health are

WATER

Much of the ill-health which affects humanity, especially in the developing countries can be traced to lack of safe and wholesome water supply. Water that is easily accessible, adequate in quantity, free from contamination, safe and readily available throughout the year. There can be no state of positive health and well-being without safe water. Water is not only a vital environmental factor to all forms of life, but it has also a great role to play in socio-economic development of human population. Each country should develop its own water resources agency which would collect all pertinent data on water resources, exploitation and hydrogeology. In 1981, the 34th World Health Assembly in a resolution emphasized that safe drinking water is a basic element of "primary health care" which is the key to the attainment of "Health for All by the year 2000 AD". More recently, Millennium Development Goals included safe water and sanitation in the attainable goals. Water is integrated with other PHC components because it is an essential part of health education, food and nutrition, and also MCH.

Safe and wholesome water

Water intended for human consumption should be both safe and wholesome. This has been defined as water that is

a. free from pathogenic agents

b. free from harmful chemical substances
c. pleasant to the taste, i.e., free from colour and odour; and
d. usable for domestic purposes.

Water is said to be *polluted* or *contaminated* when it does not fulfil the above criteria. Water pollution is a growing hazard in many developing countries owing to human activity. Without ample and safe drinking water, we cannot provide health care to the community.

Water requirement

The basic physiological requirements for drinking water have been estimated at about 2 litres per head per day. This is just for survival. But from the standpoint of public health and improvement of the quality of life, water should be provided in adequate volume. It will help to reduce the incidence of many water-related diseases among the people most at risk. The consumption of water, however, depends upon climate conditions, standard of living and habits of the people. A daily supply of 150–200 litres per capita is considered as an adequate supply to meet the needs for all urban domestic purposes. In India 40 litres of water supply per capita per day was the set target to be achieved in rural areas.It must be available close to the people, else they have to spend hours and a lot of energy, going back and forth to obtain it and the water is often polluted in the process.

Uses of water

The uses of water in a community are many, and the requirement in quantity and quality are varied. Conventionally, it has been convenient and economical to provide a single water supply sufficient in quantity to serve all uses and suitable in quality to meet drinking requirements, even though only a small fraction of the total water supply is actually used for drinking.

The uses of water include : (1) Domestic use : on domestic front, water is required for drinking, cooking, washing and bathing, flushing of toilets, gardening etc. (2) Public purposes : cleaning streets, recreational purposes like swimming pools, public fountains and ornamental ponds, fire protection and public parks. (3) Industrial purposes : for processing and cooling; (4) Agricultural purpose : irrigation (5) Power production from hydropower and steam power; (6) Carrying away waste from all manner of establishments and institutions. Water is therefore an essential factor in the economic, social and cultural development of a community. It can eliminate diseases, promote rural development and improve quality of life.

Sources of water supply

Water may be abstracted for use from any one of a number of points in its movement through the hydrological cycle. The safe yield of the source must be sufficient to serve the population expected at the end of the design period, which may be 10 to 50 years in future. The safe yield is generally defined as the yield that is adequate for 95 per cent of the year. The selection of a source requires professional advice. In general, water sources must conform to two criteria : (a) the quantity must be sufficient to meet present and future requirement (b) the quality of water must be acceptable. There are three main sources of water :

1. RAIN
2. SURFACE WATER
    - Impounding reservoirs
    - Rivers and streams
    - Tanks, ponds and lakes.

3. GROUND WATER
    Shallow wells
    Deep wells
    Springs.

1. Rain

Rain is the prime source of all water. A part of the rain water sinks into the ground to form ground water; part of it evaporates back into the atmosphere, and some runs off to form streams and rivers which flow ultimately into the sea. Some of the water in the soil is taken up by the plants and is evaporated in turn by the leaves. These events are spoken of as "water cycle". *CHARACTERISTICS* : Rain water is the purest water in nature. Physically, it is clear, bright and sparkling. Chemically, it is very soft water containing only traces of dissolved solids (0.0005 per cent). Being soft, it has a corrosive action on lead pipes. Bacteriologically, rain water from clean districts is free from pathogenic agents. *IMPURITIES* : Rain water tends to become impure as it passes through the atmosphere. It picks up suspended impurities from the atmosphere such as dust, soot and microorganisms and gases such as carbon dioxide, nitrogen, oxygen and ammonia. Gaseous sulphur and nitrogen oxides are emitted from power plants that use fossil fuels. These gases react with atmospheric water, forming dilute solution of sulphuric and nitric acid. The precipitation of these acids (acid rain) has begun to have serious impacts on surface water quality and on plants etc. There are very few places in the world like Gibralter which depend upon rain as a source of water supply.

2. Surface water

Surface water originates from rain water. It is the main source of water supply in many areas. Examples of surface water include rivers, tanks, lakes, wadis (water source which are dry, except in rainy season), man-made reservoirs and sea water. Surface water is prone to contamination from human and animal sources. As such it is never safe for human consumption unless subjected to sanitary protection and purification before use.

The vast majority of Indian cities and towns depend upon surface water sources, which are (1) Impounding Reservoirs, (2) Rivers and Streams, and (3) Tanks, Ponds and Lakes. In general, surface water supplies possess a high probability of organic, bacterial and viral contamination.

(1) IMPOUNDING RESERVOIRS

(These are artificial lakes)constructed usually of earthwork or masonry in which large quantities of surface water is stored. Dams built across rivers and mountain streams also provide large reserves of surface water. The area draining into the reservoir is called "Catchment area". Cities such as Mumbai, Chennai and Nagpur derive their water supply from impounding reservoirs. One disadvantage of storing water for long periods in reservoirs is the growth of algae and other microscopic organisms, which impart bad tastes and odours to water. *CHARACTERISTICS* : Impounding reservoirs usually furnish a fairly good quality of water. The water is usually clear, palatable and ranks next to rain water in purity. If the surrounding hills are covered with peat, the water may acquire a brownish coloration. The water is usually soft and considered to be free of pathogenic organisms. *IMPURITIES* : The upland surface water derives its impurities from the catchment area, the sources being human habitations and animal keeping or grazing. It is therefore very necessary to keep the catchment area free from human or animal intrusion. The general belief that mountain streams are very pure water is often untrue. Even if there is no human habitation or cattle near, there is still a possibility of contamination caused by wild animals.

(2) RIVERS

Many rivers furnish a dependable supply of water. Cities such as Delhi, Kolkata and Allahabad rely on river water for their needs. The chief drawback of river water is that it is always grossly polluted and is quite unfit for drinking without treatment. *CHARACTERISTICS* : River water is turbid during rainy season; it may be clear in other seasons. Clarity of water is no guarantee that the river water is safe for drinking. River water contains dissolved and suspended impurities of all kinds. The bacterial count, including the human intestinal organisms may be very high. *IMPURITIES* : Rivers are described as a direct connection between the alimentary canal of the people living upstream and the mouths of those below. The impurities of river water are derived from surface washings, sewage and sullage water, industrial and trade wastes, and drainage from agricultural areas. The customs and habits of the people like bathing, animal washing and disposal of the dead, all add to the pollution of water. *SELF-PURIFICATION* : Certain amount of self-purification does occur in river water by natural forces of purification such as dilution, sedimentation, aeration, oxidation, sunlight, plant and animal life but these agencies are not sufficient to render the water potable. River water needs purification before it can be used for drinking purposes.

(3) TANKS *(5,6)*

Tanks are large excavations in which surface water is stored. They are an important source of water supply in some Indian villages. Tanks are recipients of contamination of all sorts. They are full of silt and colloidal matter, especially immediately after the rains. The older tanks may be full of aquatic vegetation. Tanks are often used for washing of clothes, cattle, humans, cooking pots; children use it for swimming and there may be regular defecation around the edges which will be washed into the tank at the next rains. Tanks are thus subjected to unlimited possibilities of contamination and are highly dangerous, as a source of drinking water, even at the best of times. But unfortunately, the tank water is drunk without being boiled, disinfected or having undergone treatment of any kind which is responsible for an incalculable number of cases of sickness and death, particularly of children.

Improvement of tanks : A certain amount of natural purification does take place in tank water because of storage, oxidation and other agencies but these are not sufficient to render the water safe. The sanitary quality of tank water may be considerably improved by observing the following : (1) the edges of the tank should be elevated in order to prevent the entry of surface washings, (2) there should be a fence around the tank to prevent access to animals, (3) no one should be permitted to get into the tank directly (note the hazard of guineaworm infestation), (4) there should be an elevated platform from where people can draw water, (5) the weeds should be periodically removed, (6) the tank should be cleaned at the end of the dry season. Inspite of these precautions, from a practical point of view, it is not possible to prevent pollution of tanks as the people who consume the tank water are often among the poorest in the country and do not have sanitary concepts. Considerable research is now in progress at national and international levels to ensure the village tank as a safe source of drinking water *(5)*. It is believed that the simplest solution consists of subjecting the tank water to some sort of sand filtration. Fig. 1 illustrates how this could be brought about. The addition of chlorine would undoubtedly add to the value of sand filtration.

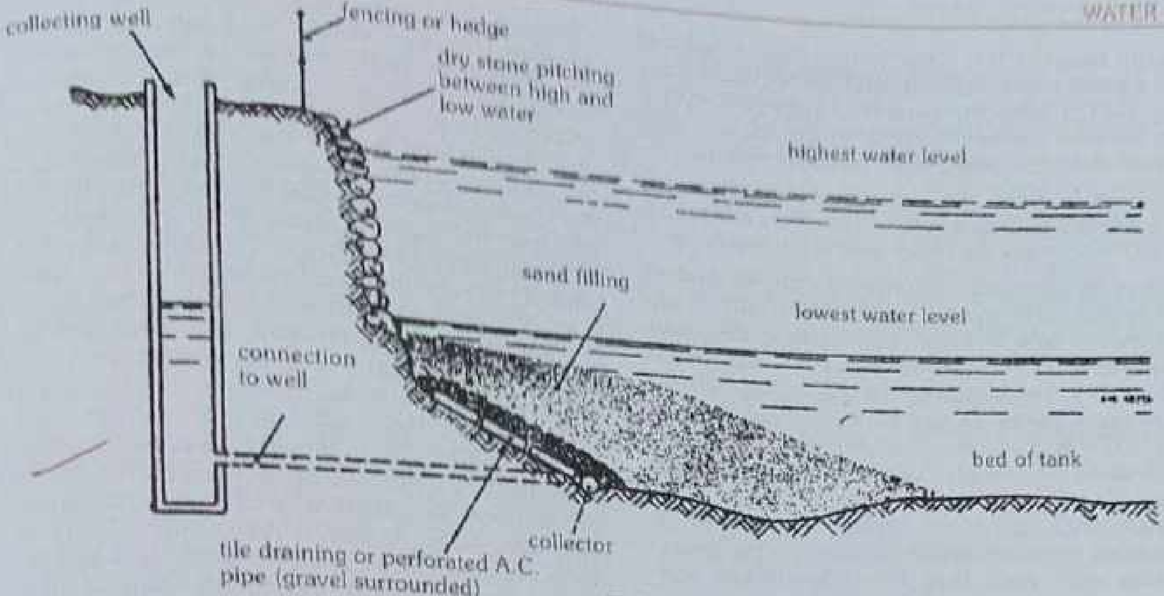

FIG. 1

Slow sand filtration of tank water

Sea water

Though this source is plentiful, it has great many limitations. It contains 3.5 per cent of salts in solution. Off-shore waters of the oceans and seas have a salt concentration of 30,000 to 36,000 mg/litre (30–36 g/litre) of dissolved solids including 19,000 mg/litre of chloride, 10,600 mg/litre of sodium and 1,270 mg/litre of magnesium. Desalting and demineralization process involves heavy expenditure. It is adopted in places where sea water is the only source available *(4)*.

3. Ground water

Rain water percolating into ground constitutes ground water. Water used by humans comes mainly from land. It is now realized that there is a limit to ground water in the world. We should withdraw only quantities of water that can be renewed.

Ground water is the cheapest and most practical means of providing water to small communities. Ground water is superior to surface water, because the ground itself provides an effective filtering medium. The advantages of ground water are: (1) it is likely to be free from pathogenic agents, (2) it usually requires no treatment, (3) the supply is likely to be certain even during dry season. (4) It is less subject to contamination than surface water. The disadvantages are: (1) it is high in mineral content, e.g., salts of calcium and magnesium which render the water hard (2) it requires pumping or some arrangement to lift the water *(7)*. The usual ground water sources are wells and springs. Wells have been classified into shallow and deep wells, dug and tube wells.

WELLS

Traditionally wells are an important source of water supply. Even today, they are an important source of water supply in many communities. Technically, wells are of two kinds – shallow and deep. (1) *Shallow wells* : Shallow wells tap subsoil water i.e. the water from above the first impervious layer in the ground. They yield limited quantities of water, and the water is notoriously liable to pollution unless care is taken in well construction. (ii) *Deep wells* : A deep well is one which taps water from the water-bearing stratum below the first impervious layer in the ground (Fig. 2). Deep wells are usually machine-dug and may be several hundred metres deep. Deep wells furnish the safest water, and are often the most satisfactory sources of water supply.

The points of difference between a shallow well and deep well are set out in Table 2.

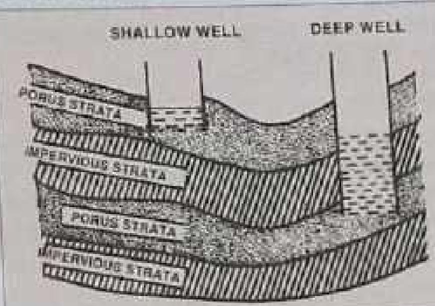

FIG.2

Shallow and deep wells

Most of the wells in India are of the shallow type. Speaking generally, shallow wells are liable to pollution from neighbouring sources of contamination such as latrines, urinals, drains, cesspools, soakage pits and collections of manure. Shallow wells are therefore a health hazard to the community if they are not made sanitary. A deep well can also

TABLE 2

Differences between a shallow well and deep well

	Shallow well	Deep well
1. *Definition*	Taps the water from above the first impervious layer	Taps the water from below the first impervious layer
2. *Chemical quality*	Moderately hard	Much hard
3. *Bacteriological quality*	Often grossly contaminated	Taps purer water
4. *Yield*	Usually goes dry in summer	Provides a source of constant supply

become a health hazard if it is open, poorly constructed and not protected against contamination. ARTESIAN WELLS are a kind of deep wells in which the water rises above the level of ground water, because it is held under pressure between two impervious strata. Artesian wells are not common in India.

Saline intrusion : Near the sea, there is danger of infiltration of sea water in to deep wells. This gives a brackish taste to water and may make the water unfit for domestic use.

Wells may also be classified, according to the method of construction, into *dug wells* and *tube wells*. DUG WELLS are by far the commonest type in India. Two types of dug wells exist in our rural areas: (a) the unlined katcha well and (b) the masonry or pucca well. The katcha well is a hole dug into the water-bearing stratum. The pucca well is an open well, built of bricks or stones. STEP WELLS are a kind of pucca wells which are becoming obsolete, fortunately. Steps are constructed into these wells to enable people to descend into the well to fetch water or quench their thirst. In these wells, there is considerable personal contact between the user and the water. Some people may even wash their faces, hands and feet which is a common Indian custom. Guineaworm disease is quite a public health problem in areas where step wells are in use. The open dug wells and step wells are a health hazard to the community.

Improvement of dug wells

The unlined katcha wells may be made sanitary by deepening the bottom, installing a hand-pump with screen, and filling the well with coarse sand up to the water level, and with clay above that level. When the material used for filling is completely consolidated a platform and drainage may be constructed.

Masonry well improvement consists of making the upper 10 feet or more of the lining water-tight, raising the lining one foot above the ground, and providing a reinforced concrete slab cover at the top. One or more hand-pumps may be installed for lifting the water. Special attention should be paid to the foundation of the pump to prevent any possible leakage of waste water into the well.

SANITARY WELL

A sanitary well is one which is properly located, well–constructed and protected against contamination with a view to yield a supply of safe water (Fig. 3). The following points should be taken into consideration while constructing sanitary wells: (1) *LOCATION* : The first step in well construction is the choosing of a proper site. If bacterial contamination is to be avoided, the well should be located not less than 15 m (50 feet) from likely sources of contamination. The well should be located at a higher elevation with respect to a possible source of contamination. The distance between the well and the houses of the users should also be considered. If the well is situated far away, people may not use it. It is therefore recommended that the well should be so located that no user will have to carry water for more than 100 m (100 yards) *(7)*. (2) *LINING* : The lining of the well should be built of bricks or stones set in cement up to a depth of at least 6 m (20 feet) so that water enters from the bottom and not from the sides of the well. The lining should be carried 60–90 cm (2–3 feet) above the ground level. (3) *PARAPET WALL* : There should be a parapet wall up to a height of at least 70–75 cms (28 inches) above the ground. (4) *PLATFORM* : There should be a cement-concrete platform round the well extending at least 1 m (3 feet) in all directions. The platform should have gentle slope outwards towards a drain built along its edges. (5) *DRAIN* : There should be a pucca drain to carry off spilled water to a public drain or a soakage pit constructed beyond the "cone of filtration" (area of drainage) of the well. (6) COVERING : The top of the well should be closed by a cement concrete cover because the bulk of the pollution is introduced into the well directly through the open top. Studies have shown that merely covering a well alone caused a marked improvement in the bacteriological quality of the water *(5)*. *Open* wells, therefore, cannot be considered sanitary, however well they might be constructed otherwise. (7) *HAND-PUMP* : The well should be equipped with a hand-pump for lifting the water in a sanitary manner. Studies have shown that when a pump is fitted there is marked improvement in the bacteriological quality of the water. The handpump should be of robust construction to withstand rough handling by the people. There should be an efficient maintenance service and arrangements for immediate repair if the pumps go out of order. (8) *CONSUMER RESPONSIBILITY* : The provision of sanitary wells does not guarantee freedom from water-borne diseases unless the consumers observe certain basic precautions at the individual and family level. Strict cleanliness should be enforced in the vicinity of the well; personal ablutions, washing of clothes and animals, and the dumping of refuse and wastes should be prohibited. Ropes and buckets from individual homes should not be used for drawing a supply from the well. Water from the well should be carried in clean sanitary vessels to individual houses. All this requires health education. (9) *QUALITY* : The physical, chemical and bacteriological quality of water should conform to the acceptable standards of quality of safe and wholesome water.

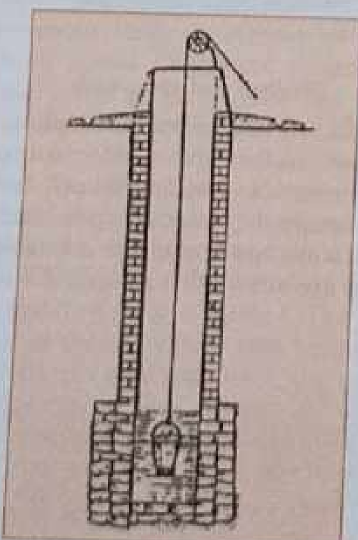

FIG. 3

Sanitary open well

TUBE WELLS

Tube wells are successful as a source of drinking water in many parts of India. They yield water which is bacteriologically safe, and are also cheap in comparison to other sources of supply. Shallow tube wells or "driven wells" have become the largest individual source of water supply to the rural community. The tube well consists of a pipe (usually galvanized iron) sunk into the water-bearing stratum and fitted with a *strainer* at the bottom, and a hand-pump at the top. A water-tight concrete platform with a drain all round should be provided. The area within 15 m of the tube well should be kept free from pollution with liquid and solid wastes. The hand-pump should be kept in good repair. The life of the tube well is not the same everywhere. It varies from place to place depending upon the type of strainer, quality of underground water and the nature of soil. An average well may last for a period of 5 to 10 years; in some cases, tube wells have given satisfactory service even after 30 years (8). When the tube well is derelict, it is withdrawn and then resunk with a new strainer using as much of the withdrawn pipes as can be recovered. *Deep tube* wells or bored wells are sunk by drilling through successive substrata of gravel or rock until a suitable supply of ground water is located. They may be several hundred feet deep and require complicated mechanical drilling equipment and skilled engineering direction. This type of wells, although costly to construct and to operate, are in many ways the ideal supply. The yield is normally very high and does not depend upon direct rainfall in the immediate vicinity. Chandigarh, the capital of Punjab, derives its entire water supply from tube wells.

SPRINGS

When ground water comes to the surface and flows freely under natural pressure, it is called a "spring". Springs may be of two types–shallow springs and deep springs. Shallow springs dry up quickly during summer months, whereas deep springs do not show seasonal fluctuations in the flow of water. In some geographic areas, springs constitute an important source of water. Springs are simpler to exploit, as no pumping is needed to bring the water to the surface. Springs are exposed to contamination. Well built protective structures are necessary to safeguard water quality.

WATER POLLUTION

Pure uncontaminated water does not occur in nature. It contains impurities of various kinds – natural and man-made. The natural impurities are not essentially dangerous. These comprise dissolved gases (e.g. nitrogen, carbon dioxide, hydrogen sulphide, etc. which may be picked up during rainfall), and dissolved minerals (e.g., salts of calcium, magnesium, sodium, etc.) which are natural constituents of water following its contact with soil; and suspended impurities (e.g., clay, silt, sand and mud), and microscopic organisms. These impurities are derived from the atmosphere, catchment area and the soil.

A more serious aspect of water pollution is that caused by human activity – urbanization and industrialization. The sources of pollution resulting from these are : (a) *sewage*, which contains decomposable organic matter and pathogenic agents (b) *industrial and trade wastes*, which contain toxic agents ranging from metal salts to complex synthetic organic chemicals (c) *agricultural pollutants*, which comprise fertilizers and pesticides, and (d) *physical pollutants*, viz heat (thermal pollution) and radioactive substances (*9*).

The indicators of pollution include the amount of total suspended solids, biochemical oxygen demand (BOD) at 20 deg. C, concentration of chlorides, nitrogen and phosphorus and absence of dissolved oxygen.

Even if the source of water supply and its treatment are of a high standard, water pollution may still occur as often happens, due to corrosion of pipe lines, leaky joints and cross connections between water supply pipes and sewage drainage pipes. Surveillance has to be exercised at every point in the distribution system to ensure supply of safe water to the consumer.

Water-related diseases

Man's health may be affected by the ingestion of contaminated water either directly or through food; and by the use of contaminated water for purpose of personal hygiene and recreation. The term water-related diseases include the classical water-borne diseases. Developing countries carry a heavy burden of water-related diseases, the heaviest being the diarrhoeal diseases. Water-related diseases may be classified as follows :

A. *Biological (Water-borne diseases)*

1. *Those caused by the presence of an infective agent* :
    - (a) Viral : Viral hepatitis A, hepatitis E, poliomyelitis, rotavirus diarrhoea in infants
    - (b) Bacterial : typhoid and paratyphoid fever, bacillary dysentery, *Esch. coli* diarrhoea, cholera
    - (c) Protozoal : amoebiasis, giardiasis
    - (d) Helminthic : roundworm, threadworm, hydatid disease.
    - (e) Leptospiral : weil's disease
2. *Those due to the presence of an aquatic host* :
    - (a) Snail : schistosomiasis
    - (b) Cyclops : guineaworm , fish tape worm.

B. *Chemical*

Chemical pollutants of diverse nature derived from industrial and agricultural wastes are increasingly finding their way into public water supplies. These pollutants include detergent solvents, cyanides, heavy metals, minerals and organic acids, nitrogenous substances, bleaching agents, dyes, pigments, sulphides, ammonia, toxic and biocidal organic compounds of great variety. Chemical pollutants may affect man's health not only directly, but also indirectly by accumulating in aquatic life (e.g. fish) used as human food. The present concern about chemical pollutants in water relates not so much as to their acute toxic effects on human health as to the possible long-term effects of low level exposure, which are often non-specific and difficult to detect. Further, some of the new pollutants are not easily removed by conventional water treatment or purification processes. In many developed countries where water-borne communicable diseases have virtually disappeared, more attention is now being paid to chemical pollution.

In addition to the above, water is associated with the following :

(a) *Dental health* : The presence of fluoride at about 1 mg/litre in drinking water is known to protect against dental caries, but high levels of fluoride cause mottling of the dental enamel;

(b) *Cyanosis in infant* : High nitrate content of water is associated with methaemoglobinaemia. This is a rare occurrence but may occur when surface water from farmland, treated with a fertilizer, gain access to the water supply.

(c) *Cardiovascular diseases* : Hardness of water appears to have a beneficial effect against cardiovascular diseases;

(d) Some diseases are transmitted because of inadequate use of water like shigellosis, trachoma and conjunctivitis, ascariasis, scabies *(10)*.

(e) Some diseases are related to the disease carrying insects breeding in or near water like : malaria, filaria, arboviruses, onchocerciasis, African trypanosomiasis *(10)*.

While pollution seems to be an inevitable consequence of modern industrial technology, the problem, now, is to determine the level of pollution that permits economic and social development without presenting hazards to health. The evaluation of the health effects of environmental pollutants is currently being carried out as part of the WHO Environmental Health Criteria Programme.

WATER POLLUTION LAW

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WATER POLLUTION LAW

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4.1. PURIFICATION OF WATER

Purification of water is of great importance in community medicine. It may be considered under two headings :

1. Purification of water on a large scale
2. Purification of water on a small scale

1. Purification of water on a large scale

The purpose of water treatment is to produce water that is safe and wholesome. The method of treatment to be employed depends upon the nature of raw water, and the desired standards of water quality. For example, ground water (e.g., wells and springs) may need no treatment, other than disinfection. Surface water (e.g., river water) which tends to be turbid and polluted, requires extensive treatment. The components of a typical water purification system comprise one or more of the following measures :

- I. Storage
- II. Filtration
- III. Disinfection

(I) STORAGE

Water is drawn out from the source and impounded in natural or artificial reservoirs. Storage provides a reserve of water from which further pollution is excluded. As a result of storage, a very considerable amount of purification takes place. This is natural purification, and we may look at it from three points of view):

(a) *Physical* : By mere storage, the quality of water improves. About 90 per cent of the suspended impurities settle down in 24 hours by gravity. The water becomes clearer. This allows penetration of light, and reduces the work of the filters.

(b) *Chemical* : Certain chemical changes also take place during storage. The aerobic bacteria oxidize the organic matter present in the water with the aid of dissolved oxygen. As a result, the content of free ammonia is reduced and a rise in nitrates occurs.

(c) *Biological* : A tremendous drop takes place in bacterial count during storage. The pathogenic organisms gradually die out. It is found that when river water is stored the total bacterial count drops by as much as 90 per cent in the first 5-7 days. This is one of the greatest benefits of storage. The optimum period of storage of river water is considered to be about 10-14 days. If the water is stored for long periods, there is likelihood of development of vegetable growths such as algae which impart a bad smell and colour to water.

(II) FILTRATION

Filtration is the second stage in the purification of water, and quite an important stage because 98-99 per cent of the bacteria are removed by filtration, apart from other impurities. Two types of filters are in use, the "biological" or "slow sand" filters and the "rapid sand" or "mechanical" filters. A brief description of these filters is given below :

1) SLOW SAND OR BIOLOGICAL FILTERS *(11)*

Slow sand filters were first used for water treatment in 1804 in Scotland and subsequently in London. During the 19th century their use spread throughout the world. Even today, they are generally accepted as the standard method of water purification.

Elements of a slow sand filter

Fig. 4 shows in diagrammatic form, the various elements of a slow sand filter. Essentially these consist of :

(1) Supernatant (raw) water

(2) a bed of graded sand

(3) an under-drainage system; and

(4) a system of filter control valves

(1) Supernatant water

The supernatant water above the sand bed, whose depth varies from 1 to 1.5 metre, serves two important purposes : it provides a constant head of water so as to overcome the resistance of the filter bed and thereby promote the downward flow of water through the sand bed, and secondly, it provides waiting period of some hours (3 to 12 hours, depending upon the filtration velocity) for the raw water to undergo partial purification by sedimentation, oxidation and particle agglomeration. The level of supernatant water is always kept constant.

Collection

(2) Sand bed

The most important part of the filter is the sand bed. The thickness of the sand bed is about 1 metre. The sand grains are carefully chosen so that they are preferably rounded and have an "effective diameter" between 0.2 and 0.3 mm. The sand should be clean and free from clay and organic matter. The sand bed is supported by a layer of graded gravel (Fig. 5), 30–40 cm deep which also prevents the fine grains being carried into the drainage pipes.

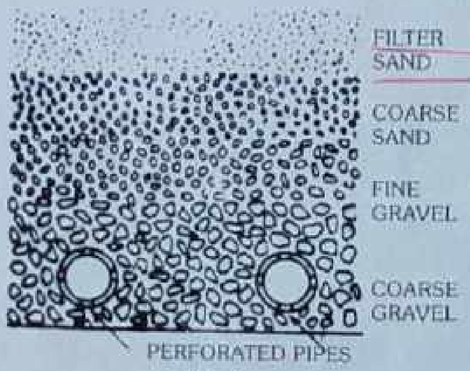
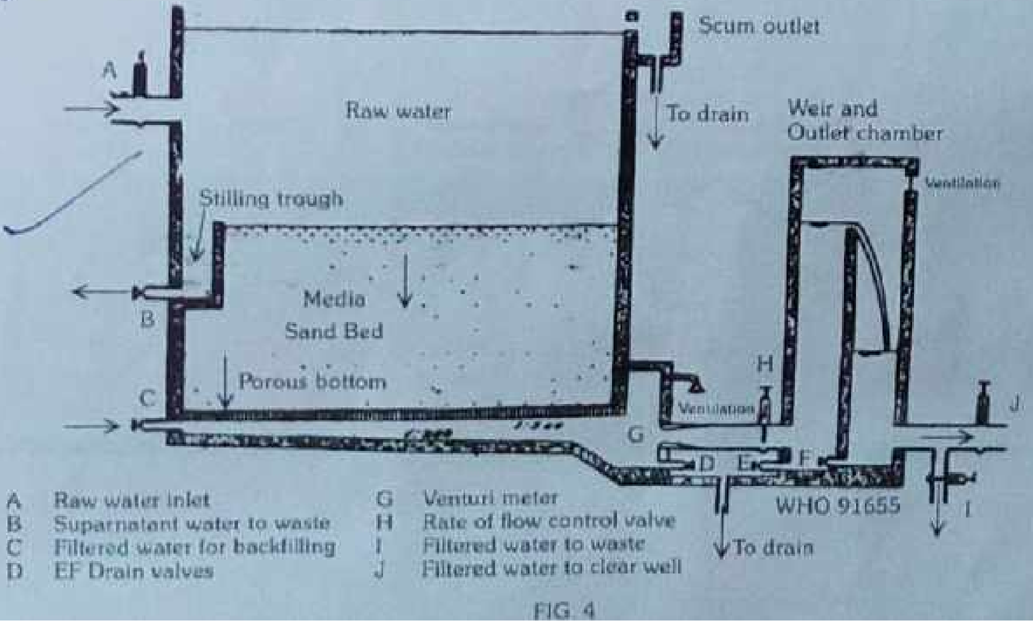


FIG. 5

Section of filter bed

The sand bed presents a vast surface area; one cubic metre of filter sand presents some 15,000 sq. metres of surface area. Water percolates through the sand bed very slowly (a process taking two hours or more), and as it does so, it is subjected to a number of purification processes – mechanical straining, sedimentation, adsorption, oxidation and bacterial action, all playing their part. The designed rate of filtration of water normally lies between 0.1 and 0.4 m3/hour/per square metre of sand bed surface.

Vital layer : When the filter is newly laid, it acts merely as a mechanical strainer, and cannot truly be considered as "biological". But very soon, the surface of the sand bed gets covered with a slimy growth known as "Schmutzdecke", vital layer, zoogleal layer or biological layer. This layer is slimy and gelatinous and consists of threadlike algae and numerous forms of life including plankton, diatoms and bacteria. The formation of vital layer is known as "ripening" of the filter. It may take several days for the vital layer to form fully, and when fully formed it extends for 2 to 3 cm into the top portion of the sand



A	Raw water inlet	G	Venturi meter
B	Suparnatant water to waste	H	Rate of flow control valve
C	Filtered water for backfilling	I	Filtered water to waste
D	EF Drain valves	J	Filtered water to clear well

FIG. 4

bed. The vital layer is the "heart" of the slow sand filter. It removes organic matter, holds back bacteria and oxidizes ammoniacal nitrogen into nitrates and helps in yielding a bacteria-free water.) Until the vital layer is fully formed, the first few days filtrate is usually run to waste.

(3) Under-drainage system

(At the bottom of the filter bed is the under-drainage system. It consists of porous or perforated pipes which serve the dual purpose of providing an outlet for filtered water, and supporting the filter medium above) Once the filter bed has been laid, the under-drainage system cannot be seen.

Filter box : The first 3 elements (e.g. supernatant water, sand bed and under-drainage system) are contained in the filter box. The filter box is an open box, usually rectangular in shape, from 2.5 to 4 metres deep and is built wholly or partly below ground. The walls may be made of stone, brick or cement. The filter box consists from top to bottom :

Supernatant water	1 to 1.5 metre
Sand bed	1.2 metre
Gravel support	0.30 metre
Filter bottom	0.16 metre

(4) Filter control

The filter is equipped with certain valves and devices which are incorporated in the outlet-pipe system. The purpose of these devices is to maintain a constant rate of filtration. An important component of the regulation system is the "Venturi meter" (Fig. 4) which measures the bed resistance or "loss of head". When the resistance builds up, the operator opens the regulating valve so as to maintain a steady rate of filtration. When the "loss of head" exceeds 1.3 metre it is uneconomical to run the filter.

Filter cleaning : Normally the filter may run for weeks or even months without cleaning. When the bed resistance increases to such an extent that the regulating valve has to be kept fully open, it is time to clean the filter bed, since any further increase in resistance is bound to reduce the filtration rate. At this stage, the supernatant water is drained off, and the sand bed is cleaned by "scraping" off the top portion of the sand layer to a depth of 1 or 2 cm. This operation may be carried out by unskilled labourers using hand tools or by mechanical equipment. After several years of operation, and say 20 or 30 scrapings, the thickness of the sand bed will have reduced to about 0.5 to 0.8 metre. Then the plant is closed down and a new bed is constructed.

The advantages of a slow sand filter are : (1) simple to construct and operate (2) the cost of construction is cheaper than that of rapid sand filters (3) the physical, chemical and bacteriological quality of filtered water is very high. When working ideally, slow sand filters have been shown to reduce total bacterial counts by 99.9 to 99.99 per cent and *E. coli* by 99 to 99.9 per cent.)

In recent years, a mistaken idea has grown that biological or slow sand filtration is an old fashioned, outdated method of water treatment which has been completely superseded by rap filtration. This is definitely not the case. Slow sand filtratio the chosen method of water purification in a number of industrialized cities as well as urban areas. In a number of ci U.S. and Europe, slow sand filters have recently been construc

RAPID SAND OR MECHANICAL FILTERS

In 1885, the first rapid sand filters were installed in the USA. Since that time, they have gained considerable popularity especially in highly industrialized countries .

Rapid sand filters are of two types, the gravity type (e.g. Paterson's filter) and the pressure type (e.g. Candy's filter). Both the types are in use. The following steps are involved in the purification of water by rapid sand filters : (Fig 6).

(1) *Coagulation* : The raw water is first treated with a chemical coagulant such as alum, the dose of which varies from 5-40 mg or more per litre, depending upon the turbidity and colour, temperature and the pH value of the water. (2) *Rapid mixing* : The treated water is then subjected to violent agitation in a "mixing chamber" for a few minutes. This allows a quick and thorough dissemination of alum throughout the bulk of the water, which is very necessary. (3) *Flocculation* : The next phase involves a slow and gentle stirring of the treated water in a "flocculation chamber" for about 30 minutes. The mechanical type of flocculator is the most widely used. It consists of a number of paddles which rotate at 2 to 4 rpm. The paddles rotate with the help of motors. (This slow and gentle stirring results in the formation of a thick, copious, white flocculent precipitate of aluminium hydroxide) The thicker the precipitate or flock diameter, the greater the settling velocity. (4) *Sedimentation* : The coagulated water is now led into sedimentation tanks where it is detained for periods varying from 2-6 hours when the flocculent precipitate together with impurities and bacteria settle down in the tank. At least 95 per cent of the flocculent precipitate needs to be removed before the water is admitted into the rapid sand filters. (The precipitate or sludge which settles at the bottom is removed from time to time without disturbing the operation of the tank.) For proper maintenance, the tanks should be cleaned regularly from time to time, otherwise they may become a breeding ground for molluscs and sponges. (5) *Filtration* : The partly clarified water is now subjected to rapid sand filtration.

Filter beds :

Each unit of Filter bed has a surface of about 80 to 90 m^2 (about 900 sq. feet). Sand is the filtering medium. The "effective size" of the sand particles is between 0.4-0.7 mm. The depth of the sand bed is usually about 1 metre ($2\frac{1}{2}$ to 3 feet). Below the sand bed is a layer of graded gravel, 30 to 40 cm. ($1-1\frac{1}{2}$ feet) deep. The gravel supports the sand bed and permits the filtered water to move freely towards the under-drains. The depth of the water on the top of the sand bed is 1.0 to 1.5 m (5-6 feet). The under-drains at the bottom of the filter beds collect the filtered water. The rate of filtration is 5-15 m^3/m^2/hour. A view of the rapid sand filter is given in Fig. 7.

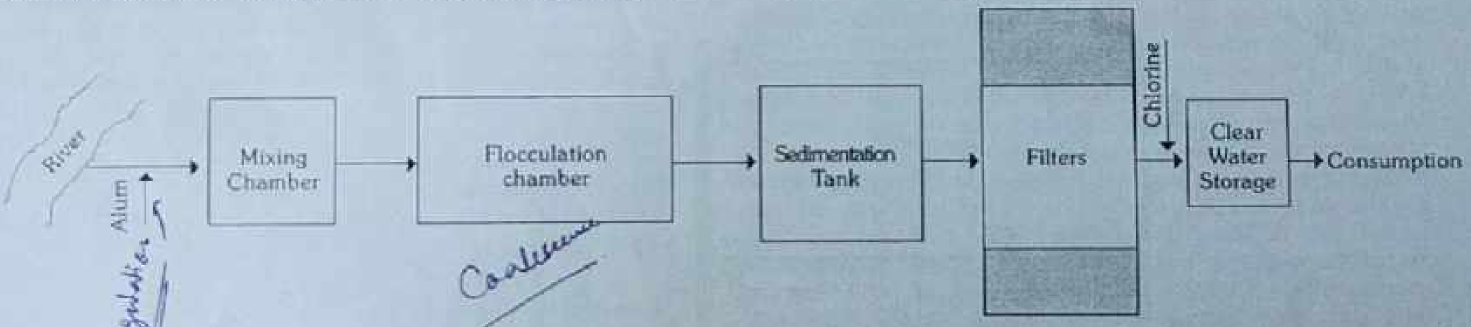


FIG. 6

Flow diagram of a rapid sand filtration plant

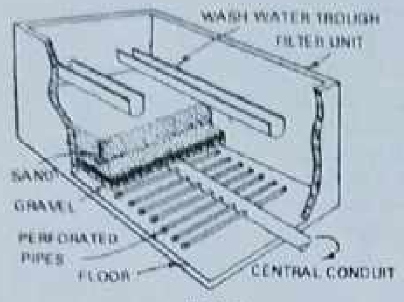


FIG. 7

A view of a rapid sand filter

Filtration

As filtration proceeds, the "alum-floc" not removed by sedimentation is held back on the sand bed. It forms a slimy layer comparable to the zoogleal layer in the slow sand filters. It adsorbs bacteria from the water and effects purification. Oxidation of ammonia also takes place during the passage of water through the filters. As filtration proceeds, the suspended impurities and bacteria clog the filters. The filters soon become dirty and begin to lose their efficiency. When the "loss of head" approaches 7-8 feet, filtration is stopped and the filters are subjected to a washing process known as "back-washing".

Back-washing

Rapid sand filters need frequent washing daily or weekly, depending upon the loss of head. Washing is accomplished by reversing the flow of water through the sand bed, which is called "back-washing". Back washing dislodges the impurities and cleans up the sand bed. The washing is stopped when clear sand is visible and the wash water is sufficiently clear. The whole process of washing takes about 15 minutes. In some rapid sand filters, compressed air is used as part of the back-washing processes.

Advantages

The advantages of a rapid sand filter over the slow sand filter are : (1) rapid sand filter can deal with raw water directly. No preliminary storage is needed (2) the filter beds occupy less space (3) filtration is rapid, 40-50 times that of a slow sand filter (4) the washing of the filter is easy (5) there is more flexibility in operation.

Comparison of rapid and slow sand filters

The main features of rapid and slow sand filters are given in Table3.

(III) DISINFECTION

For a chemical or an agent to be potentially useful as a disinfectant in water supplies, it has to satisfy the following criteria :

(a) it should be capable of destroying the pathogenic organisms present, within the contact time available and not unduly influenced by the range of physical and chemical properties of water encountered particularly temperature, pH and mineral constituents;

(b) should not leave products of reaction which render the water toxic or impart colour or otherwise make it unpotable;

(c) have ready and dependable availability at reasonable cost permitting convenient, safe and accurate application to water;

(d) possess the property of leaving residual concentration to deal with small possible recontamination; and

(e) be amenable to detection by practical, rapid and simple analytical techniques in the small concentration ranges to permit the control of the efficiency of the disinfection process.

In water works practice, the term disinfection is synonymous with chlorination.

CHLORINATION

Chlorination is one of the greatest advances in water purification. It is supplement, not a substitute to sand filtration. Chlorine kills pathogenic bacteria, but is has no effect on spores and certain viruses (e.g., polio, viral hepatitis) except in high doses. Apart from its germicidal effect, chlorine has several important secondary properties of value in water treatment : it oxidizes iron, manganese and hydrogen sulphide; it destroys some taste and odour-producing constituents; it controls algae and slime organisms; and aids coagulation.

Action of chlorine : When chlorine is added to water, there is formation of hydrochloric and hypochlorous acids. The hydrochloric acid is neutralised by the alkalinity of the water. The hypochlorous acid ionizes to form hydrogen ions and hypochlorite ions, as follows :-

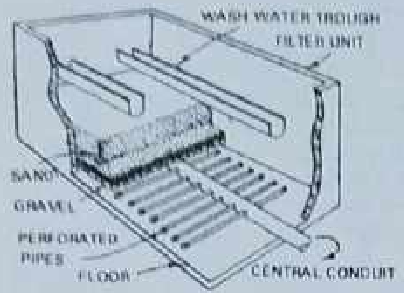
$$H_2O + Cl_2 \rightarrow HCl + HOCl$$
$$HOCl \rightarrow H + OCl$$

The disinfecting action of chlorine is mainly due to the hypochlorous acid, and to a small extent due to the hypochlorite ions. The hypochlorous acid is the most effective form of chlorine

TABLE 3

Comparison of rapid and slow sand filters

		Rapid sand filter	Slow sand filter
1.	Space :	Occupies very little space	Occupies large area
2.	Rate of Filtration :	200 m.g.a.d	2-3 m.g.a.d.
3.	Effective size of sand :	0.4-0.7mm	0.2-0.3mm
4.	Preliminary treatment :	Chemical coagulation and sedimentation	Plain sedimentation
5.	Washing :	By back-washing	By scraping the sand bed
6.	Operation :	Highly skilled	Less skilled
7.	Loss of head allowed :	6-8 feet	4 feet
8.	Removal of trubidity :	Good	Good
9.	Removal of colour :	Good	Fair
10.	Removal of bacteria :	98-99 per cent	99.9-99.99 per cent



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for water disinfection. It is more effective (70–80 times) than the hypochlorite ion. Chlorine acts best as a disinfectant when the pH of water is around 7 because of the predominance of hypochlorous acid. When the pH value exceeds 8.5 it is unreliable as a disinfectant because about 90 per cent of the hypochlorous acid gets ionized to hypochlorite ions. It is fortunate that most waters have a pH value between 6–7.5.

Principles of chlorination : The mere addition of chlorine to water is not chlorination. There are certain rules which should be obeyed in order to ensure proper chlorination : (1) First of all, the water to be chlorinated should be clear and free from turbidity. Turbidity impedes efficient chlorination (2) Secondly, the "chlorine demand" of the water should be estimated. "The chlorine demand of water is the difference between the amount of chlorine added to the water, and the amount of residual chlorine remaining at the end of a specific period of contact (usually 60 minutes), at a given temperature and pH of the water". In other words, it is the amount of chlorine that is needed to destroy bacteria, and to oxidize all the organic matter and ammoniacal substances present in the water. The point at which the chlorine demand of the water is met is called the "break-point". If further chlorine is added beyond the break point, free *chlorine* (HOCl and OCl) begins to appear in the water (3) Thirdly the contact period. The presence of free residual chlorine for a contact period of atleast one hour is essential to kill bacteria and viruses *(20)*. It should be noted however, that chlorine has no effect on spores, protozoal cysts and helminthic ova, except in higher doses. (4) The minimum recommended concentration of free chlorine is 0.5 mg/L for one hour(12). The free residual chlorine provides a margin of safety against subsequent microbial contamination such as may occur during storage and distribution. (5) The sum of the chlorine demand of the specific water plus the free residual chlorine of 0.5 mg/L constitutes the correct dose of chlorine to be applied.

METHOD OF CHLORINATION

For disinfecting large bodies of water, chlorine is applied either as (1) chlorine gas (2) chloramine or (3) perchloron. Chlorine gas is the first choice, because it is cheap, quick in action, efficient and easy to apply. Since chlorine-gas is an irritant to the eyes and poisonous, a special equipment known as "chlorinating equipment" is required to apply chlorine gas to water supplies. Paterson's chloronome is one such device for measuring, regulating and administering gaseous chlorine to water supplies. In some water treatment plants, they use *chloramine* instead of chlorine gas. Chloramines are loose compounds of chlorine and ammonia. They have a less tendency to produce chlorinous tastes and give a more persistent type of residual chlorine. The greatest drawback of chloramines is that they have a slower action than chlorine and therefore they are not being used to any great extent in water treatment. Perchloron or high test hypochlorite (H.T.H.) is a calcium compound which carries 60–70 per cent of available chlorine. Solutions prepared from H.T.H. are also used for water disinfection. As mentioned already, chlorine gas has replaced all the other chlorine derivatives in the disinfection of urban water supplies.

B REAK POINT CHLORINATION

The addition of chlorine to ammonia in water produces chloramines which do not have the same efficiency as free chlorine. If the chlorine dose in the water is increased, a reduction in the residual chlorine occurs, due to the destruction of chloramine by the added chlorine. The end products do not represent any residual chlorine. This fall in residual chlorine will continue with further increase in chlorine dose and after a stage, the residual chlorine begins to increase in proportion to the added dose of chlorine. This point at which the residual chlorine appears and when all combined chlorines have been completely destroyed is the breakpoint and corresponding dosage is the breakpoint dosage. Breakpoint chlorination achieves the same results as superchlorination in a rational manner and therefore be construed as controlled superchlorination *(4)*.

SUPERCHLORINATION

Superchlorination followed by dechlorination comprises the addition of large doses of chlorine to the water, and removal of excess of chlorine after disinfection, this method is applicable to heavily polluted waters whose quality fluctuates greatly.

ORTHOTOLIDINE (OT) TEST

Orthotolidine test enables both free and combined chlorine in water to be determined with speed and accuracy. The test was developed in 1918. The reagent consists of analytical grade O-tolidine, dissolved in 10 per cent solution of hydrochloric acid. When this reagent is added to water containing chlorine, it turns yellow and the intensity of the colour varies with the concentration of the gas. The yellow colour is produced by both free and combined chlorine residuals. OT reacts with *free chlorine* instantaneously but reacts more slowly with *combined* chlorine *(12)*.

The test is carried out by adding 0.1 ml of the reagent to 1 ml of water. The yellow colour produced is matched against suitable standards or colour discs. Commercial equipment is available for this purpose. It is essential to take the reading within 10 seconds after the addition of the reagent to estimate *free chlorine* in water *(14)*. The colour that is produced after a lapse, say 15–20 minutes, is due to the action of both free and combined chlorine.

ORTHOTOLIDINE-ARSENITE (OTA) TEST

This is a modification of the OT test to determine the free and combined chlorine residuals separately (13, 14, 15). Further, the errors caused by the presence of interfering substances such as nitrites, iron and manganese all of which produce a yellow colour with o-tolidine, are overcome by the OTA test *(12)*.

Other Agents

While chlorine continues to be the most commonly used sterilizing agent because of its germicidal properties and the comparatively low cost and ease of application, its pre-eminence in water disinfection is being seriously challenged because of the discovery that chlorination of water can lead to the formation of many "halogenated compounds" some of which are either known or suspected carcinogens. As a result, many chlorine alternatives are receiving renewed interest. These include bromine, bromine-chloride, iodine and chlorine dioxide- but these do not seem to present a viable alternative to chlorine at the present time. Ozone is showing the greatest promise, and ultra-violet irradiation's limited usefulness as complimentary agents for chlorine in water disinfection.

(a) OZONATION : Ozone is a relatively unstable gas. It is a powerful oxidizing agent. It eliminates undesirable odour, taste and colour, and removes all chlorine from the water. Most importantly, ozone has a strong virucidal effect. It inactivates viruses in a matter of seconds, whereas minutes are required to inactivate them with either chlorine or iodine. This has prompted many municipalities to consider ozone for potable water treatment. More than 1000 municipal water treatment plants around the world are using ozone, the oldest of these is in France, which has been in operation since 1906 *(16)*.

The drawback of ozone is that after it has done its job, it decomposes and disappears. There is no residual germicidal effect. The current thinking is that ozone should be used as a pre-treatment of water to destroy not only viruses and bacteria but also organic compounds that are precursors for undesirable chloro-organic compounds that form when chlorine is added. A carefully controlled minimum dose of chlorine is added to the water before it is pumped into the distribution system. Thus ozonation is usually employed in combination with chlorination. In this combined treatment, the two methods complement each other taking advantage of the best features of each (16). The ozone dosage required for potable water treatment varies from 0.2 to 1.5 mg per litre *(17)*.

(b) ULTRAVIOLET IRRADIATION : Germicidal property of UV rays have been recognised for many years. UV irradiation is effective against most microorganisms known to contaminate water supplies including viruses.

This method of disinfection involves the exposure of a film of water, upto about 120 mm thick, to one or several quartz mercury vapour arc lamps emitting ultraviolet radiation at a wavelength in the range of 200 to 295 mm. Applications are limited to individual or institutional systems. The water should be free from turbidity and suspended or colloidal constituents for efficient disinfection.

The advantages are that the exposure is for short period, no foreign matter introduced and no taste and odour produced. Overexposure does not result in any harmful effects. The disadvantages are that no residual effect is available and there is a lack of a rapid field test for assessing the treatment efficiency; moreover, the apparatus needed is expensive *(4)*.

2. Purification of water on a small scale

(1) Household purification of water

Three methods are generally available for purifying water on an individual or domestic scale. These methods can be used singly or in combination.

(a) BOILING

Boiling is a satisfactory method of purifying water for household purposes. To be effective, the water must be brought to a "rolling boil" for 5 to 10 minutes. It kills all bacteria, spores, cysts and ova and yields sterilized water. Boiling also removes temporary hardness by driving off carbon dioxide and precipitating the calcium carbonate. The taste of water is altered, but this is harmless. While boiling is an excellent method of purifying water, it offers no "residual protection" against subsequent microbial contamination. Water should be boiled preferably in the same container in which it is to be stored to avoid contamination during storage.

(b) CHEMICAL DISINFECTION

(1) *Bleaching Powder* : Bleaching powder or chlorinated lime ($CaOCl_2$) is a white amorphous powder with a pungent smell of chlorine. When freshly made, it contains about 33 per cent of "available chlorine". It is, however, an unstable compound. On exposure to air, light and moisture, it rapidly loses its chlorine content. But when mixed with excess of lime, it retains its strength; this is called "stabilized bleach." Bleaching powder should be stored in a dark, cool, dry place in a closed container that is resistant to corrosion. The chlorine content of bleaching powder stocks should be frequently checked.

Appendix III gives in a tabular form the amount of bleaching powder required to disinfect certain quantities of water. The principle in chlorination is to ensure a "free" residual chlorine of 0.5 mg/litre at the end of one hour contact. Highly polluted and turbid waters are not suited for direct chlorination.

(2) *Chlorine solution* : Chlorine solution may be prepared from bleaching powder. If 4 kg of bleaching powder with 25 per cent available chlorine is mixed with 20 litres of water, it will give a 5 per cent solution of chlorine *(13)*. Ready-made chlorine solutions in different strengths are also available in the market. Like bleaching powder, the chlorine solution is subject to losses on exposure to light or on prolonged storage. The solution should be kept in a dark, cool and dry place in a closed container.

(3) *High test hypochlorite* : High test hypochlorite (HTH) or perchloron is a calcium compound which contains 60 to 70 per cent available chlorine. It is more stable than bleaching powder and deteriorates much less on storage. Solutions prepared from HTH are also used for water disinfection. Appendix III (page 510) shows the amount of HTH needed to disinfect certain quantities of water.

(4) *Chlorine tablets* : under various trade names (viz., halazone tablets) are available in the market. They are quite good for disinfecting small quantities of water, but they are costly. The National Environmental Engineering Research Institute, Nagpur has formulated a new type of chlorine tablet which is 15 times better than ordinary halogen tablets. These tablets are manufactured in various strengths and are now available in plenty in the Indian market at a cheap rate. A single tablet of 0.5 g is sufficient to disinfect 20 litres of water.

(5) *Iodine* : Iodine may be used for emergency disinfection of water. Two drops of 2 per cent ethanol solution of iodine will suffice for one litre of clear water. A contact time of 20 to 30 minutes is needed for effective disinfection. Iodine does not react with ammonia or organic compounds to any great extent; hence it remains in its active molecular form, over a wide range of pH values and water conditions and persists longer than either chlorine or bromine. Iodine is unlikely to become a municipal water supply disinfectant in a broad sense. High costs and the fact that the element is physiologically active (thyroid activity) are its major disadvantages *(17)*.

(6) *Potassium permanganate* : Once widely used it is no longer recommended for water disinfection. Although a powerful oxidizing agent, it is not a satisfactory agent for disinfecting water. It may kill cholera vibrios, but is of little use against other disease organisms*(15)*. It has other draw-backs, too, such as altering the colour, smell and taste of water.

(c) FILTRATION

Water can be purified on a small scale by filtering through ceramic filters such as Pasteur Chamberland filter, Berkefeld filter and "Katadyn" filter. The essential part of a filter is the "candle" which is made of porcelain in the Chamberland type, and of kieselgurh or infusorial earth in the Berkefeld filter (Fig.8). In the Katadyn filter, the surface of the filter is coated with a silver catalyst so that bacteria coming in contact with the surface are killed by the "oligodynamic" action of the silver ions, which are liberated into the water. Filter candles of the fine type usually remove bacteriae found in drinking water, but not the filter-passing viruses. Filter candles are liable to be logged with impurities and bacteriae. They should be cleaned by scrubbing with a hard brush under running water and boiled at least once a week. Only clean water should be used with ceramic filters. Although ceramic filters are effective in purifying water, they are not quite suitable for widespread use under Indian conditions.

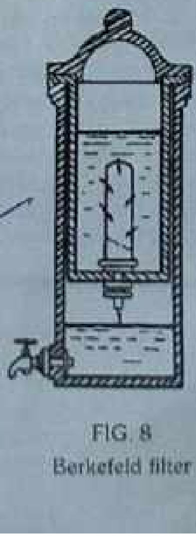

FIG. 8
Berkefeld filter

(2) Disinfection of wells

Wells are the main source of water supply in the rural areas. The need often arises to disinfect them, sometimes on a mass scale, during epidemics of cholera and gastroenteritis. The most effective and cheapest method of disinfecting wells is by bleaching powder. *Potassium permanganate* should not be used, as it is not a satisfactory disinfecting agent.

STEPS IN WELL DISINFECTION

(1) Find the volume of water in a well :

(a) Measure the depth of water column ... (h) metre

(b) Measure the diameter of well .. (d) metre

Take the average of several readings of the above measurements.

(c) Substitute h and d in :

$$\text{Volume (litres)} = \frac{3.14 \times d^2 \times h}{4} \times 1000$$

(d) One cubic metre = 1,000 litres of water

(2) Find the amount of bleaching powder required for disinfection :

Estimate the chlorine demand of the well water by "*Horrock's Apparatus* (vide Annex I) and calculate the amount of bleaching powder required to disinfect the well. Annex III gives the amount of chemicals needed to disinfect water for drinking. Roughly, 2.5 grams of good quality bleaching powder would be required to disinfect 1,000 litres of water. This will give an approximate dose of 0.7 mg of applied chlorine per litre of water.

(3) Dissolve bleaching powder in water

The bleaching powder required for disinfecting the well is placed in a bucket (not more than 100 g in one bucket of water) and made into a thin paste. More water is added till the bucket is nearly three-fourths full. The content are stirred well, and allowed to sediment for 5 to 10 minutes when lime settles down. The supernatant solution which is chlorine solution is transferred to another bucket, and the chalk or lime is discarded. (Note : the lime sediment should not be poured into the well, as it increases the hardness of well water).

(4) Delivery of chlorine solution into the well

The bucket containing the chlorine solution is lowered some distance below the water surface, and the well water is agitated by moving the bucket violently both vertically and laterally. This should be done several times so that the chlorine solution mixes intimately with the water inside the well.

(5) Contact period

A contact period of one hour is allowed before the water is drawn for use.

(6) Orthotolidine arsenite test

It is good practice to test for residual chlorine at the end of one hour contact. If the "free" residual chlorine level is less than 0.5 mg/litre, the chlorination procedure should be repeated before any water is drawn. Wells are best disinfected at night after the day's draw off. During epidemics of cholera, wells should be disinfected every day.

THE DOUBLE POT METHOD *(13, 18)*

During an emergency, it is desirable to ensure a constant dosage of chlorine to well water. Several simple and effective methods have been devised for this purpose, of which the pot method of chlorination is one which has been used with success in various countries. The double pot method is an improvement devised by the National Environmental Engineering R Institute, Nagpur, India. This method uses two cylindrica one placed inside the other. The inside height and diamet 30 cm and 25 cm respectively, for the outer pot. A hole 1 c diameter is made in each pot; in the inner pot the hole is in upper portion, near the rim and in the outer pot it is 4 cm ab the bottom.

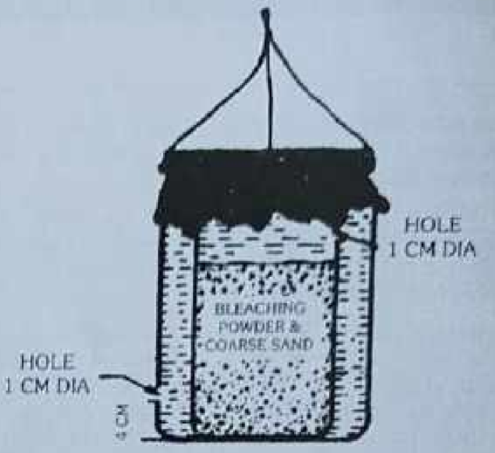

FIG. 9

Double pot

A mixture of 1 kg of bleaching powder and 2 kg of coarse sand (approx. 2 mm in diameter) is prepared and slightly moistened with water. The inner pot is filled with this mixture up to 3 cm below the level of the hole. The inner pot is introduced into the outer one, and the mouth of the latter closed with polyethylene foil. The use of two pots makes it possible to have larger holes without the risk of over chlorination.

The double pot is lowered into the well by means of a rope attached to the well kerb. The pot should be immersed at least 1 m below the water level to prevent damage by the buckets used for drawing water. It has been found that this device works satisfactorily for 2–3 weeks in small household wells containing about 4,500 litres of water and having a draw–off rate of 360–450 litres per day.

WATER QUALITY–CRITERIA AND STANDARDS

The quest for pure water dates back to antiquity. In modern times, it has led to the formulation of specific standards to provide a basis for judging the quality of water. These standards are exposure limits for bacteriological, viral, chemical and physical agents that have been adopted by governments or appropriate authorities and therefore have legal force. The purpose of standards is to minimise all the known health hazards, since it is obviously impossible to prevent all pollution.

The WHO has published in 1993 vol. 1 and in 1996 vol. 2 of second edition of *guideline for drinking water quality* intended for use by countries as a basis for the development of standards, which, if properly implemented, will ensure the safety of drinking water supplies. In order to define standards, it is necessary to consider these recommendations in the context of prevailing environmental, social, economic and cultural conditions. These guidelines are intended to supersede the guidelines for drinking water published in 1984 *(19)*.

The guidelines for drinking water quality recommended by WHO (1993 and 1996) relate to following variables :

I Acceptability aspects
II Microbiological aspects
III Chemical aspects
IV Radiological aspects

I. ACCEPTABILITY ASPECTS

A. Physical parameters

The ordinary consumer judges the water quality by its physical characteristics. The provision of drinking water that is not only safe but also pleasing in appearance, taste and odour is a matter of high priority. The supply of water that is unsatisfactory in this respect will undermine the confidence of consumers, leading to use of water from less safe source. The acceptability of drinking – water can be influenced by many different constituents. These are :

1. *Turbidity* : On aesthetic grounds, drinking water should be free from turbidity. Turbidity in drinking water is caused by particulate matter that may be present as a consequence of inadequate treatment or from resuspension of sediment in the distribution system. It may also be due to the presence of inorganic particulate matter in some ground water. Turbidity interferes with disinfection and microbiological determination. Water with turbidity of less than 5 nephelometric turbidity units (NTU) is usually acceptable to consumer.

2. *Colour* : Drinking water should be free from colour which may be due to the presence of coloured organic matter (primarily humic substances), metals such as iron and manganese, or highly coloured industrial wastes. Consumers may turn to alternative, perhaps unsafe, sources when their water is coloured to an aesthetically displeasing degree. The guideline value is upto 15 true colour units (TCU) although levels of colour above 15 TCU can be detected in a glass of water.

3. *Taste and odour* : Taste and odour originate from natural and biological sources or processes, from contamination by chemicals, or as a by-product of water treatment (e.g., chlorination). Taste and odour may develop during storage and distribution. It is indicative of some form of pollution or malfunction during water treatment or distribution. The cause should be investigated, particularly if there is substantial change. An unusual taste or odour might be an indication of the presence of potentially harmful substances. No health – based guideline value is proposed for taste and odour.

4. *Temperature* : Cool water is generally more palatable. Low water temperature tends to decrease the efficiency of treatment process, including disinfection, and may thus have a deleterious effect on drinking-water quality. However, high water temperature enhances the growth of microorganisms and taste, odour, colour and corrosion problem may increase. No guideline value is recommended since its control is usually impracticable.

To sum up, we cannot judge the quality of drinking water by physical characteristics alone. A detailed chemical and microbiological examination are also needed for complete assessment.

B. Inorganic constituents

1. *Chlorides* : All waters including rain water contain chlorides. In the neighbourhood of the sea, the salinity of water tends to be high. Since the chloride content of water varies from place to place, it is necessary, first of all, to determine the normal range of chlorides of the unpolluted surface and ground water in the given locality. Any excess over the normal range should arouse suspicion of water contamination. The standard prescribed for chloride is 200 mg/litre. The maximum permissible level is 600 mg/litre.

2. *Hardness* : Public acceptability of the degree of hardness may vary considerably from one community to another, depending on local conditions. The taste threshold for the calcium ion is in the range of 100–300 mg/litre, depending on the associated anion, and the taste threshold of magnesium is probably less than that for calcium. In some instances water hardness in excess of 500 mg/litre is tolerated by consumers.

Depending on the interaction of other factors, such as pH and alkalinity, water with a hardness of approximately 200 mg/litre may cause scale deposition in the distribution system and will result in excessive soap consumption and subsequent scum formation. On heating, hard water forms deposits of calcium carbonate scale. Soft water, with a hardness of less than 100 mg/litre, may, on the other hand, have a low buffer capacity and so be more corrosive for water pipes *(19)*.

3. *Ammonia* : The term ammonia includes the non-ionized (NH_3) and ionized (NH_4^+). Ammonia in the environment originates from metabolic, agricultural and industrial processes and from disinfection with chloramine. Natural levels in ground and surface waters are usually below 0.2 mg/litre. Anaerobic ground waters may contain upto 3 mg/litre. Intensive rearing of farm animals can give rise to much higher levels in surface water. Ammonia contamination can also arise from cement mortar pipe linings. Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution. Ammonia can compromise disinfection efficiency, result in nitrite formation in distribution systems, can cause the failure of filters for the removal of manganese, and cause taste and odour problems.

4. *pH* : One of the main objectives in controlling the pH is to minimize corrosion and incrustation in the distribution system. pH levels of less than 7 may cause severe corrosion of metals in the distribution pipes and elevated levels of certain chemical substances, such as lead, may result. At pH levels above 8 there is a progressive decrease in the efficiency of the chlorine disinfection process. An acceptable pH drinking water is between 6.5 and 8.5. In the absence of a distribution system, the acceptable range of pH may be broader.

5. *Hydrogen sulphide* : The taste and odour threshold of hydrogen sulphide in water are estimated to be between 0.05 and 0.1 mg/litre. The "rotten eggs" odour of hydrogen is particularly noticeable in some ground waters and in stagnant drinking water in the distribution system, as a result of oxygen depletion and the subsequent reduction of sulphate by bacterial activity. Sulphide is oxidized rapidly to sulphate in well-aerated water, and hydrogen sulphide level in oxygenated water supplies are normally very low. The presence of hydrogen sulphide in drinking water can be easily detected by the consumer and requires immediate corrective action.

6. *Iron* : Anaerobic ground water may contain ferrous iron at concentrations of upto several mg/litre without discoloration or turbidity in water when directly pumped from the well. On exposure to the atmosphere, however, the ferrous iron oxidizes to ferric iron, giving an objectionable reddish – brown colour to the water. Iron also promotes the growth of "iron bacteria", which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on the pipe. At level above 0.3 mg/litre, iron stains laundry and plumbing fixtures.

7. *Sodium* : The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution. At room temperature, the average taste threshold for sodium is about 200 mg/litre.

8. *Sulphate* : The presence of sulphate in drinking water can cause noticeable taste. Taste impairment varies with the nature of the associated cation. It is generally considered that taste impairment is minimal at levels below 250 mg/litre. It has been found that addition of calcium and magnesium sulphate (but not sodium sulphate) to distilled water improves the taste; optimal taste was recorded at 270 and 90 mg/litre for the two compounds respectively.

9. *Total dissolved solids* : Total dissolved solids (TDS) can have an important effect on the taste of drinking water. The palatability of water with a TDS level of less than 600 mg/litre is generally considered to be good. Drinking water becomes increasingly unpalatable at TDS levels greater than 1200 mg/litre. Water with extremely low concentrations of TDS may be

unacceptable because of its flat, insipid taste. The presence of high level of TDS may also be objectionable to consumers owing to excessive scaling in water pipes, heaters, boilers and household appliances. Water with concentrations of TDS below 1000 mg/litre is usually acceptable to the consumers.

10. *Zinc* : Zinc imparts an undesirable astringent taste to water. Tests indicate a taste threshold concentration of 4 mg/litre (as zinc sulphate). Water containing zinc at concentrations in excess of 5 mg/litre may appear opalescent and develop a greasy film on boiling, although these effects may also be noticeable at concentrations as low as 3 mg/litre. Drinking water seldom contains zinc at concentrations above 0.1 mg/litre, levels in tapwater can be considerably higher because of the zinc used in plumbing material.

11. *Manganese* : Manganese concentrations below 0.1 mg/litre are usually acceptable to consumers, this may vary with local circumstances. At levels above 0.1 mg/litre, manganese in water supplies stains sanitary ware and laundry, and causes an undesirable taste in beverages. It may lead to accumulation of deposits in the distribution system. Even at concentration of 0.02 mg/litre, manganese will often form a coating on pipes, which may slough off as a black precipitate.

12. *Dissolved oxygen* : The dissolved oxygen content of water is influenced by the raw water temperature, composition, treatment and any chemical or biological processes taking place in the distribution system. Depletion of dissolved oxygen in water supplies can encourage microbial reduction of nitrate to nitrite and sulphate to sulphide, giving rise to odour problem. It can also cause an increase in the concentration of ferrous iron in solution. No health-based guideline value has been recommended.

13. *Copper* : The presence of copper in a water supply may interfere with the intended domestic uses of water. It increases the corrosion of galvanized iron and steel fittings. Staining of laundry and sanitary ware occurs at copper concentrations above 1 mg/litre.

14. *Aluminium* : The presence of aluminiu concentrations in excess of 0.2 mg/litre often leads to depo of aluminium hydroxide floc in distribution system and exacerbation of discoloration of water by iron.

Substances and parameters in drinking water and the reaso for consumer complaints are listed in Table 4.

II. MICROBIOLOGICAL ASPECTS

(a) *Bacteriological indicators* : Natural and treated waters vary in microbiological quality. Ideally, drinking water should not contain any microorganisms known to be pathogenic. It should also be free from bacteria indicative of pollution with excreta. Failure to provide adequate protection, effective treatment and disinfection of drinking water will expose the community to the risk of outbreaks of intestinal and other infectious diseases. Those at greatest risk of water-borne diseases are infants and young children, people who are debilitated or living under insanitary conditions, the sick and the elderly. For them the infective dose is significantly lower than for the healthy population. The potential consequences of microbial contamination are such that its control must always be of paramount importance and must never be compromised.

The primary bacterial indicator recommended for this purpose is the coliform group of organisms as a whole. Supplementary indicator organisms, such as faecal streptococci and sulphite-reducing clostridia, may sometimes be useful in determining the origin of faecal pollution as well as in assessing the efficiency of water treatment processes.

(1) *Coliform organisms* : The "coliform" organisms include all aerobic and facultative anaerobic, gram-negative, non-sporing, motile and non-motile rods capable of fermenting lactose at 35 to 37 deg. C in less than 48 hours. The coliform group includes both faecal and non-faecal organisms. Typical example of the faecal group is *E. coli* and of the non-faecal group, *Klebsiella aerogens*. From a practical point of view it is assumed that all coliforms are of faecal origin unless a non-faecal origin can be proved.

TABLE 4

Substances and parameters in drinking-water that may give rise to complaints from consumers

Constituents or characteristics	Levels likely to give rise to consumer complaints	Reasons for consumer complaints
Physical parameters		
Colour	15 TCU	appearance
Taste and odour	-	should be acceptable
Temperature	-	should be acceptable
Turbidity	5 NTU	appearance; for effective terminal disinfection, median turbidity £ NTU, single sample 5 NTU
Inorganic constituents		
Aluminium	0.2 mg/L	depositions, discolouration
Ammonia	1.5 mg/L	odour and taste
Chloride	250 mg/L	taste, corrosion
Copper	1 mg/L	staining of laundry and sanitary ware (health based provisional guideline value 2 mg/L)
Hardness	-	high hardness : scale deposition, scum formation; low hardness; possible corrosion
Hydrogen sulfide	0.05 mg/L	odour and taste
Iron	0.3 mg/L	staining of laundry and sanitary ware
Manganese	0.1 mg/L	staining of laundry and sanitary ware (health-based provisional guideline value 0.5 mg/L)
Dissolved oxygen	-	indirect effects
pH	-	low pH : corrosion; high pH : taste, soapy feel preferably < 8.0 for effective disinfection with chlorine
Sodium	200 mg/L	taste
Sulfate	250 mg/L	taste, corrosion
Total dissolved solids	1000 mg/L	taste
Zinc	3 mg/L	appearance, taste

Source : *(19)*

Ans.

There are several reasons why coliform organisms are chosen as indicators of faecal pollution rather than the water-borne pathogens directly : (1) the coliform organisms are constantly present in great abundance in the human intestine. It is estimated that an average person excretes 200-400 billion of these organisms per day. These organisms are foreign to potable waters, and hence their presence in water is looked upon as evidence of faecal contamination, (2) they are easily detected by culture methods – as small as one bacteria in 100 ml of water, whereas the methods for detecting the pathogenic organisms are complicated and time-consuming, (3) they survive longer than the pathogens, which tend to die out more rapidly than coliform bacilli, (4) the colilform bacilli have greater resistance to the forces of natural purification than the water borne pathogens. If the coliform organisms are present in a water sample, the assumption is the probable presence of intestinal pathogens.

(2) *Faecal streptococci* : Faecal streptococci regularly occur in faeces, but in much smaller numbers than *E. coli*; in doubtful cases, the finding of faecal streptococci in water is regarded as important confirmatory evidence of recent faecal pollution of water. Streptococci are highly resistant to drying and may be valuable for routine control testing after laying new mains or repairs in distribution systems or for detecting pollution by surface run-off to ground or surface waters.

(3) *Cl. perfringens* : They also occur regularly in faeces, though generally in much smaller numbers than *E. coli* : The spores are capable of surviving in water for a longer time than organisms of the coliform group and usually resist chlorination at the doses normally used in waterworks practice. The presence of spores of *Cl. perfringens* in a natural water suggests that faecal contamination has occurred, and their presence, in the absence of the coliform group, suggests that faecal contamination occurred at some remote time. Its presence in filtered supplies may indicate deficiency in filtration practice.

The guideline values for bacteriological quality are give in Table 5. It is only a guide required to ensure bacteriologically safe supplies of drinking water whether piped, unpiped or bottled.

(b) **Virological aspects** : It is recommended that, to be acceptable, drinking-water should be free from any viruses infections for man. Disinfection with 0.5 mg/L of free chlorine residual after contact period of at least 30 minutes at a pH of 8.0 is sufficient to inactivate virus. This free chlorine residual is to be insisted in all disinfected supplies in areas suspected of endemicity of hepatitis A to take care of the safety of the supply from the virus point of view which incidently takes care of safety from the bacteriologic point of view as well. For other areas 0.2 mg/L of free residual chlorine for half an hour should be insisted. The turbidity condition of 1 NTU or less, must be fulfilled prior to disinfection of water if adequate treatment is to be achieved. Ozone has been shown to be effective viral disinfectant, preferably for clean water, if residuals of 0.2-0.4 mg/L are maintained for 4 minutes, but it is not possible to maintain a ozone residual in distribution system.

(c) **Biological aspects** : (i) *Protozoa* - Species of protozoa known to have been transmitted by the ingestion of contaminated drinking-water include *Entamoeba histolytica, Giardia spp.* and *rarely*, Balantidium coli. These organisms can be introduced in to water supply through human or, in some instances, animal faecal contamination. Drinking-water should not contain any pathogenic intestinal protozoa. Rapid or slow sand filtration have been shown to be effective in removing a high proportion of pathogenic protozoa. Standard methods are not currently available for the detection of pathogenic protozoa in water supplies in the context of a routine monitoring programme; (ii) *Helminths* : The infective stages of many parasitic roundworms and flatworms can be transmitted to man through drinking-water. A single mature larva or fertilized egg can cause infection and such infective stages should be absent from drinking-water. However, the water route is relatively unimportant except in the case of *Dracunculus medinensis* (guineaworm) and the human schistosomes, which are primarily hazards of unpiped water supplies. Source protection is the best approach to prevention. The methods for detection of these parasites are unsuited for routine monitoring; (iii) *Free-living organisms* : Free living organisms that may occur in water supplies include fungi, algale etc. The most common problem with these are their interference in the operation of water-treatment process, colour, turbidity, taste and odour of finished water.

III. CHEMICAL ASPECTS

The health risk due to toxic chemicals in drinking water differs from that caused by micro-biological contaminants. There are few chemical constituents of water that can lead to acute health problems except through massive accidental contamination of a supply. Moreover, experience shows that, in such incidents the water usually becomes undrinkable owing to unacceptable taste, odour and appearance.

The chemicals selected for the development of guideline value include those considered potentially hazardous to human

TABLE 5

Bacteriological quality of drinking-water[a]

Organisms	Guideline value
All water intended for drinking	
E.coli or thermotolerant coliform bacteria[b,c]	Must not be detectable in any 100 ml sample
Treated water entering the distribution system	
E.coli or thermotolerant coliform bacteria[b]	Must not be detectable in any 100 ml sample
Total coliform bacteria	Must not be detectable in any 100 ml sample
Treated water entering the distribution system	
E.coli or thermotolerant coliform bacteria[b]	Must not be detectable in any 100 ml sample
Total coliform bacteria	Must not be detectable in any 100-ml sample. In the case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12-month period.

a. Immediate investigative action must be taken if either *E.coli* or total coliform bacteria are detected. The minimum action in the case of total coliform bacteria is repeat sampling; if these bacteria are detected in the repeat sample, the cause must be determined by immediate further investigation.

b. Although *E.coli* is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory tests must be carried out. Total coliform bacteria are not acceptable indicators of the sanitary quality of rural water supplies, particularly in tropical areas where many bacteria of no sanitary significance occur in almost all untreated supplies.

c. It is recognized that, in the great majority of rural water supplies in developing countries, faecal contamination is widespread. Under these conditions, the national surveillance agency should set medium-term targets for progressive improvement of water supplies.

health, those detected relatively frequently in drinking water and those detected in relatively high concentrations. The problem associated with chemical constituents of drinking water arise primarily from their ability to cause adverse health effects after prolonged periods of exposure; of particular concern are contaminants that have cumulative toxic properties, such as heavy metals and substances that are carcinogenic.

Health – related chemical constituents

The presence of certain chemicals in excess of prescribed limits may constitute ground for rejection of the water as a source of public water supply. These substances may be inorganic or organic *(9)*.

a. Inorganic Constituents : These substances include arsenic, cadmium, chromium, cyanide, fluoride, lead, mercury, nickel, nitrate, selenium etc. The guide line value of these constituents are shown in Table 6.

1. *Arsenic :* Arsenic is introduced into water through the dissolution of minerals and ores, from industrial effluents, and from atmospheric deposition; concentrations in ground water in some areas are sometimes elevated as a result of erosion from natural sources. The average daily intake of inorganic arsenic in water is estimated to be similar to that from food. Intake from air is negligible. A provisional guideline value for arsenic in drinking water of 0.01 mg/litre is established.

2. *Cadmium :* Cadmium metal is used in the steel industry and in plastics. Cadmium compounds are widely used in batteries. It is released to the environment in waste-water and diffuse pollution is caused by contamination from fertilizers and local air pollution. Contamination in drinking water may also be caused by impurities in the zinc of galvanized pipes and some metal fittings, although levels in drinking water are usually less than 1 μg/litre. Absorption of cadmium compound is dependent on the solubility of the compound. Cadmium accumulates primarily in the kidneys and has a long biological half-life in humans of 10–35 years. A guideline value for cadmium is established at 0.003 μg/litre *(19)*.

3. *Chromium :* Chromium is widely distributed in the earth's crust. In general, food appears to be the major source of intake. The absorption of chromium after oral exposure is relatively low and depends on the oxidation state. The guideline value for chromium is 0.05 mg/litre, which is considered to be unlikely to give rise to significant health risks.

4. *Cyanide :* The acute toxicity of cyanide is high. Cyanides can be found in some foods, particularly in some developing countries, and they are usually found in drinking water, primarily as a consequence of industrial contamination. Effects on thyroid and particularly the nervous system were observed in some populations as a consequence of the long-term consumption of inadequately processed cassava containing high levels of cyanide. The guideline value of 0.07 mg/litre is considered to be safe.

5. *Fluoride :* Fluoride accounts for about 0.3 g/kg of the earth's crust. Inorganic fluorine compounds are used in the production of aluminium, and fluoride is released during the manufacture and use of phosphate fertilizers which contain upto 4 per cent fluorine. Levels of daily exposure of fluoride depends on the geographical area. If diets contain fish and tea, exposure via food may be particularly high. In specific areas, other foods and indoor air pollution may contribute considerably to total exposure. Additional intake may result from the use of fluoride toothpastes.

Exposure to fluoride from drinking water depends greatly on natural circumstances. Levels in raw water are normally below 1.5 mg/litre, but ground water may contain about 10 mg/litre in areas rich in fluoride – containing minerals. High fluoride levels, above 5 mg/litre, have been found in several countries (e.g., China, India and Thailand). Such high levels have at times led to dental or skeletal fluorosis. Fluoride is sometimes added to drinking water to prevent dental caries. Soluble fluorides are readily absorbed in the gastrointestinal tract after intake in drinking water. The guideline value suggested is 1.5 mg/litre. In setting national standards for fluoride, it is particularly important to consider climatic conditions, volume of water intake and intake of fluoride from other sources (e.g., food and air).

6. *Lead :* Lead is present in tapwater to some extent as a result of its dissolution from natural sources, but primarily from household plumbing systems containing lead in pipes, solder, fittings or the service connections to homes. The amount of lead dissolved from the plumbing system depends on several factors, including pH, temperature, water hardness and standing time of the water, with soft, acidic water being the most plumbosolvent.

Placental transfer of lead occurs in humans as early as twelfth week of gestation and continues throughout development. Young children absorb 4–5 times as much lead as adults, and the biological half-life may be considerably longer in children than in adults. Lead is a general toxicant that accumulates in the skeleton. Infants, children up to six years of age, and pregnant women are most susceptible to its adverse health effects. Lead also interferes with calcium metabolism, both directly and by interfering with vitamin D metabolism. Lead is toxic to both central and peripheral nervous system, inducing subencephalopathic neurological and behavioural effects. Renal tumours have been induced in experimental animals exposed to high concentrations of lead compounds in the diet and it is grouped in Group B (possible human carcinogen). The health-based guideline value of lead is 0.01 mg/litre.

Lead is exceptional in that most lead in drinking water arises from plumbing in buildings and the remedy consists principally of removing plumbing and fittings containing lead. This requires much time and money, and it is recognized that not all water will meet the guideline immediately. Measures to control corrosion should also be implemented.

7. *Mercury :* Mercury is present in inorganic form in surface and ground water at concentrations usually less than 0.5 μg/litre. The kidney is the main target organ for inorganic mercury, whereas methylmercury affects mainly the central nervous system. The guideline value for total mercury is 0.001 mg/litre.

8. *Nitrate and nitrite :* Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. Naturally occurring nitrate level in surface and ground water are generally a few milligrams per litre. In many ground waters, an increase of nitrate level has been observed owing to the intensification of farming practice. In some countries, up to 10 per cent of the population may be exposed to nitrate levels in drinking water of above 50 mg/litre.

In general, vegetables are the main source of nitrate intake when levels in drinking water is below 10 mg/litre. When nitrate level in drinking water exceeds 50 mg/litre, drinking water will become the main source of total nitrate intake. The guideline value for nitrate in drinking water is solely to prevent methamoglobinaemia, which depends upon the conversion of nitrate into nitrite. Bottle-fed infants of less than 3 months of age are most susceptible.

The guideline value should not be expressed on the basis of nitrate-nitrogen but on the basis of nitrate itself, which is the chemical entity of concern to health and the guideline value for nitrate is 50 mg/litre.

As a result of recent evidence of the presence of nitrite in some water supplies, it was concluded that a guideline value of 3 mg/litre for nitrite should be proposed. Because of the possibility of simultaneous occurrence of nitrite and nitrate in drinking water, the sum of the ratios of the concentration of each to its guideline value should not exceed 1, i.e.

$$\frac{\text{Concentration of nitrate}}{\text{guideline value of nitrate}} + \frac{\text{Concentration of nitrite}}{\text{guideline value of nitrite}} = \le 1$$

9. *Selenium* : Selenium levels in drinking water vary greatly in different geographical areas, and are usually much less than the guideline value of 0.01 mg/litre. Food stuffs are the principal source, and the level depends according to geographical area of production. Selenium is an essential element for humans and forms an integral part of the enzyme glutathione peroxidase. Most selenium compounds are water soluble. In humans, the toxicity of long-term exposure are manifested in nails, hair and liver.

TABLE 6

Inorganic chemicals of health significance in drinking water

Constituents	Recommended maximum limit of concentration (mg/litre)
Antimony	0.005 (P)
Arsenic	0.01 (P)
Barium	0.7
Boron	0.3
Cadmium	0.003
Chromium	0.05 (P)
Copper	2 (P)
Cyanide	0.07
Fluoride	1.5
Lead	0.01
Manganese	0.5 (P)
Mercury (total)	0.001
Molybdenum	0.07
Nickel	0.02
Nitrate (as NO_3)	50
Nitrite (as NO_2)	3 (P)
Selenium	0.01

P - Provisional guideline value

Source : *(19)*

b. Organic Constituents : The guideline value of some of the organic chemical constituents in water is as shown in Table 7.

TABLE 7

Guideline values for health related organic constituents

Organic constituents	Upper limit of concentration (µg/litre)
Chlorinated alkanes	
Carbon tetrachloride	2
Dichloromethane	20
Chlorinated ethenes	
Vinyl chloride	55
1,1 - dichloroethene	30
1,2 - dichloroethene	50
Aromatic hydrocarbons	
Benzene	10
Toluene	700
Xylenes	500
Ethylbenzene	300
Styrene	20
Benzolalpyrene	0.7

Source : *(19)*

Polynuclear aromatic hydrocarbons : A large number of polynuclear aromatic hydrocarbons (PAHs) from a variety of combustion and pyrolysis sources have been identified in the environment. The main source of human exposure to PAHs is food, with drinking water contributing only minor amounts.

Little information is available on the oral toxicity of PAHs, especially after long-term exposure. Benzo (a) pyrene, which constitutes a minor fraction of total PAHs have been found to be carcinogenic in mice by the oral route of administration. Some PAH compounds have been found to be carcinogenic by non-oral routes. Benzo (a) pyrene has been found to be mutagenic in a number of in *vitro* and in *vivo* assays.

The following recommendations are made for the PAH group :

- Because of the close association of PAH with suspended solids, the application of treatment, when necessary to achieve the recommended level of turbidity will ensure that PAH levels are reduced to a minimum.
- Contamination of water with PAH should not occur during water treatment or distribution. Therefore, the use of coal-tar-based and similar materials for pipe lining and coatings on storage tanks should be discontinued.
- In situation where contamination of drinking water by PAH has occurred, the specific compounds present and the source of the contamination should be identified, as the carcinogenic potential of PAH compounds varies.

Pesticides : The pesticides that are of importance in connection with water quality include chlorinated hydrocarbons and their derivatives, persistent herbicides, soil insecticides, pesticides that are easily leached out from the soil, and pesticides that are systematically added to water supplies for disease vector control. The recommended guideline value (Table 8) are set at a level to protect human health.

TABLE 8

Guideline values of certain pesticides

Pesticides	Upper limit of concentration (µg/litre)
Aldrin/dieldrin	0.03
Chlordane	0.2
DDT	2
2,4-D	30
Heptachlor and heptachlor epoxide	0.03
Hexachlorobenzene	1
Lindane	2
Methoxychlor	20
pentachlorophenol	9 (P)

P - Provisional value

Source : *(19)*

Drinking water consumption and body weight : The average *daily per capita* consumption of drinking water is usually found to be around 2 litres, but there are considerable variations between individuals as water intake is likely to vary with climate, physical activity and culture, e.g., at temperature above 25°C, there is a sharp rise in fluid intake, largely to meet the demands of an increased sweat rate. In developing the guideline values for potentially hazardous chemicals, a daily *per capita* consumption of 2 litres by a person weighing 60 kg was generally assumed. However, such an assumption may underestimate the consumption of water per unit weight, and this exposure, for those living in hot climates as well as for infants and children, who consume more fluid per unit weight than adults. Where it was judged that this segment of the population was at a particularly high risk from exposure to certain chemicals, the guideline value was derived on the basis of a 10 kg child consuming 1 litre water per day or a 5 kg infant consuming 0.75 litre water per day.

Health risk assessment : For most kinds of toxicity, it is generally believed that there is a dose below which no adverse effects will occur. For chemicals that give rise to such toxic effects, a tolerable daily intake (TDI) can be derived.

Tolerable daily intake (TDI) : The TDI is an estimate of the amount of a substance in food or drinking water, expressed on a body weight basis (mg/kg or µg/kg of body weight), that can be ingested daily over a lifetime without appreciable health risk *(19)*.

Acceptable daily intake (ADI) are established for food additives and pesticide residues that occur in food for necessary technological purposes or plant protection reasons. For chemical contaminants, which usually have no intended function in drinking water the term TDI is seen as more appropriate than ADI, as it signifies permissibility rather than acceptability.

No - observed - adverse - effect level (NOAEL) : The NOAEL is defined as the highest dose or concentration of a chemical in a single study, found by experiment or observation, that causes no detectable adverse health effect *(19)*. Whenever possible, the NOAEL is based on long-term studies, preferably of ingestion in drinking water.

Lowest - observed - adverse effect level (LOAEL) : LOAEL is the lowest observed dose or concentration of a substance at which there is a detectable adverse health effect *(19)*. When LOAEL is used instead of NOAEL, an additional uncertainty factor (UF) is normally used.

Uncertainty factors (UF) : The application of uncertainty factors has been widely used in the derivation of ADI for food additives, pesticides and environmental contaminants. The derivation of these factors requires expert judgement and a careful sifting of the available scientific evidence.

In the derivation of the WHO drinking water quality guideline values, uncertainty factors were applied to the lowest NOAEL or LOAEL for the response considered to be most biologically significant and were determined by consensus among a group of experts using the approach outlined below :

Source of uncertainty	Factor
Interspecies variation (animal to humans)	1 - 10
Interspecies variation (individual variation)	1 - 10
Adequacy of studies or database	1 - 10
Nature and severity of effect	1 - 10

The total uncertainty factor should not exceed 10,000. If the risk assessment would lead to a higher uncertainty factor, then the resulting TDI would be so imprecise as to lack meaning. For substances for which uncertainty factors were greater than 1000, guideline values are designated as provisional in order to emphasize the high level of uncertainty inherent in these values *(19)*.

Derivation of guideline value using a TDI approach : TDI can be calculated by following formula..

$$TDI = \frac{NOAEL\ OR\ LOAEL}{UF}$$

The guideline value (GV) is then derived from the TDI as follows :

$$GV = \frac{TDI \times bw \times P}{C}$$

Where bw = body weight (60 kg for adult, 10 kg for children, 5 kg for infants)

P = fraction of the TDI allocated to drinking water

C = daily drinking water consumption (2 litres for adults, 1 litre for children and 0.75 litre for infants)

IV. RADIOLOGICAL ASPECTS

The effects of radiation exposure are called "somatic" if they become manifest in the exposed individual, and "hereditary" if they affect the descendants. Malignant disease is the most important delayed somatic effect *(30)*. For some somatic effects such as carcinogenesis, the probability of an effect occurring, rather than its severity, is regarded as a function of dose without a threshold (stochastic effect). Whereas for other somatic effects the severity of the effect varies with the dose (non-stochastic effects); a threshold may therefore exist for such effects. The aim of radiation protection is to prevent harmful non-stochastic effects and to reduce the probability of stochastic effects to a level deemed acceptable.

Radioactivity in drinking water should not only be kept within safe limits; it should also, within those limits, be kept as low as is reasonably possible. The guideline values recommended take account of both naturally occurring radioactivity and any radioactivity that may reach the water source as a result of man's activities. From a radiological point of view, they represent a value below which water can be considered potable without any further radiological examination.

The activity of a radioactive material is the number of nuclear disintegration per unit of time. The unit of activity is a becquerel (Bq); 1 Bq = 1 disintegration per second. Formerly, the unit of activity was curie (Ci).

The proposed guideline values are :
gross alpha activity 0.1 Bq / L
gross beta activity 1.0 Bq / L

SURVEILLANCE OF DRINKING WATER QUALITY *(20)*

The activities that ideally should be included in the surveillance function are :

a. approval of new sources (including private-owned supplies);
b. watershed protection;
c. approval of the construction and operating procedures of waterworks, including :
    (i) disinfection of the plant and of the distribution system after repair or interruption of supply,
    (ii) periodic flushing programmes and cleaning of water storage facilities,
    (iii) certification of operators,
    (iv) regulation of chemical substances used in water treatment,
    (v) cross-connection control, back-flow prevention and leak detection control ;
d. sanitary surveys;
e. monitoring programmes, including provision for central and regional analytical laboratory services;
f. development of codes of practice for well construction, pump installation and plumbing;
g. inspection quality control in bottled-water and ice manufacturing operations.

Surveillance of drinking water is essentially a health measure. It is intended to protect the public from water-borne diseases. The elements of a surveillance programme are :

1. Sanitary survey

Sanitary survey is an on-the-spot inspection and evaluation by a qualified person of the entire water supply system. The purpose of the survey is detection and correction of faults and bacterial purity of water. A single count is of little value, but counts from the same source at frequent intervals may be of considerable value. A sudden increase in the colony count may give the earliest indication of contamination. The recommended plate counts are:

Water at the point of consumption	Plate count after 2 days at 37 deg C	Plate count after 3 days at 22 deg C
(i) Disinfected	0	20
(ii) Not-disinfected	10	100

Recent studies indicate that a bacterial plate count on yeast extract agar after incubation at 22 deg C for 7 days might serve as the best general purpose indicator of microbiological quality because in the absence of chlorine residual, the number of bacteria growing at 22 deg C after 7 days incubation can increase enormously *(22)*.

4. Biological examination

Water may contain microscopic organisms such as algae, fungi, yeast, protozoa, rotifers, crustaceans, minute worms, etc. These organisms are collectively called 'plankton'. The plankton organisms produce objectionable tastes and odours in water. They are an index of pollution. The degree of pollution is assessed qualitatively and quantitatively by noting the type and number of organisms prevailing in water.

5. Chemical surveillance

Chemical surveillance of drinking water is assuming greater importance in view of industrial and agricultural pollutants finding their way into raw water sources. Tests for pH, colour, turbidity, chlorides, ammonia, chlorine demand and residual chlorine are the basic tests. Regular measurement of chlorine residuals in supply may in part replace bacteriological surveillance. Tests for iron and manganese are required when these substances are present in the raw water in sufficient amount to influence water treatment. Complete chemical analysis would also include analysis for toxic metals, pesticides, persistent organic chemicals and radioactivity.

HARDNESS OF WATER

Hardness may be defined as the soap destroying power of water. The consumer considers water hard if large amounts of soap are required to produce lather. The hardness in water is caused mainly by four dissolved compounds. These are (1) Calcium bicarbonate (2) Magnesium bicarbonate (3) Calcium sulphate, and (4) Magnesium sulphate. The presence of any one of these compounds produces hardness. There are others which are of less importance. Chlorides and nitrates of calcium and magnesium can also cause hardness but they occur generally in small amounts. Iron, manganese and aluminium compounds also cause hardness, but as they generally are present in such small amounts, it is customary not to consider them in connection with hardness.

Hardness is classified as carbonate and non-carbonate. The carbonate hardness which was formerly designated as "temporary" hardness is due to the presence of calcium and magnesium bicarbonates. The non-carbonate hardness, formerly designated as "permanent" hardness, is due to calcium and magnesium sulphates, chlorides and nitrates.

Hardness in water is expressed in terms of "milli-equivalents per litre (mEq/L)". One mEq/L of hardness-producing ion is equal to 50 mg $CaCO_3$ (50ppm) in one litre of water *(23)*. The terms soft and hard water are used when the levels of hardness are as given in Table 9.

TABLE 9
Classification of hardness in water

Classification	Level of hardness (mEq./litre)
(a) Soft water	Less than 1 (<50 mg/L)
(b) Moderately hard	1–3 (50–150 mg/L)
(c) Hard water	3–6 (150–300 mg/L)
(d) Very hard water	over 6 (> 300 mg/L)

Drinking water should be moderately hard. Softening of water is recommended when the hardness exceeds 3 mEq/l (150 mg per litre).

DISADVANTAGES OF HARDNESS

Hardness in water presents several disadvantages both to the domestic and industrial consumer. These may be stated as follows: (1) hardness in water consumes more soap and detergents (2) when hard water is heated, the carbonates are precipitated and bring about furring or scaling of boilers. This leads to great fuel consumption, loss of efficiency and may sometimes cause boiler explosions (3) hard water adversely affects cooking; food cooked in soft water retains its natural colour and appearance (4) fabrics washed with soap in hard water do not have a long life (5) there are many industrial processes in which hard water is unsuited and gives rise to economic losses (6) hardness shortens the life of pipes and fixtures.

SPECIAL TREATMENT

(a) Removal of hardness

The methods of removal of hardness are briefly stated as below:

Temporary hardness
- (a) Boiling
- (b) Addition of lime
- (c) Addition of sodium carbonate
- (d) Permutit process.

Permanent hardness
- (a) Addition of sodium carbonate
- (b) Base exchange process.

1. BOILING

Boiling removes the temporary hardness by expelling carbon dioxide, and precipitating the insoluble calcium carbonate. It is an expensive method to soften water on a large scale.

$$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$$

2. ADDITION OF LIME

Lime softening not only reduces total hardness but also accomplishes magnesium reduction. Lime absorbs the carbon dioxide, and precipitates the insoluble calcium carbonate. In the Clark's method of softening water, one ounce of quick lime is added to every 700 gallons of water for each degree (14.25 ppm.) of hardness.

$$Ca(OH)_2 + Ca(HCO_3)_2 \rightarrow 2CaCO_3 + 2H_2O$$

3. ADDITION OF SODIUM CARBONATE

Sodium carbonate (soda ash) removes both temporary and permanent hardness, as shown below :

(i) $Na_2CO_3 + Ca(HCO_3)_2 \rightarrow 2NaHCO_3 + CaCO_3$
(ii) $CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$

4. BASE EXCHANGE PROCESS

In the treatment of large water supplies, the permutit process is used. Sodium permutit is a complex compound of sodium, aluminium and silica ($Na_2 Al_2 Si_2O H_2O$). It has the property of exchanging the sodium cation for the calcium and magnesium ions in the water. When hard water is passed through the permutit the calcium and magnesium ions are entirely removed by base exchange and the sodium permutit is finally converted into calcium and magnesium permutit. By this process, water can be softened to zero hardness. Since water of zero hardness is corrosive, a part of the raw water is mixed with the softened water to secure the desired hardness. After permutit has been used for sometime, it loses its effectiveness but it may be regenerated by treating with concentrated solution of sodium chloride or brine and washing away the soluble calcium and magnesium chloride formed. Permutit process removes both temporary and permanent hardness.

Water hardness and cardiovascular diseases

Reports from several countries have shown an inverse statistical association between the hardness of drinking water and the death rate from cardiovascular diseases. Areas supplied with soft drinking water showed a significantly higher prevalence of either arteriosclerotic heart disease, or degenerative heart disease, hypertension, sudden deaths of cardiovascular origin, or a combination of these. The evidence is based solely on circumstantial evidence and statistical association. Further studies are in progress to establish a possible connection between certain water characteristics and the development of cardiovascular diseases *(24)*.

(b) Fluoridation of water

Fluorine is one of the constituents naturally present in water supplies. In fact, the main source of fluorine is drinking water. Deficiency of fluorine in drinking water is associated with dental caries, and excess with dental and skeletal fluorosis. Leading workers in India regard fluorine in concentration of 0.5 to 0.8 ppm in drinking water as optimum (a concentration of 1 ppm is regarded as optimum in temperate climates because the consumption of water is low). The term "fluoridation" has been given to the process of supplementing the natural fluoride content of potable waters to the point of optimum concentration. The WHO in 1969 recommended fluoridation of community water supplies in areas where the total intake of fluorides by the population is below the optimal levels for protection against dental caries. Fluoridation is now an accepted public health procedure in many developed countries *(25)*.

(c) Defluoridation

In some geographic areas, water may contain a high level of fluorides. In such communities, water is defluoridated by phosphate to reduce fluorides to optimum levels.

SELECTION OF SOURCE OF WATER

In selecting a source, attention must be given to possible future developments that may influence the continued suitability of the source. Other considerations include (a) *Quantity (source capacity)* : The quantity of water should be sufficient to meet continuing water demands, taking into account daily and seasonal variations and projected growth in the size of the community being served. (b) *Quality* : The quality of raw water should be such that, with appropriate treatment, it meets the drinking water standards. (c) *Protection* : The watershed must be protected from pollution with human excreta, industrial discharge and agricultural run-off. (d) *Feasibility* : The source should be available at reasonable cost. (e) *Treatability* : The raw water should be treated adequately under locally prevailing conditions.