement efficiency of about 60% is ideal, while a figure between 30% and 50% may be considered good, if it is less than 30% some improvements are needed. The reserve capacity available from a basin may be gauged by testing its displacement efficiency. If the efficiency is high enough, the basin may be overloaded in an emergency. If it is low, the test itself may help to expose the aspects of the basin that need improvement. It is also necessary to check that the machinery for sludge scraping and sludge removal is maintained in good order.

Sedimentation will be achieved by the provision of horizontal flow sedimentation tanks allowing for appropriate horizontal velocity and desirable detention time. To facilitate cleaning of the tank without interrupting the supply it is customary to provide a tank with two compartments separated by a central dividing wall along the full length of the tank. The tank will comprise arrangements for inflow of raw water, scouring of settled matter (sludge) and collection of settled water.

For the simple type of sedimentation tanks only one scour valve will be provided for each compartment at the deeper end, which will be the inlet end. The scour valve should be opened at least twice a day to discharge the sludge collected. As most of the sludge cannot be withdrawn under hydrostatic head it would be necessary to desludge manually one compartment at a time. Under normal circumstances, this may have to be done once a quarter.

This could be achieved by closing the inflow into the particular compartment and emptying the tank by opening the sludge valve while at the same time moving the sludge manually with the aid of a brush or a shovel. This type of manual dislodging will become necessary at more frequent intervals during the rainy season when the raw water is generally turbid. When dislodging the tank, opportunity should be taken to clean the inside walls as well, if found necessary.

Settled water generally flows over a weir. This should also be cleaned by using a brush.

The scour valves should be maintained well since, if some foreign matter gets lodged in the valve, it may not be possible to close the valve fully and this will cause loss of water by way of leakage through the valves. Such foreign matter should be removed promptly. From time to time when the tank is desludged the valves should be serviced by opening and greasing the moving parts.

12.9 Filtration

The turbidity of the influent and effluent water is a reliable index of the efficiency of filtration and also of the removal of bacteria in the case of slow sand filters.

1) In slow sand filters it is useful to check that influent turbidity is normally less than 50 mg/litre to ensure optimum filter operation, and to check the efficiency of the filter skin as revealed by the degree and constancy of bacterial purity of the filtrate. The rate of filtration should be maintained as constant as possible. In order to assess the level of filter efficiency and its capacity for overload in an emergency, a critical study of the following factors would be necessary: the length of the filter runs, filter-head build-ups, the periodicity of filter cleaning and overhauling, the depth and texture of the sand layer in the filter, and the condition of the filter gravel and underdrain system.
2) In rapid sand gravity filters a critical study would be required of the length of filter runs, the filtration rates, the duration of washing, wash-water consumption, the

efficiency of filter washing, the hydraulic of filter washing, the reliability and efficiency of surface wash and air wash acid where provided, spacing of laterals, mudball formations, loss of sand and displacement of gravel, undulations and cracks in the filter surface, constancy of filter effluent quality, general reliability of filter appurtenances, rate controllers, valves and indicators.

Usually the filters are designed for a normal flow-through rate of about 5 m/h but with the inlet and outlet control equipment designed to permit 100% overloading. The actual output from the filter plant, should be studied, in quality and quantity and the reserve capacity available should be assessed. The necessity for temporary additions at the inlet and outlet controls to cater for such overload should also be studied, even if the initial design did not cover this aspect.

3) The inherent deficiencies of *pressure filters* also influence plant performance. The vertical type should be more satisfactory than the horizontal type. The survey should examine whether filter washing is done only with filtered water; whether inlet and outlet pressure indicators are reliable;whether effluent quality is uniform; and whether frequency of washing and consumption of washwater are normal. The search for a reserve capacity in such types of filter is somewhat restricted as visual inspection of the filter bed is not possible at the time of cleaning.If the raw water is stable and clear, it can be assumed that a marginal reserve capacity exist and could be used by increasing the pressure as much as possible with available pumps and by strict postchlorination. Extra capacity could also be gained by working the filters for longer hours if normal demands required only part time working.

12.10 Chlorination

The survey should examine: the points of application, from the point of view of adequacy and of the methods provides; the rating, capacity range, quality and reliability of the equipment; the condition of the working parts of the chlorinators and the safety measures against escape of chlorine gas; whether the chlorine dosage is based on laboratory tests and is applied correctly; whether the residual chlorine is maintained in the most distant parts of the system and the frequency and adequacy of sampling and laboratory tests to ensure safety of supply at all points. In view of its critical importance, chlorination equipment should be installed in duplicate.

In rural water supply, bleaching powder is commonly used for chlorination. Bleaching powder is a variable mixture of calcium hydroxide, calcium chloride and calcium hypochlorite. When it is mixed with water, the calcium hypochlorite decomposes into calcium chloride and chlorine. Bleaching powder is characterized by its content of "available chlorine" (i.e.) the chlorine which can be liberated by complete reactions with water. Commercial brands have an availability of 20 to 30 percent (i.e.), 20 to 30 parts by weight of chlorine per 100 parts by weight of bleaching powder.

Bleaching powder can be mixed at the rate of 100 grams to 5 liters of water in a bucket. This mixture is allowed to stand for some hours after which the clean solution is decanted without disturbing the sediments deposited in the bottom of the bucket. Clear chlorine solution is then filled in the doser. Filling with clear chlorine solution is important, otherwise tubes and orifices are likely to get choked.

In order to maintain the chlorine content in the bleaching powder it should be stored in an airtight container. If the container is not closed properly, the chlorine content can reduce rapidly.

Generally the size of the container selected is such that with each charging it will be able to chlorinate the days or 1/2 days supply at the usual level of 1 to 2 ppm. Based on the illustration given the operator should make adequate chlorine solution to dose the supply at the desired level.

12.11 Supply Main

The pipe line leading from the intake works to the service reservoir, or in cases where there is no reservoir up to the commencing point of the distribution system, is referred to as the supply pipe. This is a very important component of the system. Generally the material used is PVC, cast iron, galvanized iron or high density polyethylene (HDP) and different types of joints are used depending on what is appropriate. Most commonly used joints are as follows:

Cast iron	:	Lead joint, mechanical joint (tyton), flanged joint.
Galvanized iron	:	Screwed joint, flanged joint.
HDP pipes	:	Butt welded joints, flanged joint.
PVC	:	Solvent cement joints.

The maintenance of the pipe line, in as far as repairing a joint or replacing a damaged length of pipe or pipe special such as bends, tees etc. or servicing of valves and fittings such as sluice valves, air valves, ball valves etc. should be done by a plumber or a maintenance worker trained in plumbing work. Hence the guide line does not describe how this work is carried out.

Apart from plumbing work, there are several routine maintenance works that will need to be carried out to maintain the pipe line in good working order.
In hilly areas failures are commonly caused by:

* Earth slips which carry that section of the pipe line along with it or leave the pipe line unsupported and exposed.
* Subsidence of ground under the pipe line; here again a section of the pipe line loses the ground support, resulting in leaking joint or damage to the pipe.

If an appropriate pipe trace is selected at the design stage taking the above factors into account, failures due to above causes should be minimal. However, protective measures made by the construction of retaining walls, buttresses and drainage facilities should be inspected and maintained in good order.

Wherever there are any visible signs of possible earth slips or subsidence, protective measures should be taken promptly. Earth slips are caused mainly by indiscriminate clearing of vegetation on hill slopes. The maintenance worker should see that this does not occur by monthly inspection during normal weather conditions and through more frequent inspection of the pipe trace during the rainy season. Generally subsidence occurs due to poor drainage. This may be detected when the routine inspection along the pipe trace is carried out.

Leakage from the pipe line either through a weak joint or cracked pipe can also cause subsidence. Generally the pipe line is buried underground provided with the minimum stipulated cover. When a pipe line has to be taken across the rock face of a hill the pipe is laid on the rock face and is fixed in position using iron clamps.

It is customary to use steel pipes or galvanized iron pipes for such crossings. These exposed pipes stand the risk of being damaged by rolling boulders. The maintenance worker should see that the clamps are intact and in order to prevent corrosion the steel pipe should be painted at regular intervals, say 2 to 3 years, with suitable bitumatic paint.

12.12 Sluice Valves

In the case of rural water supplies, especially when small diameter pipes are used, it is not customary to have sluice valves installed at regular intervals in order to be able to shut the flow in the main by closing the valve located immediately upstream, should there be a pipe burst. This prevent local flooding and also loss of water.

However if such valves are provided, they should be inspected say once in 3 months and, if they show any leakage from the gland, this should be repaired. The moving part of the valve should be greased at least once a year to prevent rusting. To maintain a proper maintenance record, the valves should be numbered.

12.13 Air Valves

These valves are located at the high points on the profile of the pipe line to release air. These valves act automatically in the release of the air that enters the pipe line as the entrapped air travels to the high points in the line. Especially when the pipe line is being commissioned or when it is drained and being recommissioned, the air in the pipe line escapes through this valve. If this valve does not function properly there will be accumulation of air at the humps or high points along the pipe line and this will prevent the flow of water either partially or fully.

When charging an empty pipe line, the water should be let in at a low rate. This will facilitate easy and complete evacuation of air. If the discharge at the free end, say the reservoir or the intermediate break pressure tank(s), is lower than the design rate of flow, the air valves in the corresponding section of the pipe line should be checked to see whether they are functioning properly; if not they must be repaired. Evacuation of entrapped air is very important, since without this the pipe cannot carry the design flow.

Sometimes if the float ball in the valve does not seat properly, water will be seen to leak as in a fountain through the air valve. Normally air valves are provided with an isolating cock; When the valve needs repair or closer inspection the isolating cock should be closed and thereafter the valve parts can be dismantled for repair or cleaning without interrupting the supply.

The air valves perform another very important function in that they let air into the pipe line should there be a burst and sudden drain off, causing a vacuum in the pipe line. This can otherwise cause the collapse of the side walls of the pipe.

12.14 Washout Valves

Washout valves are generally provided at the low points along the profile of the pipe line. In the case of rural water supplies the pipe line carries untreated water and during the rainy season the water can become very turbid and a lot of the suspended material may settle in the pipe. Most of the material gets lodged at low points or valleys along the profile.

The washouts are located at the low points and by opening one at a time it should be possible, under the hydraulic pressure, to evacuate the settled material. This is made easier if the washing out or scouring operation is made at regular intervals, say half yearly, and more frequently, say once a month during the rainy season. When the washout valve is opened the operator will be able to see the silt being evacuated and the valve should be left open till the water becomes clear. From the quantity of silt evacuated the operator should be able to determine the intervals at which such cleaning should be made.

Very often when a burst pipe is replaced or when a repair to a joint is made, there is the possibility of earth and muddy water entering the pipe despite the normal precautionary measures taken. The sections of the pipe line where foreign matter could have lodged should be thoroughly flushed before re-commissioning the pipe line. Good water-works practice would be to disinfect the pipe line after such repairs.

These valves should be inspected while carrying out the routine patrolling of the pipe line and repaired if found leaking. The valves should be greased once a year to facilitate easy operation and also to prevent rusting.

12.15 Break Pressure Tank

These are masonry covered tanks provided along the pipe to reduce the pressure. They consist of the inlet pipe, outlet pipe, overflow and washout arrangement. Generally valves are provided both on the inlet and outlet to balance the inflow and outflow so that the mouth of the outlet pipe will always be sub-merged. If not balanced and if the inflow rate is higher, the water will keep on overflowing and going to waste. On the other hand if the outflow rate is higher, the outlet pipe will not be fully sub-merged and will in the process keep sucking in air. This should not be allowed to happen.

If there is accumulation of silt in the tank this should be cleared from time to time by draining the water through the washout.

The break pressure tank is one place where contamination can take place after the water enters the pipe line, if the tanks is not securely covered and protected.

12.16 Special Crossings

Generally, and especially in the context of the hilly areas of Nepal, the supply pipe may have to be carried across ravines and streams. If the span is large it would become necessary to have a special bridge to carry the pipe line or suspend the pipe line on a cable. It will be necessary for the maintenance worker to inspect the structural safety of these structures during routine patrolling of the pipe line. In the case of the bridge, the items to look for are the foundations of the supporting masonry works or columns.

If erosion near the foundation is noticed, protective measures should be taken to arrest this and also strengthen the foundation if needed. If any members of the bridge shows signs of deterioration they should be replaced. Similarly if any of the brackets or clamp supports become loose or show signs of deterioration, they should be attended to. The metal parts will need to be painted, say once in two years.

Similarly in the cable supports the items to be inspected and remedial measures taken are the stability of the anchor blocks, supporting cable, clamps etc.

12.17 Service Reservoirs:

Generally the gravity fed rural water supplies would have a ground-level reservoir, usually built of rubble or brick masonry with a galvanized iron sheeting roof. Very often the walls are of masonry with concrete core filling. In some cases the reservoir may consist of two compartments with or without by-pass.

The main components of a reservoir are the floor, side walls, roof, inlet, outlet, overflow and washout pipes, manholes for providing both access into the reservoir and also to let-in light and air when needed, and ventilators.

If the structure is built properly it will not need frequent maintenance work.
If the inlet is provided with a ball valve (float valve) care should be taken to see that it operates properly. The valve should close automatically when the water reaches the top water level and the water should not keep overflowing. In such an event the valve should be adjusted or repaired, as the case may be.

All the valves should be cleaned and greased where necessary and kept in good working order.

The tank should be cleaned if it is found to have collected silt, sand etc. This can be effectively done at regular intervals if the tank is of the two compartments type without interrupting the supply. Even if it is of the single compartment type the cleaning should be done by by-passing the reservoir, if a by-pass is provided, and, if not, by closing the supply for as short a period as possible. The cleaning operation can be started making use of the water in the tank up to about the level of the outlet pipe. The cleaning operation will consist of scrubbing the sidewalls, sweeping the silt collected on the floor of the tank and flushing through the washout. It would be better if the tank could be disinfected after cleaning.

The disinfection could be effected by filling up the tank and adding chlorine solution to give a 10 ppm dosage and allow the water to remain for 6 hours. Alternatively 50 ppm could be used and disinfection time reduced to 1 hour.

The distribution system can also be disinfected using the disinfected water if needed by adding some more chlorine solution to raise the level of dosage to 10 ppm. This should be done only if the distribution system has been prepared for disinfection.

Very often the manhole covers get damaged, making it impossible to close the manhole properly; this continues to remain a convenient point of entry for foreign matter. The manhole covers should be maintained in good order, and repaired or replaced as found necessary.

Ventilators are provided to allow air in the reservoir space to escape when the water enters and let in air when the water is drawn out. Ventilation openings are generally screened with fine mesh wire to keep out birds, animals, mosquitoes and other insects. If the ventilator is to serve its purpose effectively without giving chance for contamination, the wire needing should be maintained in good order and replaced or mended if damaged.

If the roofing is of galvanized iron it should be painted at least once in two years to prevent corrosion. The ground around the reservoir should be kept clean and tidy with good surface drainage facilities.

12.18 Distribution System

There are two main systems of distribution water in a community, the dead-end system and the gridiron system. In the gridiron system the extremities of the pipes are connected to form loops, with the result that dead-ends, and consequently stagnant water is eliminated. It is seldom possible to adopt this ideal system in rural water supplies where the population settle along ridges to the hills or a trail and the system in general is elongated in shape with several dead-ends, each line leading to a cluster of houses.

Rural water supplies are essentially standpipe supply systems. A limited number of private connections is given where there is ample water. In hilly terrain the pressure at different points of the system will vary greatly depending on the elevation of the point with respect to the reservoir.

In order to maintain the design flow in the different sections of the system it will be necessary to balance the flow and also control the pressure by setting of the valves and ferrules at appropriate levels of opening. This will need to be done over a period of time by monitoring the pressure and flow at different taps in the system and this will generally be carried out at the time of commissioning the system. Much water is wasted at the standpipes if the pressure is high.

The discharge at a standpipe can effectively be controlled be setting the ferrule opening at an appropriate level. As the majority of the population will be obtaining their supplies at the standpipes, constant care should be taken to see that the public standpipes function satisfactorily.

Points to be noted are:

I To maintain adequate rate of flow.
II To prevent leakage at the top when not in use.
III To maintain the waste-water lead away system, cleaned at regular intervals and well maintained.

The users should be advised not to damage the tab by improper handling. Very often self closing tabs are kept in the open position be wedging in a twig and the water keeps on flowing all throughout the supply period. This not only results in wastage, but also affects the flow at the tabs in other sections of the system. This practice should not be allowed. Further, water from a standpipe system is essential meant for domestic use, especially for drinking and cooking. Apart from washing small items, the people should be debarred from bathing or laundering at the standpipes. People should not be allowed to take water into their homes using a hose pipe connection from a public standpipe. In the rural water supply systems where there may be several dead-ends, the stagnant water at the dead-end sections should be flushed out at regular intervals.

Very often it is rather difficult to evacuate air entering a distribution system especially where the supply is via standpipes. Generally provision is made in the system by providing air release cocks, sometimes this is achieved be locating some of the standpipes at the high points in the system.

If the flow tab is found to be low, the operator should check the following:

I Whether there is any obstruction at the ferrule.
II Whether the discharge at low points in the system is too high, in which case the flow should be adjusted resetting of valve and ferrule opening.
III Whether the reduction is due to air entrapped in the system, in which case the air should by released through the provision made in the system.

As in the case of the reservoir it would be good practice to disinfect the system at least once a year and this could be dine at the same time the disinfection of the supply pipe and reservoir is done.

12.19 Operation in Emergencies

An emergency arises when an epidemic of enteric disease occurs or is threatened. Intensive disinfection operations must be a prominent past of all precautionary activities in the vulnerable areas, including chlorination of domestic water supplies. The operator should be able to mobilize the needed manpower and carry out this operation in close liaison with the Department of Health Services. The DHS will need to supply the required materials and equipment for this emergency operation.

12.20 Check List

12.20.1 Spring/Stream/Drainage Basin

I *Once a quarter:*

* Inspect the spring, stream intake where water is drawn off via a channel or water course to the intake chamber.
* Clean channel, water course.
* Trim overgrown vegetation and remove obstacles fallen in the water course/channel.
* Check for any erosion of the embankment or the foundation under the built-up channel and take remedial measures.
* Check for possible earth slips that may disrupt the supply and take remedial measures.

II *Half-year:*

* Carry out sanitary inspection of spring intake area, clear and maintain the diversion ditch around the collection chamber.
* Check whether the protected area continues to remain protected. Fencing to be repaired if damaged. If the encroachment is noted, the matter must be brought to the notice of the Department as the case may be.
* Carry out sanitary inspection of the stream intake site and take preventive measures to protect stream from being polluted upstream through:
    * Foul or contaminated water being discharged upstream.
    * Habitation living nearby polluting the stream water.

* Habitation using the banks of the stream or immediate drainage area as defecation ground.
* Any new unauthorized settlement taken place in the vicinity of the stream, especially upstream, and causing pollution, take remedial measures. In most instances any change in environment which will impair the quality if water should be brought to the notice of the Department.
* Any temporary or permanent part-diversion of the flow in the stream without prior approval of the Department should be blocked and brought to the notice of the concerned authority.

12.20.2 Dam/Weir Maintenance

I *Half-yearly*

* Inspect structure for nay signs of cracks of scouring under foundation and take immediate remedial measures as deemed necessary. If the situation demands closer inspection and major repairs bring it to the notice of the concerned authority.
* If the ponding basin is silted and is there is presence of foreign matter, empty the ponded water via washout or penstock and clean the area. It may be necessary to divert the stream to carry out this cleaning. It is preferable to carry out this cleaning operation immediately after the rainy season.

12.20.3 Spring Intake Chambers

I *Once a month during the rainy season:*

* Set the outlet valve at the level of opening needed, overflow to take place at the source and not downstream form other components of the system.
* Inspect collection chamber and if there is accumulation of sand, pebbles or silt then flush out, clean chamber and recommission.

II *Once a quarter:*

* Clean the surrounding area and check whether the protective measures provided are in good order. If not take corrective measures.
* Inspect collection chambers and if needed clean.

III *Yearly:*

* Check all the valves, open, clean and grease as found necessary.

12.20.4 Intake Sedimentation Tank

I *Once a month during the rainy season:*

* Inspect and if there is accumulation of sand, pebbles, etc. clean as described for the collection chambers.

II *Once a quarter:*

* Inspect sedimentation tank and clean if needed.

12.20.5 Diversion of Part or Full Flow

I *Weekly during the rainy season:*

* Clear material caught in the grating.
* Lift the mesh scream, clean and put back in position.

II *Monthly:*

* Inspect the sedimentation tank. If it needs de-silting clean and recommission.

III *Yearly:*

* After the rainy season, inspect the ponded area and if it needs cleaning, drain out water, clean bottom and the face of the diversion/weir wall.
* Check all valves, open and clean and grease as found necessary.

12.20.6 Intake Pipe

I *Weekly during the rainy season:*

* Clear the entry to the inlet pipe.

II *Monthly:*

* Clean the collection chambers/sedimentation tank if needed.

III *Yearly:*

* Check all the valves, open, clean and grease as found necessary.

12.20.7 Infiltration Pipes

I *Monthly during the rainy season, when the stream water is turbid:*

* Check whether inflow from infiltration pipes is high and if the quality is not satisfactory, reduce inflow rate by throttling the valve.
* If discharge from the infiltration pipe(s) is low, try flushing by pumping water into the infiltration pipe in the reverse direction.
* Clear the collection chambers if there is accumulation of sand, pebbles, silt etc.

II *Once a quarter:*

* Inspect and clear chambers.

III *Once a year:*

* Check during the dry season whether the infiltration pipes are functioning satisfactorily. If not, drain the water or temporarily divert the stream, remove graded filter material in the trench where the filtration pipe has been laid, clean any blockages in the perforations, clean filter material and refill. It should not be necessary to do this each year.

12.20.8 Sedimentation Tank

I *Daily or is the intake works is far away, weekly:*

* Desludge the sedimentation tank(s) be opening the scour valve.

II *Monthly during the rainy season, when the raw water is turbid:*

* desludge the sedimentation tank by emptying one compartment at a time and flush out all settled matter with manual aid.

III *Once a quarter (Normal season):*

* If there is accumulation of settled matter, desludge the sedimentation tank by emptying one compartment at a time and flush out all settled matter with manual aid.

IV *Once a year:*

* Desludge the sedimentation tank, scrub and clean the floor and the side walls including the weir over which the settled water flows.
* Check all valves, open, clean and grease as found necessary. This should be done by a plumber.

12.20.9 Chlorination

I *Daily:*

* Make chlorine solution of appropriate strength and of required quality to meet the day's need.
* Change doser and set chlorinator working, feeding the appropriate dosage.
* Repair or replace damaged parts when found necessary.

II *Monthly:*

- Follow up bleaching powder stock and place purchase order well in advance, depending on the remoteness of the site. Maintain 3 month stock or more as the case may be.

III *Half yearly:*

- Check stock of spare parts and place order well in advance.

12.20.10 Supply Pipe

I *Monthly:*

* Inspect the pipe trace to check for possible earth-slips or subsidence and take corrective measures. If serious, report to Department to carry out major protective measures or repair.
* Inspect the condition of exposed pipes on crossings and the state of the clamps and brackets supporting the pipe. If supports are loose, causing the pipe line to sag and fail at the joints, reinstate pipe line as found necessary. if serious, report to Department to effect necessary repairs.
* Check if any boulder has become dislodged which could cause damage to the pipe line. If so, remove the boulder.

II *Once a year:*

* Check if the exposed pipe and/or brackets need painting to prevent corrosion. if so, paint as needed.

12.20.11 Sluice Valves

I *Once a quarter:*

* Inspect the supply pipe line and should there be unusual overflow at the source or the intermediate break pressure tanks, it may be due to the pipe section immediately

below the overflow point not functioning properly. In such an event check whether the air valve in the particular section is functioning correctly. If not, isolate and affect the needed repair. This should be done by a plumber.

* Repair if found leaking due to the float ball in the valve not seated properly. This could also happen if the float ball has developed a leak and water has entered the ball. In which case the float ball should be repaired or replaced. this will need to be done by a plumber.

II *Once a year:*

* Clean and grease the moving parts of the valves as deemed necessary. This work should be done by a plumber.
* Clean the overflow and check on the lead-away arrangement and repair if needed.

12.20.12 Special Crossing

I *Once a quarter:*

* Conduct routine inspection of the pipe support arrangements, foundations of the structures, anchorages etc. Note down maintenance work to be done as part of annual maintenance. Anything urgent should be attended to immediately.

II *Once a year:*

* Carry out close inspection of the foundations of the support bridge abutments, piers, anchorages of cable etc, and make necessary repairs and paint components needing painting.

12.20.13 Service Reservoir

I *Once a quarter:*

* Carry out routine inspection of the ball valve (if provided), the overflow arrangement including the lead-away, ventilators, wash-out arrangement, the reservoir premises including the surface drainage facilities and perform the required routine maintenance. This would include clearing of premises, cleaning of the ventilators, closing and opening the valves to see if they are in good working order. if any overhauling or greasing of the valves, or adjustment to the ball valve is needed, this should be attended to be the plumber.

* Look into the reservoir for any accumulation of sand, silt etc. If the condition indicates need for cleaning, arrange for cleaning operation. It should normally not be necessary to clean more than once a year and this could be timed after the rainy season. However if the need for cleaning is indicated, the procedure set out under once a year operation should be followed.

II Once a year:

* Inspect reservoir and if there is accumulation of sand, silt etc. indicating need for cleaning, proceed as follows:
* If the reservoir is of the two compartment type shut off the inflow to the compartment to be cleaned first, shut off the outlet from the other reservoir thus make use of the water in the compartment to be cleaned, until the water level drops to near the level of the outlet. open outlet from other compartment to give uninterrupted supply to the community. With the use of the remaining water in the compartment, clean the sidewalls and sweep the mud accumulated on the floor and flush out through wash-out. If fresh water is needed, let in some water and clean thoroughly. Then fill up the tank when the consumption is low, in preparation for disinfection. Chlorine solution can be added while filling to give a final dosage of 10 ppm and allow the water to remain in the reservoir for 6 hours.
* Prepare other compartment for cleaning and disinfection.
* The chlorinated water in the reservoir could be used to disinfect the distribution system at the same time.
* Check condition of ventilator netting and if damaged mend or replace.
* Check all the valves. Clean and grease if needed. This should be done by a plumber.
* Check whether the manhole covers and roofing are in good order. If not repair and paint as indicated.

12.20.14 Distribution System

I Weekly:

* Check whether any standpipe is leaking due to defect in the tab, repair as needed and if it cannot be repaired replace with a new tap. Repair work or replacement should be done by a plumber.
* Check the arrangement made for the disposal of waste water and clean if not functioning properly due to block in the outlet pipe or drain.

* Check whether all the standpipes are delivering water and providing the desired level of service. if there is any notable reduction in the level of service, open the ferrule and the stopcock fully so that any foreign matter lodged in these valves they may get flushed away. If this gives no improvement, check whether the cause is unusual heavy draw-off in other sections. It could also be due to leaks from several public taps or private taps if private house connections have been given. Taps found to be leaking should be repaired or replaced.

II *Once a quarter:*

* Conduct house to house inspection of those houses having private connections. The intention of the inspection is to check whether water supply fittings are in good condition and water is not being wasted or used for unapproved purposes.
* Flush out the water remaining stagnant in dead-end sections through the wash-outs provided or be removing the end caps provided for this purpose.

III *Once a year:*

* Check whether all the valves in the system are working smoothly. If not, clean and grease those valves as required.
* Disinfect the mains after a flushing operation by changing the mains with chlorinated water of dosage 10 ppm and allowing it to remain in the mains for at least 6 hours. As stated earlier this could be done at the same time the reservoir disinfection is done. After 6 hours the chlorinated water will be let out of the system through the wash-outs and end caps.

12.21 References

Rajagopalan, S. & Shiffman, M. A. (1974). Guide to Simple Sanitary Measures for the Control of Enteric Diseases. WHO. Geneva.

This chapter is based on a paper given by N. Saravanapavanthan.

13 Experimental Studies

13.1 Water Works Survey

13.1.1 Principle

Organized inspection and appraisal of a water works would help improve functional efficiency, better control of treatment operations and preventive maintenance.

13.1.2 Theoretical Background

A critical survey of a water treatment plant would comprise of:

I Collection and study of engineering and physical data pertaining to the plant.

II Detailed study of the various unit operations and processes.

III Collection and analysis of water samples at various stages of treatment to assess the functional efficiency of the units.

IV Inspection of the operating records for daily production, chemical consumption, water quality etc..

If the water works is having any problems or deficiencies in design or in operation and maintenance, these can be identified through the water works survey and possible remedial measures for improvement can be suggested.

13.1.3 Materials

I Information on physical and engineering data of the plant.

II Sampling bottles depending upon the need.

III Portable test kits, if available.

13.1.4 Analysis Parameters

To be selected by the group, e.g. turbidity, DO, coliform, total counts, residual chlorine, conductivity.

See Evaluation Planning Diagram, figure 13.1.1 and Evaluation Operation Diagram, figure 13.1.2.

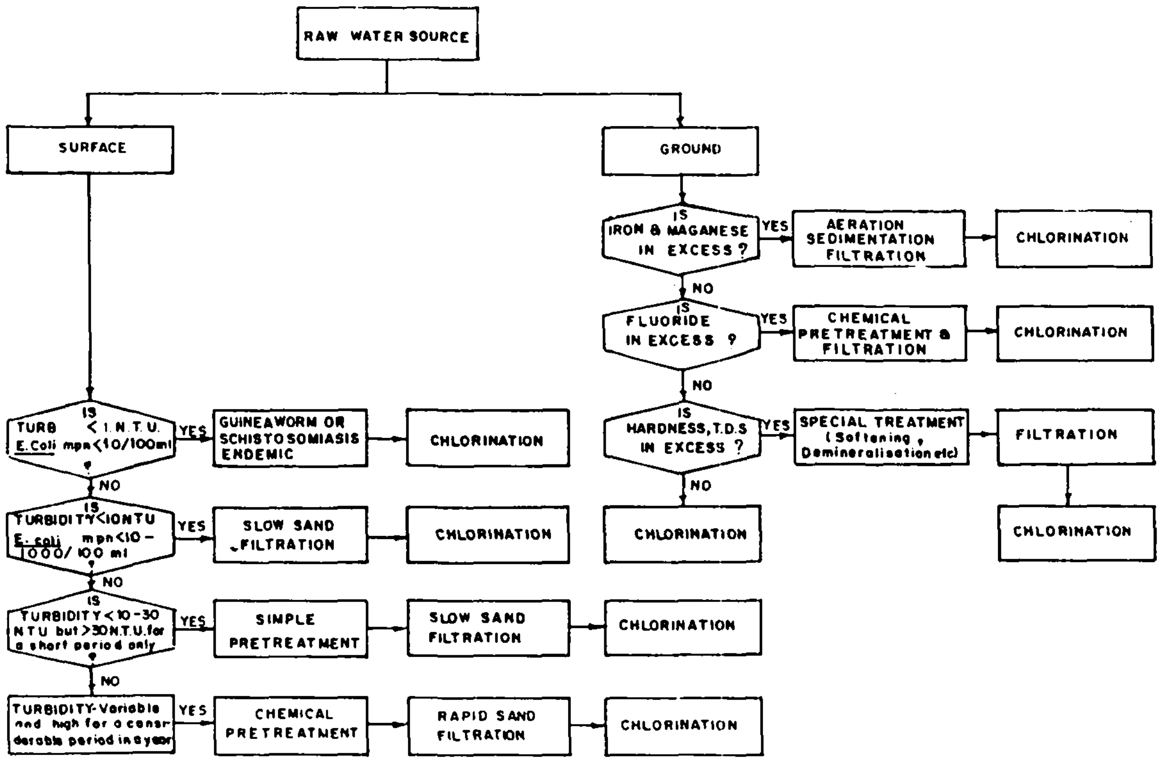

FIG.13.1.1 Evaluation & planning diagram.

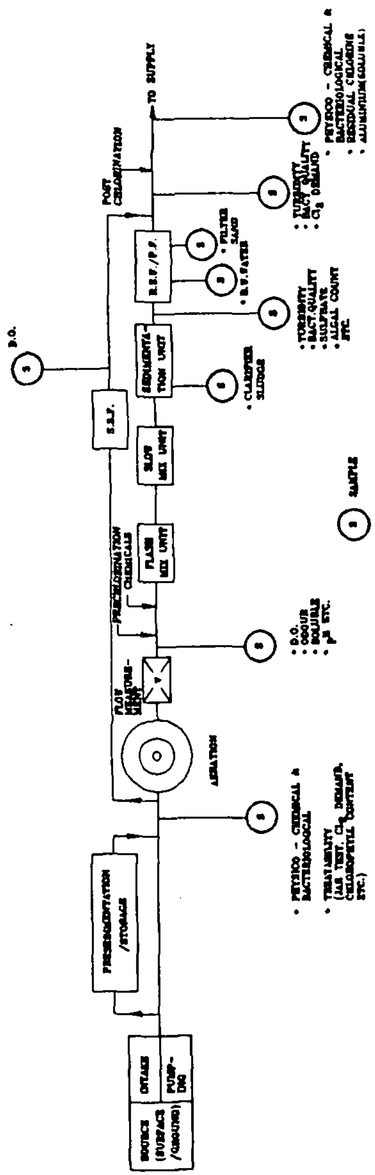

FIG. 13.1.2 Evaluation operation diagram.

13.1.5 Procedure

I Prepare plant layout and treatment flow sheet.

II Collect information on water quality, chemicals used, doses applied, seasonal problems experienced, if any.

III Collect water samples at appropriate points for on the spot/laboratory examination.

IV Record your observations on the physical conditions and functional aspects of the different units.

13.1.6 Data Processing

In the light of the data collected and your observations:

I Draw a flow diagram for the water works.

II Calculate hydraulic loadings of the plants.

III Calculate removal efficiencies of plants.

IV State the problems and deficiencies observed.

13.1.7 Interpretation

Compare the observed removal efficiencies with literature data on appropriate design and expected removal.

Give an appraisal of the plant performance and suggestions, if any, for improvement.

13.1.8 References

Paramasivan, R. (1989), Water Works Survey, p. 4.39-42. IN: Exercises on Water Supply. 344 pp. (Ed. E. Dahi). Centre for Developing Countries, Technical University of Denmark.

13.2 Break Point Chlorination

13.2.1 Principle

Chlorination using bleaching powder requires estimation of chlorine content in the chemical product, as well as determination of the chlorine demand of the water.

13.2.2 Theoretical Background

Chlorine and chlorine compounds are commonly used for disinfection of water. B.P. is often used especially for small and medium water supplies, because it is easy to handle compared to chlorine gas and sodium hypochlorite solution. However, it is often necessary to analyze the content of "active chlorine" in the powder as the chlorine content is not persistent. Commercially available B. P. usually contains 25-33 percent of available chlorine.

Moreover it is important to assess the chlorine demand of water, as most of the chlorine added may be consumed for oxidation of impurities present in water, before chlorine starts acting as a disinfectant.Chlorine demand is defined as the difference between the total quantity of chlorine added to water and the free chlorine obtained at the end of a specified contact period, say 1 h.

When chlorine is added to water containing impurities (reducing substances such as Fe^{++}, Mn^{++}, sulfide, ammonia, organics, bacterial contamination), it reacts with them and in the presence of excess chlorine, produces a residual. Depending upon the pH and the nature of impurities, the residual will be in combined form (chloramines) or as free residual. In drinking water supplies, it should be ensured that the treated water at the consumers end has a minimum residual chlorine of 0.2 mg/l for protection of public health.

13.2.3 Materials

I Sample of bleaching powder, 20 g.

II Sample(s) of water for which the chlorine demand is to be determined.

III Iodine/thiosuphate titration facility.

IV Free and combined chlorine analysis chemicals and photometer.

V Weighing balance.

VI Glassware including 10 conical flasks of 250 ml and 2 one litre volumetric flasks.

13.2.4 Analysis Parameters

ESTIMATION OF CHLORINE IN B. P.

I Weigh about 1 g of bleaching powder, precisely W g.

II Make a paste and add it to 1 litre volumetric flask. Make the volume to 1.00 litre with distilled water.

III Leave it for 10 minutes.

IV Take 25.00 ml of supernatant in a conical flask.

V Titrate it with standard sodium thiosulfate (0.025/N) iodometrically using starch as indicator till colorless, say X ml.

VI Carry out this experiment in triplicate.

VII Note the normality of the titration solution, say N.

VII Calculate the per cent available chlorine in bleaching powder in Z % W/W :

$$Z = \frac{X_{av} \cdot N \cdot 35.45 \cdot 100}{25.00 \cdot 10000} \text{ g Cl/100 g B.P.}$$

Equation 13.2.A.

13.2.5 Experimental Set Up

Ten conical flasks used as reactors for chlorination of water samples.

13.2.6 Procedure

I Prepare a standard chlorine solution containing 0.2 g/l chlorine, i.e. if B.P. strength is Z % take 20/Z g in 1.00 l distilled water as described above.

II Take 100 ml aliquots of water sample in 10 conical flasks.

III To each one of the aliquots add bleaching powder solution:

FLASK No :	A	B	C	D	E	F	G	H	I	J
Cl-SOL.ml :	0	0.5	1	2	3	4	5	6	8	10
ADDED mg/l:	0	0.1	0.2	0.4	0.6	0.8	1.0	1.2	1.6	2.0

IV Thoroughly mix the samples and allow them to stand for the contact period, say 60 min.

V Add 5 ml of Orthotolidine reagent to each of the flasks. Mix the contents thoroughly and allow the color to develop in 5 minutes.

VI Measure the intensity of color using spectrophotometer at 420 nm wavelength.

VII Obtain the corresponding concentration of total residual chlorine using the pre-calibrated graph (supplied to you).

VIII Add the ascorbic acid reagent and measure the color intensity in the spectrophotometer.

IX Obtain the corresponding concentration of combined chlorine residual.

X If the results show that the dosage is out of range, i.e. too small or too high, repeat the experiment selecting more appropriate dosage.

13.2.7 Data Processing

I Draw the break point curve.

II From the observed values of free residual chlorine identify the point and the corresponding dose of chlorine added which gives a free residual of 0.2 mg/l.

III Calculate the chlorine demand of water as the difference between the chlorine added and free residual at the 0.2 mg/l level.

13.2.8 Interpretation

From the observed values of percent available chlorine in the B. P. and the chlorine demand, comment on the quality of B. P. and the quality of water sample.

13.2.9 References

Paramasivan, R. (1989), Break Point Chlorination, p. 4.49-50. IN: Exercises on Water Supply. 344 pp. (Ed. E. Dahi). Centre for Developing Countries, Technical University of Denmark.

13.3 Disinfection of Wells

13.3.1 Principle

Appropriate disinfection of an open well may require estimation of chlorine demand of the water, addition of appropriate amount of bleaching powder, (B. P.) to establish free chlorine residual, about say 0.2 mg/l, after a contact period of 1.0 hr and subsequent sustaining of the residual using the pot chlorinator technique.

13.3.2 Theoretical Background

Contaminated open wells may be difficult to disinfect by addition of a single dose of any chlorine compound, especially if overdosage has to be avoided. So far the double pot chlorinator technique seems to be the method of choice, particularly in rural areas. Efficient disinfection however, would require initial satisfaction of the chlorine demand of water in the well.

$$D = \frac{V \cdot (\delta + 0.2)}{0.01 \cdot Z}$$

Where:

- D is the amount of bleaching powder required, g.
- V is the estimated volume of water in the well, m^3.
- δ is the chlorine demand of the water, g/m^3.
- Z is the strength of bleaching powder, g/100 g.

δ and Z are estimated as given in the previous exercise.

The subsequent inflow of chlorine demanding impurities to the well and the natural decay of already established chlorine residual is covered by using the pot chlorinator.

By measuring the chlorine concentration decay and the decay of bacterial contamination in the well it may be possible to control the water quality and to estimate the disinfection kinetics to predict better design and preparation of the pot chlorinator.

13.3.3 Materials

I Bleaching powder, about 5 kg.

II Clean coarse sand, 3 kg, grain size 1.4-1.6 mm.

III One pot, external Dia 180 mm, height 300 mm, 10 mm hole 40 mm from upper edge.

IV One pot, external dia 280 mm, height 330 mm, 10 mm hole 40 mm from bottom.

V Polytene sheet, wire, rope.

VI Tray and instruments for mixing sand and B.P..

VII Kit and chemicals for measurement of free and combined chlorine.

VIII Kit, substrates, glassware, chemicals and incubators for measurement of plate counts and coliform.

IX Glassware for sampling and chlorine analysis as per group planning.

X Glassware for sampling and bacterial analysis as per group planing (sterile bottles containing about 100 mg of sterile thiosulfate).

13.3.4 Analysis Parameters

I MEASUREMENT OF B. P. STRENGTH:

See previous exercise.

II MEASUREMENT OF CHLORINE DEMAND OF WELL WATER:

See previous exercise.

III MEASUREMENT OF CHLORINE RESIDUALS:

See kit user information.

IV MEASUREMENT OF BACTERIAL CONTAMINATION:

See kit user information and Standard Methods.

13.3.5 Experimental Set Up

See figure 7.7 and 9.2.

13.3.6 Procedure

I Select an open well, supposed to be contaminated.

II Take samples for measurement of Plate Counts, (PC), and Total and Faecal Coliform, TC + FC.

III Estimate the volume of water in the well before going back to laboratory.

IV Determine the strength of B.P. available.

V Determine the chlorine demand of the water.

VI Prepare the pot chlorinator by thorough mixing of 1 kg of B. P. and 2 kg of sand.

Keep the holes on opposite directions. Cover the pots with the polytene sheets leaving the holes free.

VII Calculate D, the amount of B. P. required for establishing free chlorine residual in the well.

VIII Add D and take samples for chemical and bacterial analysis.

IX Lower the double pot about 1 meter below surface level and tie the rope to the edge of the well.

X Take and analyze samples according to group planning.

13.3.7 Data Processing

Calculate and plot the observed chlorine concentration and the bacterial contamination as a function of time and activities.

13.3.8 Interpretation

Compare the observed chlorine demand using laboratory testing and field results. Estimate bacterial inactivations and suggest optimized procedures for similar situation.

13.3.9 References

Dahi 1989 (ed.) p. 4.51-54 IN: Exercises on Water Supply. 344 pp. Centre for Developing Countries, Technical University of Denmark.

13.4 Defluoridation

13.4.1 Principle

Addition of Alum to fluoride water results in hydrolysis of Al+++ which results in a precipitation of $Al(OH)_3$. $Al(OH)_3$ removes fluoride while precipitating. In the JAR TEST this experiment is conducted in six different batches simultaneously and under same conditions, apart from one parameter, say the dose of chemical. The jar test helps to design the defluoridation process with respect to this parameter.

13.4.2 Theoretical Background

See problem and problem solution on defluoridation and referred literature.

13.4.3 Materials

I 10 l of water containing approximately 6 mg/l fluoride.
II Jar Test Apparatus
III Fluoride analysis facilities; Colorimeter, Nesslers tubes, SPADNS-reagent, $ZrOCl_2$, concentrated HCl.
IV Turbidimeter.
V Alum, approximately 100 g.
VI Distilled Water 1 l.
VII Pipettes for taking 0.5 to 10 ml samples.
VIII Bleaching Powder.
IX Lime, 100 g.
X Balance.

13.4.4 Analysis Parameters

I Fluoride.
II Turbidity.

13.4.5 Procedure

I Prepare 2 l of 10 % alum stock solution, 1 ml of this solution corresponds to 100 mg.
II Add 1 l of fluoride water in each beaker of the Jar Test apparatus.
III Add different doses of the Alum solution to the beakers. Add as 0 50, 100, 200, 400, 600 and 1000 mg of Alum. Ensure thorough mixing by high R. P. M. during addition of the Alum solution.
IV Flocculate, i.e. gentle mixing at 20 R. P. M., for 10 minutes.

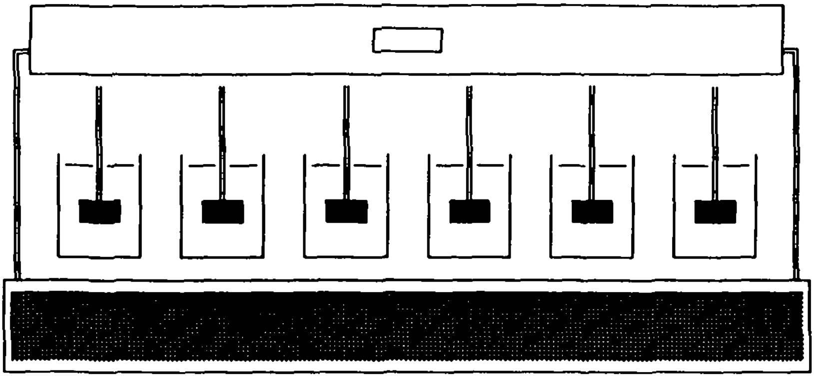

FIG 13.4.1 The Jar Test Apparatus.

V Allow to settle for 30 minutes.
VI Also carry out settling by addition lime.
VII Repeat steps II to V using alum along with settling aid in stead of alum alone.
VIII Decant the water and measure the residual Fluoride.

13.4.6 Experimental Set Up

See figure 13.4.1.

13.4.7 Data Processing

Determine the removal efficiencies for different chemical doses. Plot removal efficiencies as amount of chemical doses.

13.4.8 Interpretation

Optimum dose of chemical can be found out for treatment of fluoride water by this experiment.

13.4.9 References

NEERI 1987. Defluoridation. Technology Mission.

Thergaonkar, V. P. (1989), Defluoridation, p. 4.59-61. IN: Exercises on Water Supply. 344 pp. (Ed. E. Dahi). Centre for Developing Countries, Technical University of Denmark.

14 Case Study

Water Supply Situation
in
Province of Mbindi, Zarunda

14.1 Introduction

In the following you will find background information about health and water supply situation in the province of Mbindi, Zarunda. The participants are requested to simulate being consultants for the government for a short period of time. The terms of reference for the groups are to work out an appropriate drinking water quality surveillance scheme for the given province.

A) Define and list the responsibilities of your advisory team.

B) Define the budget of the surveillance work, covering staff salaries, operation and maintenance of the inspection, remedial activities and monitoring work.

C) Define the criteria which you will adopt for selecting villages in the pilot project area. How will you increase surveillance ?

D) Design appropriate water quality standards for use in the area.

E) Design appropriate inspection forms for the local survey teams.

F) Define the organizational structure and composition of the survey teams.

G) Take into consideration the location of water sources and the distribution of the population in your design of the sampling and inspection programme.

H) Consider introducing remedial action plan including operation and maintenance of private water facilities.

I) Define a training programme for the local surveillance staff.

J) Discuss and indicate the help and collaboration you expect from international and bi-lateral agencies.

The groups are expected to submit report on their advisory work and to present the report for discussion in a accordance with the course programme.

14.2 The Republic of Zarunda

14.2.1 History and Geography

The Democratic People's Republic of Zarunda has a population of 6.5 millions. The country has been an independent state since 1945 and following a popular military coup against a corrupt regime in 1979 civilian rule was established in 1982. Since 1982, the country has made a good progress in economic development and the Government now places a very high priority on health and education.

14.2.2 Economy

The Gross National Product of Zarunda, which was 280 US$ pr. person in 1983, has been increasing by 1.2 % pr. year. The country economy is based on production of coffee, cotton, sisal, tobacco, cashew nut and different fruits and spices. More than 80 % of all export income derives from these cash crop export. Copper mining play a secondary role. Manufacturing output remains low. Foreign debt has decreased since 1979 from 30.5 % of GNP to 22.6 % in 1985.

14.2.3 Socioculture

The official language of Zarunda is Kiswahili, however, some Arabic and much tribal Bantu languages are spoken. English is spoken particularly in the capital city of Zarunda. Despite rapid increases in literacy in the capital, adult literacy in the country is only 42 %.

The annual growth rate of the entire population is 1.9 % (1980 - 1985), but that of Ndarashu is higher at 3.2 %. Due to the war in the neighboring country of Kenigeni, some 55,000 refuges have entered the central and northern provinces of Zarunda since 1981. Many of these refugees have semi-permanent status in camps supervised by international relief organizations.

42 % of the economically active labor force is involved in agriculture. There has been no acute food shortage since 1974 and calories available per head of population are approximately 2 % greater than estimated requirements. There are only 26 trained engineers and scientists for every 100,000 population (compare with the US which has more than 200).

Life expectancy in Zarunda is 51 for men and 54 for women (compare with Denmark with 74 for men and 77 for women). Infant mortality reduced by 35 % between 1979 and 1985 and is presently less than 80 per 1000 live births. The improvements are thought to be mostly due to increases in health care provision in Richardville and the success of ORT schemes in the southern and western provinces.

14.3 The Province of Mbindi

Mbindi is the least developed and poorest of the 7 regions of Zarunda. There are 550 villages in Mbindi spread over an area of 21,000 km^2. Mbindi has a population of 340,000 of whom 19,000 are refugees living in camps around the northern border. The population of the provincial capital Ndarashu is 90,000, but during the dry season this may increase to more than 120,000. 70 % of the villages in Mbindi have a population of less than 500 people and 20 % have a population in a range 500-1000 persons.

The provence is tropical. There is desert to the west and in the south-east of the Province are the mountains of Sulu. Mbindi relies heavily on substance agriculture. There is no access to ocean ports and there is no railway (although there is a plan to extend the railway from the western province of Nhugo to Ndarashu). Road transport to the capital takes 36-48 hours and is largely on unmade roads. The State airline Zarundaair flies to Ndarashu two times per week, and intends to increase this frequency to four times per week in 1988.

All transport is unreliable during the wet season, especially air travel. Rainfall is restricted to the months of March - June, and unlike many countries of the region, it has not failed in recent times.

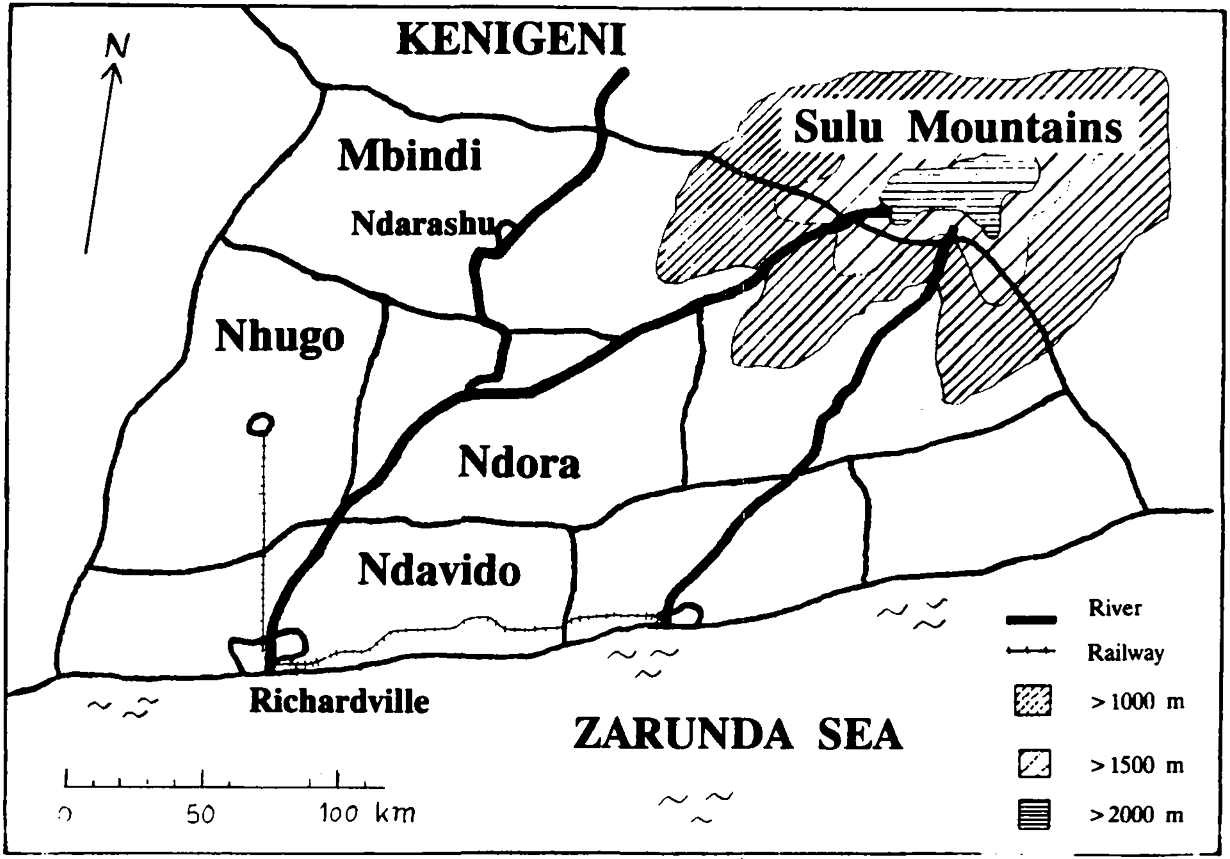

FIG. 14.1 Map of the Democratic People's Republic of Zarunda.

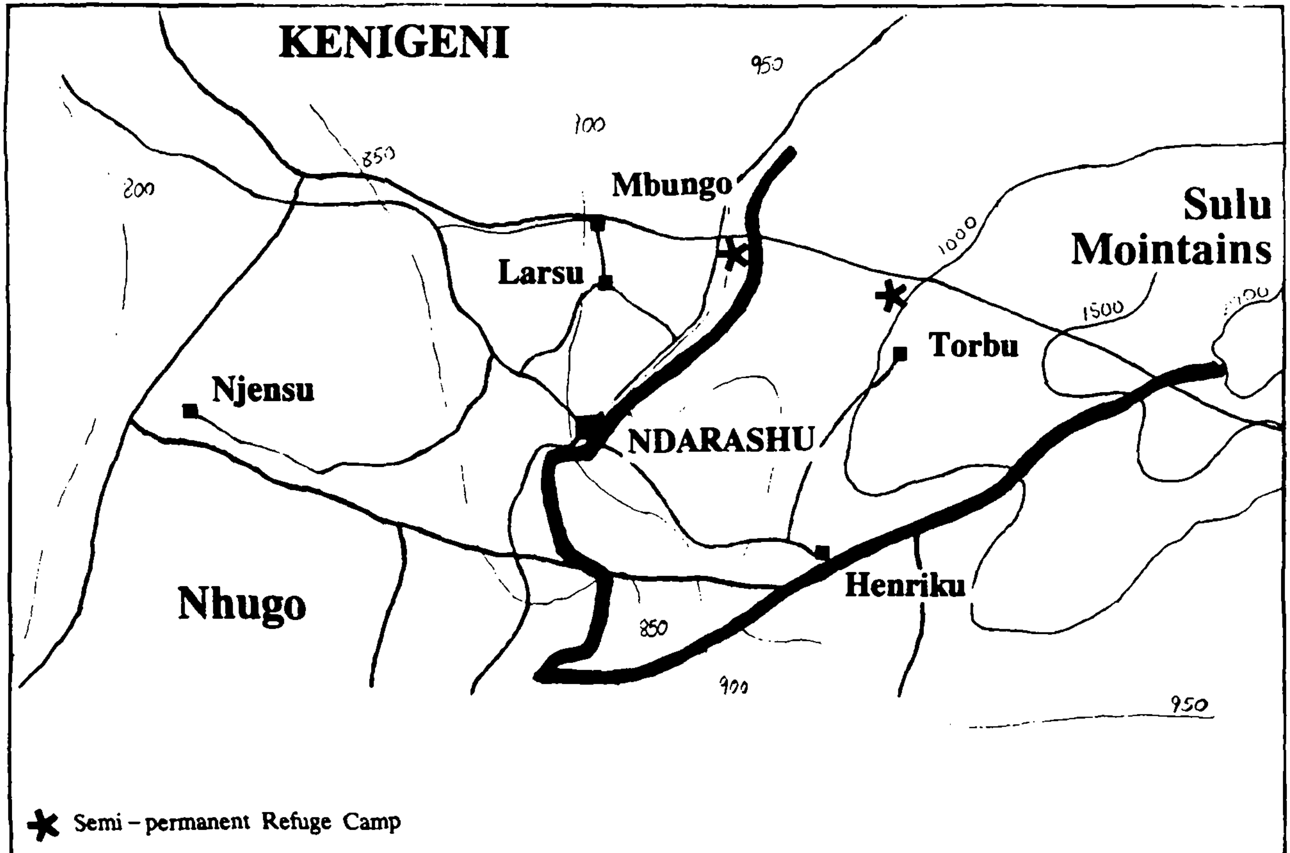

FIG. 14.2 Map of the province of Mbindi in Zarunda.

14.4 Health in Mbindi

In Zarunda as a whole, 25,000 deaths are directly attributable to diarrhoeal disease every year. An estimated 70% of infant mortality (0 - 5 year age group) is associated with diarrhoeal disease. Although there are no reliable statistics for Mbindi, there is no reason to suspect that the problem of high infant mortality due to diarrhoea is any less in the Province.

Indeed, many consultants and development agencies believe that the health status of the people of Mbindi is actually much worse than the rest of the country. In particular, several reports have suggested that a high proportion of diarrhoeal disease in Mbindi is water related. This includes endemic giardiasis in many areas, and there have been outbreaks of acute gastro-enteritis and typhoid in Kenigeni refugee camps.

A recent survey of nutritional status in Ndarashu found some evidence that cases of malnutrition were mostly clinical (caused by recurrent diarrhoeal disease) rather than due to dietary deficiency. Special blame was placed on the town's water supply which is generally believed to be a disaster; the treatment works break down frequently, supplying untreated surface water to the population. It has been estimated that approximately 60% of all patients admitted to Ndarashu hospital suffer from diseases associated with poor water supply and sanitation. Of the 980 children admitted to the paediatric ward in 1985/86. 491 were cases of acute gastro-enteritis. There are no equivalent data for the rural areas.

Due to certain political difficulties during the last 10 years, the ministry of Health has not functioned well in Mbindi. They have insufficient resources and major problems of transportation in the rural areas. A system of Primary Health Care (PHC) is being developed slowly. A network of rural health centres has been established, but to date these have been principally concerned with the provision of basic drugs and oral rehydration salt sachets (Oralyte). The health centres have not been directly involved in public health initiatives concerned with water or sanitation

The Ministry of Health in Richardville is trying to promote programmes of Control of Diarrhoeal Disease (CCD) and Extended Programme of Immunization (EPI) for the whole country, but a large amount of training and major expansion of the Regional Ministry of Health is required in order to establish the basis for PHC in Mbindi.

14.5 Water Resources

Typical rural water supplies are based on dams and dug wells in the rural Mbindi. It has been estimated that only 2 % of surface water in Mbindi is used for water resources (usually by damming of rivers during the wet season or diversion of rivers into reservoirs). The remainder of surface water is lost through drainage to the River Mbindi seepage and evaporation.

The aquifers of the region are productive and accessible (usually 10 - 30 metres below surface). They are relatively unexploited at present, but there are no plans to install handpumps in 300 more rural villages by 1995.

The responsibility for management of water resources in Mbindi resides with the Mbindi Regional Water Authority (BRWA). It is directly responsible to the Regional Government; but also forms a constituent part of the national Department of Water Supply and Sanitation (part of the Ministry of Public Works and Development).

14.6 Water Demand

The resources described in table 1 only provide 38 % of existing water demand. They do not include water abstracted from simple dug wells, brick wells or private supplies. However, the scarcity of water resources is responsible for lower consumption rates than normally considered essential. In a survey of 125 rural villages, the average per capita consumption of water was observed to be only 15 litres per day.

Population projections imply that water demand for human consumption will rise to 19.5 million m^3 per annum by the year 2000. Meanwhile, animal consumption of water is expected to rise from 23.4 million m^3 (in 1987) to 28.1 million m^3 in the year 2000. These figures are based on per capita consumption of 70 litres per person per day in the urban sector, 40 lpppd in the peri-urban sector and 25 lpppd in the rural sector. In the analysis, animals are allowed the following volumes of water per day: cattle - 35 litres, camels - 60 litres, sheep and goats - 15 litres per day.

Existing resources which are the responsibility of the Regional Water Authority are illustrated in Table 14.1

TAB. 14.1 Existing water resources in the Province of Mbindi (Data from the Mbindi Regional Water Authority - excludes wells etc).

	Rural Area	Urban Area	Total
Mountain Stream/Spring	5	0	5
Surface reservoirs			
Water Yards	133	0	133
Lakes & Dams	21	2	23
Rivers	2	2	4
Dug Wells	Many	Many	Many
Boreholes			
Shallow Aquifer	170	10	180
Deep Aquifer			

TAB. 14.2 Water quality data from the Ndarashu urban water supply and from household containers in five rural villages of Mbindi.

	Ndarashu Town	Njensu Village	Henriku Village	Torbu Village	Larsu Village	Mbungo Village
Population	90,000	580	1500	400	270	750
Water sources Coverage (%)						
Dams	60	-	60	10	10	20
Dug Wells	10	90	20	90	60	80
Deep Boreholes	30	-	-	0	30	0
Water Quality of Main Sources:						
FC (n)[a]	0-450(41)	0-1(13)	250-1720(7)	12-2000(5)	50-420(3)	71-981(5)
Free Cl (n)	0-0.3(120)	0*	0*	0*	0*	0*
Turbidity[b] (n)	<5-350(35)	<5(13)	25-700(7)	<5-400(5)	50-350(0)	90-500(5)
Alkalinity[c] mg/l	120-200	205-340	50-150	200-500	340-420	240-390
Chloride mg/l	100-200	110-120	140-205	300-350	250-300	120-250
Fluoride	0.1-2	0.5-1.5	4-17	6-12	0.7-2.2	0.8-1.8
Nitrate mgN/l	0.5-2	5-15	2-8	1-7	5-10	4-6
Nitrite	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ammonia	n.d.	0-3	n.d.	0.5-0.8	2-5	0.5-0.7
Hydrogen Sulfide	n.d.	n.d.	2-2.5	n.d.	1-6	-
Sulphate	33-46	20-50	25-60	19-30	30-65	25-70
Calcium	20-30	40-80	50-90	50-60	80-90	60-80
Magnesium	5-15	10-20	20-25	15-22	10-18	8-16
Iron	n.d.	0.1-0.2	n.d.	n.d.	4-6	3-8
Manganese	n.d.	n.d.	n.d.	n.d.	0.2-0.4	0.9-1

[a] n gives the number of samples taken during last year. [b] as NTU. [c] as calcium carbonate.

14.7 Water Quality

Surveys on existing hand-dug wells in rural Mbindi showed that most wells are microbial contaminated. From 120 dug wells tested, 90 % of the wells had more than 100 faecal coliforms per 100 ml of sample, see also table 14.2.

Table 14.2 describes typical water quality data from the Ndarashu water supply and five selected rural villages in the Province.

In summary, there is an urgent need to address the problems of the Ndarashu water treatment and supply system. There is also a pressing need for the hand pump installation programme for improving the quality and quantity of water resources available to the rural villages of Mbindi.

14.8 References

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15 Course Certificate

World Health Organization
Division of Environmental Health

Technical University of Denmark
Centre for Developing Countries

WHO/DANIDA Course

on

Surveillance & Control of Drinking Water Quality

This is to certify, that

has attended The WHO/DANIDA Course on SURVEILLANCE & CONTROL OF DRINKING WATER QUALITY, November 12-23th, 1990. During the Course the participant has obtained knowledge and proficiency in:

* Planning for water quality surveillance in rural and urban areas.
* Health problems emerging from physical, bacteriological and chemical constituents in drinking-water.
* Analyzing water with respect to various physical, bacteriological and chemical parameters.

This training course is a joint activity of the World Health Organization, the Centre for Developing Countries at the Technical University of Denmark and the Water Ministry of Tanzania, sponsored by the Danish International Development Agency DANIDA, Copenhagen, Denmark.

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