normally used for aeration, the most common are some special nozzles which direct thin jets of water into metallic plates to produce fine sprays exposing water to the atmosphere; cascade-type aerators which create turbulence in thin streams of water flowing down; tray-type aerators consisting of some five perforated trays, increasing in size from top to bottom, where water (falling from tray to tray) is exposed to air; and diffused air aerators, which are tanks where air is bubbled upwards from diffuser pipes laid on their floor. The latter method is the most efficient, the amount of air needed may be regulated, the tanks are normally about 4 metres deep and have a retention time of about 15 minutes. Among all the methods, however, trays are the most commonly used because of their low cost, simple operation and reasonably high efficiency

13. *Algal control* is necessary to eliminate outbreaks of these organisms which are usually classified as plants and which proliferate in rivers and reservoirs. These outbreaks tend to be sporadic or seasonal but normally severe and can cause trouble to waterworks' operators. Fairly alkaline waters, with an appreciable concentration of nitrates or phosphates, are likely to develop important algal colonies. Although heavy pollution may impede the growth of algae, water treatment, by itself, may encourage it (once pollution has been eliminated). Chlorine doses of up to 1 mg /l may kill the algae (See 8.21-24). Algal growth is inhibited by Copper sulphate in concentrations of 0.3 mg /l; these doses are, however, toxic to some fish species and may therefore not be acceptable in some circumstances. Strainers are widely used to remove algae, some of them functioning as rapid sand filters (See 8.18) which, if their filtration medium is coarse, are known as "roughing filters" (See 8.14). Other devices, called "microstrainers", which are mainly of proprietary make, are excellent, provided that the water is relatively free of silt

14. Where sediment loads in raw water can reach concentrations of more than 1000 mg./l, it is helpful to put in small, non-chemically assisted, horizontal flow basins immediately upstream of other treatment works, such as normal sedimentation basins, to increase the effectiveness of the treatment process, minimize plant maintenance and save on the use of chemicals. These facilities are called "*pre-settlement* basins". Alternatively, *horizontal roughing filters* may be used to improve the quality of raw water that will undergo further treatment through slow sand filtration devices; they are rectangular boxes similar to the basins used in plain sedimentation (See 8.16), their raw water inlet is situated on one side of the box, their outlet at the opposite side (Figure 29). In the main direction of flow, water passes through various layers of graded coarse material (in the sequence coarse-fine-coarse). Vertical depths of filtration are in the range of 0 8 to 1.5 m.; suitable filtration rates are in the range of 0.4 to 1.0 m/h); the total length of the filter would vary between 4 and 10 metres. Pre settlement basins and horizontal roughing filters are sometimes built as a remedy, where changing raw water characteristics have put in jeopardy existing waterworks facilities (a common occurrence in developing countries).

Coagulation, Mixing and Flocculation

15. The main chemical means of dealing with the improvement of surface waters is *coagulation.* Chemical coagulation removes turbidity-producing colloids such as clay particles, bacteria and other organic matter and colourants resulting from the decaying vegetation, animal or industrial wastes. It is directly followed by *flocculation,* a process whereby the products of coagulation are made to agglomerate and form "flocs" of sufficient size and specific weight to allow removal by sedimentation or filtration. As the use of chemicals should be avoided as much as possible, coagulation should be used only when strictly necessary. The most widely used coagulant is Aluminium sulphate, commonly known as alum; Iron salts (such as ferric chloride) can be used, despite their higher cost, when broader pH ranges for coagulation are required. (N.B. pH values for alum's effectiveness range from 5 to 8, while those for the Iron salts range from 4 to 9). These coagulants react with the alkalinity of the water and hydrolyze in it, if the required alkalinity is not present in the raw water it should be added through dosage of lime or Sodium carbonate. The optimum dosing, pH, concentration of coagulant and the most effective order in which to add the various chemicals will be determined with a jar-test which should be carried out by qualified technicians and requires the collection of water samples and the use of specialized laboratory equipment (See 12.8). During emergency situations, before jar-tests are done and if there is a need to lower the turbidity of raw water, dosing alum at 50 mg./l is recommended. Dosing is usually done in the form of solutions prepared in special tanks with a holding capacity of 10 or more hours of coagulant feeding requirements; two tanks are required as a minimum (one in operation, the

other for the preparation of new solution) To accomplish flocculation, mixing is necessary and may be accomplished hydraulically, in turbulent flow conditions at specially made structures such as weirs or "flocculation chambers", or at the suction side of the pump; it can also be accomplished mechanically (manually or with paddles, rakes, turbines, propellers, etc) Normally, water should be retained in flocculation tanks for at least 30 minutes to ensure maximum flocculation. Coagulation and flocculation processes should be done (only if required) before sedimentation, filtration and disinfection. The sedimentation basin should be designed in such a way that the last flocs settle before the filtration units.

Sedimentation

16. The process to eliminate all impurities present as suspended particles which are carried along by flowing raw waters but which will settle in quiescent or semi-quiescent conditions is called *sedimentation*. It is usually considered the *minimum* treatment for turbid surface waters; if 24 hours can be allotted for sedimentation, clarified waters can be directly chlorinated The sun's bactericidal effect has also been documented Below a certain particle size, depending on the material concerned, settling velocity becomes very small and therefore sedimentation becomes unfeasible. This is the case for colloidal matter, which, as it has been discussed, requires coagulation and flocculation before the sedimentation process. Sedimentation facilities normally operate under continuous flow to:

- i) achieve quiescent conditions in the settling zone,
- ii) ensure uniform flow across the settling zone;
- iii) obtain uniform concentration of solids as flow enters the settling zone;
- iv) ensure that solids entering the sludge zone are not re-suspended.

The efficiency of these structures basically depends on the ratio between the influent flow rate and the surface area of the tank; their design should be based on the settling velocities of the particles to be removed, a factor that should be assessed by qualified technicians and requires the collection of water samples and specialized laboratory equipment (See 12.8) The main tanks found in practice are shown in Figure 30 Horizontal tanks are compact; sludge is removed from them under hydrostatic head. Circular tanks offer the advantage of simpler scraping mechanisms but are not so compact. The vertical flow tanks, like the one shown in the figure, operate with a sludge blanket which serves to strain out particles smaller than those that could be removed by sedimentation alone at the flow rates employed

Filtration

17. Filtration of suspensions through porous media, usually sand, is an important stage in the treatment of potable water to achieve final clarification. It follows the settlement process and, to a certain extent, could be considered complementary: the more effective the settlement, the less the filters have to do. It is the final stage in water clarification and unless clear groundwater is used, it should be regarded as essential. The process consists of passing the water through a bed of sand or any other suitable porous medium. The sand retains suspended matter while permitting the water to pass, if the process is effective, the filtrate should be clear and sparkling in appearance. There are limits to the capacity of filters to achieve this final degree of clarity; pre-treatment and sedimentation processes are used to improve the water quality to levels more easily handled by filters.

18. One of the most commonly found filters is the *rapid gravity sand filter*, it can handle low turbidity waters and for this reason is normally operated with coagulants and often follows settling basins. The *Rapid pressure filter* has many characteristics similar to those of the gravity type, but is enclosed in steel pressure vessels and is used where hydraulic conditions in the system make its adoption desirable; it equally depends on coagulants for its action, although it does not always follow settling basins. A refinement of the rapid gravity filters may be called the *mixed media filter* where media of different densities are used; as a result a very coarse upper layer of light weight material (pumice, anthracite) provides void space to store impurities removed from incoming water. The rapid filter requires, in general, a raw water input of fairly good quality and is therefore limited in its application to only very

particular situations, which normally do not include emergency response.

19. The *slow sand filter* is a simple filtration device which is increasingly being used in refugee camps and rural areas in view of its simple operation and maintenance requirements (See Figure 31). Its construction, also very simple, may be carried out using widely available materials; a medium coarse sand, similar to the one use for concrete mixtures, is often a good enough filtration medium. Filters may also be obtained in prefabricated versions ("filtration package kits") which have proven their value in many emergency refugee camps during the last decade. During the slow sand filtration process the water quality improves considerably not only in its physical characteristics but also due to the reduction of the number of micro-organisms (bacteria, viruses, cysts), the removal of colloidal matter and changes in its chemical characteristics. Bacteriological changes are due to the development of a thin and active layer of algae, plankton, bacteria and other forms of life on the surface of the sand bed called the *schmutzdecke,* where these micro-organisms break down organic matter. While rapid sand filters require cleaning by rather complicated backwashing operations, slow sand filters are cleaned by the relatively simple periodical removal of the top of the filter bed, including the schmutzdecke. The design of a slow sand filter is a complex engineering problem that should be left to specialists. Its capacity should be such that no serious water shortages occur at the camp at any time; the quality of the supplied water should under no circumstances deteriorate below safety limits (See 3.13; 8.7) and provisions should be made therefore to deal with possible future deterioration of the raw water quality (See 8.14), breakdowns of critical elements in the system and malfunctioning due to operational failure or unfavourable conditions (low temperatures do not allow slow sand filters to operate effectively) (See 11.9). The dimensions of the filter should be decided upon after its mode of operation and output have been established to achieve a filtration rate of about 0.1 m/h, bearing in mind that it is desirable that the filters are operated for part of the day at a so-called declining head filtration (which may be achieved by closing the raw water inlet valve at the end of the day's working shifts while keeping the filter outlet valve open). The use of at least two filters in any water supply system is recommended to maintain the supply of treated water even during the time one of the filters requires cleaning or another type of maintenance. Pre fabricated filtration package kits are available on the international market which allow a quick and relatively easy installation of slow sand filtration plants even in remote locations. The most typical kit consists of two raw water storage tanks and two slow sand filtration tanks and may be fitted with adequate pumping sets, if needed. Both filters would function simultaneously except during the process of cleaning, when one unit may be left in operation while the other one is cleaned. Some of these filters are provided with a synthetic filter fabric which is located at the top of the filter bed and allows a quick cleaning process, since the need to scrape off the upper sand layer each time is eliminated. These kits do not normally provide the sand, which has to be obtained, washed and graded locally. Assembling this kit would require only a few hours and may be carried out by unskilled labour with minimal supervision.

20. Other types of sand filter include the *packed drum filter* that can be improvised if drums and sand are available and may be a very good way of providing limited quantities of safer water quickly to cover small water demands (at household or health post levels, for instance). In these filters, water passes down through sand on a 5 cm. layer of gravel and is drawn off at a rate that should not exceed 60 litres per hour for a 200 litre drum; infiltrated water equal to the amount drawn off is added to the top. The *river bed filter* consists of a well (See 6.18) or infiltration galleries (See 6.58) that may be constructed in permeable river beds and may be used to treat large amounts of water; they are likely to be difficult to construct.

Disinfection

21. Disinfection serves to destroy pathogenic organisms which may cause various types of water-borne diseases and it can be considered as the final stage in the water treatment process. Although water disinfection can be accomplished by the addition of certain chemicals, by ozone, by ultraviolet light or by boiling (See 8.4) the vast majority of waterworks, including those for the supply of emergency refugee camps, use chlorine or chlorine compounds. *Bleaching powder,* also known as *chlorinated lime*, is a mixture of Calcium hydroxide, Calcium chloride and Calcium hypochlorite which may contain between 20% and 35% of *available chlorine,* i.e. 20-35 parts by weight of chlorine per 100 parts by weight of bleaching powder. Although bulky and relatively unstable, bleaching powder is easy to handle; it is sold in drums; once the drum is opened it loses its chlorine relatively quickly: if the

container is opened once a day for 10 minutes it loses some 5% of its initial available chlorine over a span of 40 days, but if it is left open all the time for the same period almost 20% will be lost; chlorine solutions made from bleaching powder, may be stored in containers kept in the dark for periods not longer than ten days. The lime content of bleaching powder is insoluble and a solution should be well mixed and allowed to settle before dosing, to avoid clogging of valves or feed lines. If 2 kg of bleaching powder, with a 25% available chlorine, is mixed with 20 litres of water, it will result in a 2.5% solution of chlorine. *HTH* (high test hypochlorite material) is easily available on the international market under different brand names and contains 60-70% available chlorine; it is granular, much more stable than bleaching powder (it deteriorates much less during storage) and due, to the fact that it is quite soluble, relatively clear solutions may be prepared if the concentration of the solution is kept below 5% (the strength of the solution should be between 2% and 4%). If 0.84 kg HTH with 60% available chlorine is mixed with 20 litres of water, the result will be a 2.5% solution of chlorine (two drops of this solution may effectively disinfect one litre of relatively clean water and leave approximately 0.5 mg/l residual of chlorine; four or more drops may be needed for cloudy waters). Chlorine compounds should be stored in a dark, cool, dry and well ventilated place in closed containers resistant to corrosion (IATA's air transport regulations for corrosive and toxic substances require special containers; these are the most desirable containers for storage in any given circumstance); chlorine gas is poisonous and may provoke fire or explosions if present in high concentrations, due to exothermic chemical reactions.

22. When added to water, chlorine reacts to form hypochlorous acid and hypochlorite. These two compound together represent the " free available chlorine" and are a powerful bactericide; if ammonia is present in the water chloramines will be formed, the type of which depends on the water's pH and its ammonia concentration. Chloramines are also powerful bactericides. At normal pH values (5-8), the total quantity of chloramines is known as the "combined available chlorine".

23. Because chlorine is an oxidizing agent, part of the chlorine applied will be used by other constituents of the water (Chlorine demand); enough chlorine must therefore be applied for reaction with such constituents and the pathogenic organisms (See 8.13). That is why chlorination should normally be done after the water has undergone other treatment processes such as sedimentation and filtration, to ensure minimum use of chlorine by anything other than bacteria.

24. Care must be taken to ensure strict control of chlorination processes and, particularly, to test the water for chemical residual levels after each disinfection and before distribution. Chlorine residual must be measured only after an appropriate *contact time*. After chlorination, and once chlorine has reacted, oxidizing the other constituents of the water (30 minutes are considered appropriate), there should still be at least 0.5 parts per million (or mg./l) of "free available chlorine" left in solution. The amount of chlorine required to achieve this concentration is usually a broad indication of the level of pollution of the water. If the amount of free available chlorine is higher than 1.0 mg./l, people may reject the water because of its unpleasant taste. A pocket size chloroscope (chlorine comparator kit, preferably of the "DPD" type) is required to test for residual chlorine levels; it consists of two tubes, each containing a measured quantity of the water under test, which can be compared by eye for colour. One of the two tube samples is coloured by the addition of a chlorine sensitive reagent (o-toludine, a common reagent, should be avoided, as it decomposes in hot climates; it is also a poor indicator if water has been over-chlorinated), the other by a range of standard glass slides; the chlorine concentration can be read off directly after matching the colour of the tube with the added reagent with that of the nearest standard. This test is simple and all treatment plant attendants should be trained to use it frequently to check the water quality; any water leaving the plant with a residual chlorine content of 0.4 mg./l of free residual chlorine can be regarded as safe. The dosage of chlorine should be of constant concern; no water should normally be distributed when chlorination equipment is not working (chlorination equipment should be fully duplicated in any water treatment plant).

Other Water Treatment Processes

25. As it has been previously suggested, the treatment of water in emergency refugee situations should be kept to the minimum required to ensure its safety. When refugees are living in rural environments, where the main water sources are dug wells or spring catchments, efforts should be directed to clean, disinfect and to protect these installations from further pollution since the onset of the

emergency and to continue monitoring water quality to ensure the effectiveness of these protective measures; further source disinfection campaigns may be necessary in the long term. In other situations, where refugees are living in large concentrations, in refugee camps or mixed with the local population in villages or towns, regular water disinfection should be regarded as strictly necessary; other simple treatment measures should be carried out if the quality of the raw water supply would require them as a way of to ensuring the effectiveness of disinfection (See 8.11 and 8.23). In these cases, processes to be used would normally include slow sand filtration and even pre-treatment processes, necessary for the due functioning of the sand filters; the aim of these treatment processes is that of improving the physical and bacteriological quality of the drinking water. The improvement of the chemical characteristics of raw water should, however, be decided only after careful consideration of potential health hazards and other risks involved in the provision of drinking water with questionable chemical components, combined with an analysis of alternative solutions, capital costs and long-term operation and maintenance requirements. This exercise would not normally be possible during emergency refugee situations and should wait until the emergency is over, when preparations for longer term care and maintenance activities are under way (See 12.20). From a health point of view this approach should not normally present major problems, as most chemical-related water quality problems do not cause serious health hazards if the water is consumed during short periods (real refugee emergencies are normally short in duration). In the case where a refugee situation evolves, which makes it necessary to prolong care and maintenance assistance programmes for an undefined period, problematic chemical characteristics should have already been recognized and, if important enough, should be addressed in a technically sound and cost-effective manner. In this case, expert advice (which should include expertise in the fields of Public Health, Environmental Health and Engineering) should be sought. Among those processes normally used to improve chemical water quality, water softening, the removal of Iron or Manganese, the control of fluorides or nitrates and the removal of detergents and pesticides should be mentioned. Water desalinization practices are, by their nature and high costs, out of reach of refugee assistance programmes and should be fully discouraged under all circumstances; the search for alternative water sources should be the only solution to high salinity in refugee water supplies.

Disposal of Treatment Plant Waste

26. The wastes of water treatment plants normally used during refugee emergencies are mainly heavy sludges consisting of highly concentrated suspensions of solids in a liquid which may or may not have chemicals, depending on the type of treatment plant. Sludges without chemicals come from primary settling tanks, roughing filters (See 8.14) and sand washers attached to slow sand filtration plants (See 8.19). Total daily volumes of sludge in treatment plants may normally be 5% of the daily plant's throughput. This sludge is inoffensive and may be returned to the river with no treatment, if the river is large enough. If the river is small, it may be necessary to dry in special drying beds before transporting it to the final dump site, which could be a land-fill site or a rubbish dump. If chemicals are present in sludge coming, for example, from sedimentation basins where coagulation takes place. (See 8.15-16), its collection, treatment and disposal become more problematic; de-watering is more difficult, recovery of chemicals is not cost-effective and the disposal of partially treated sludge may create big nuisances. If allowed to accumulate, the sludge putrefies; this process occurs very quickly in warm climates. Although "lagooning" is a traditional method of sludge treatment, sludge lagoons are complicated to build and to operate; they require large plots of land, and the end product is a very sticky stuff that should be picked up and carted away to a dump site. The use of concentration tanks and drying beds is also common. This is normally done at two settling basins (one being filled and the other one being cleaned at any given moment); the thickened sludge is transported (sometimes by pumping) to drying beds similar to lagoons but with permeable sand and gravel bottoms for efficient drainage and, when dry, it is picked up and transported away to dump sites. Choosing the right site for a sludge dump requires the same care and considerations as if it was for rubbish, in view of the need to avoid contamination of surface or groundwater. Contrary to a common belief, these sludges have no manurial value.

9. Water Storage

- All refugee sites must be provided as soon as possible with adequate water storage facilities.

- Water storage may be the only means of ensuring a constant availability of water to cover the needs of a camp population at a given site and therefore could become the main source of supply.
- The use of local technology for the design and construction of storage tanks or reservoirs should always be pursued. In many refugee emergencies, however, the use of prefabricated tanks may be the only way of ensuring the availability of water where needed in the quickest way.
- As storage tanks are a main component of water supply systems, their design should satisfy all the system's technical requirements.

General

1. In nearly all water supply systems it will be necessary to store water between the source and distribution points. Substantial water storage may be needed and will always be an advantage in monitoring, collecting, treating (See 8.10) and distributing safe water as well as for the provision of a reserve to meet the various needs during emergency and long-term use.

2. In any given situation, storage tanks may be located in four different locations within the water supply system:

i) At the water collection point (raw water tanks at surface water intakes, run-off water collection and storage facilities such as "birkas" or "haffirs", at rainfall water collection points, etc.).

ii) At central storage tanks, before or after treatment, to balance the supply from the sources with the needs and in many cases, to provide the system with enough hydraulic head to allow for gravity-fed distribution (See 6.1; 10.16).

iii) At distribution points, which may include public standposts, other service points (health or feeding centres, camp administration facilities, and sometimes at staff houses).

iv) At refugee household level. At this level, use is normally made of small containers; in this case, an effort should be made to ensure a clear distinction between the containers used to obtain and transport water form distribution points and those used for storage (See 4.5; 10.9).

3. Whatever type of storage is needed, adequate enclosure should be provided to prevent any contamination from humans, animals, dust or from any other source. A tight cover and dark storage also prevent algal growth and the breeding of mosquito larvae.

Open Air Storage

4. Under certain circumstances, notably in areas with pronounced dry and rainy seasons, and where alternative sources are limited, the construction of reservoirs to collect water to be used during the dry season may be an option, despite the dangers of pollution and of mosquito breeding. To locate the right site for these type of structures requires a good knowledge of regional environmental conditions and local technological approaches; considerable engineering experience is also needed for the design of the most appropriate structures. An erosion-protected overflow spillway should always be provided to allow for the evacuation of excess water. Enough attention should also be given to the need to control excessive weed growth on the banks of water ponds, haffirs or valley dams. Water losses in open ponds due to evaporation are considerable and efforts should be made to minimize this: well-located wind-breaks will prove useful for this purpose. With time, the loss of storage capacity due to siltation is also important; silt-traps in their inlet structures will lower siltation rates and facilitate maintenance. Water quality in these ponds degrades very easily; fencing-off the reservoirs to avoid access by people and animals should be regarded as strictly necessary; pumping and pipeline facilities to transport water

to conveniently-located service tanks and distribution points should, therefore, be required.

Centralized Water Storage

5. *Service tanks* are used to store water which is ready for distribution. Their size and location should be decided by experienced engineers based on the location of highest consumption points and the overall distribution network, the topography of the terrain and its ability to provide support to the tank's foundations as well as on the technique, materials and design to be used for their construction. Although *brick* and *stone masonry* tanks are most appropriate for larger storage volumes, they may be difficult and time consuming to build under certain emergency conditions. *Reinforced concrete* tanks are common in many areas and have the advantage of being possible to build of virtually any size; while they are very durable, their construction is time consuming and may not be the right solution for water storage needs during refugee emergencies. A number of types of simple, air-portable, plastic or butyl rubber storage tanks (known as pillow tanks, onion tanks or bladder tanks, depending on their design and shape) are available and can be speedily supplied to any given location to meet the most urgent storage requirements during emergencies. Metal storage tanks may be made from different materials, the most common being galvanized iron sheets; their size is limited by the tendency of the material to deform unless a reinforcement framework, made out of wood or steel, is incorporated into their design. The use of *corrugated metal* sheets makes it possible to construct self-supporting prefabricated structures which are easy to transport, erect and commission to respond to emergency needs; some of these tanks are supplied in kit form, and may be obtained in different sizes (10, 45, 70 and 95 cubic metres) to meet different storage needs. The kit may contain other fit tings and material to allow for appropriate pipeline connections and for water chlorination. The use of pre-fabricated fibreglass tanks may be advisable during refugee emergencies, especially when water has been found to be corrosive.

6. The choice of tank type and design should always be entrusted to an experienced engineer. Several features, however, should always be present in storage tanks to allow for their fullest and safer utilization in a water supply system. Their foundations and structure should be sound as water is heavy and even the smallest structural weakness would cause the tank to either leak or completely fail. All tanks should be provided with an outlet hole situated some 20 cm from the bottom; an overflow and vent pipe (with an appropriate screen to avoid the entrance of small animals) and the inlet pipe should always be at the top and at the opposite end to the outlet, to allow for water mixing and aeration; the tank's bottom should slope towards its lowest point, where a drain should be installed for cleaning and flushing the tank. The drain's outlet should be piped away from the tank to avoid the creation of unsanitary conditions around the tank or the destabilization of the tank's foundations by excess water. A manhole, with an appropriate cover and ladders, should be provided to allow access to the interior for cleaning and inspection purposes; storage tanks should be fenced-off to avoid free access to people, and in many cases, there could be a need to have them guarded to protect the structures and pipe work from vandalism or to avoid theft of water (See Figure 32). Elevated tanks (water towers) are mainly used to gain the necessary pressure head to allow an efficient gravity flow into the distribution network, to stabilize pressures within the system and to facilitate meeting fluctuations in water demand; if the topography of the camp and its surroundings is adequate (hills of adequate elevation), surface reservoirs should be preferred for this purpose as the economic limit of height and volume.

Storage Capacity Needs

7. It has been previously suggested that water supply systems should be provided with maximum storage capacities. Practical limits, some of them technical, but also budgetary ones, should, however, be taken into account when planning this important feature of any water supply system. Among the most important technical aspects to bear in mind are the dependability of the source and the possible fluctuations of its output, which may be seasonal (See 6.20) or related to other causes such as well interference (See 6.27; 6.38; 6.55) or well-efficiency (See 6.41). The possibility of conveying water from the storage tanks to distribution points should also be considered, as the need to use towers to elevate tanks for the obtention of the necessary hydraulic heads to achieve this would, of course, limit the size of the tanks that may be built with the available funds (water towers should be used only when strictly required as they are expensive and difficult to construct and maintain) (See 9.6). If the population to be supplied is small (say smaller than 2000 people), the aim should be to store a volume equal to at least

one day's water demand (See 3.1-9). For economic reasons, larger camp populations will have less storage capacity but, under no circumstances should this capacity be smaller than 1/6 of the camp's daily water demand. In camps with a population of more than 5000 people, the total storage capacity could be obtained through a battery of smaller (and less expensive) reservoirs, strategically located to facilitate the construction of a hydraulically efficient and well balanced water distribution network to provide an even coverage of the total camp population.

Water Storage at Distribution Points

8. It is always advisable to provide individual storage facilities to service centres (such as health or supplementary feeding facilities, administrative buildings and even staff houses). Special circumstances (distribution points located along gravity-fed mains, for instance) could make it advisable to provide individual storage facilities for each public distribution standpost. In these cases the aim should be to have a volume of storage equal to the daily water consumption at each of the individual water points. For this purpose, the use of properly adapted oil drums, metallic, rubber or fibreglass tanks may be considered. When water is being conveyed to the camp by water tanker (bowser), care should be taken to avoid water pollution and waste when filling the tanks. As soon as the piped distribution system is operational, these tanks may be connected to it, after the installation of appropriate float valves to avoid overflows and waste. These individual tanks should be located high enough to ensure an efficient gravity flow and other head requirements (See 10.9) to all taps. In view of complicated operation and maintenance requirements of this type of systems, their use should be restricted to only very special cases.

Water Storage at Household Level

9. Average size refugee households (5 to 7 people) should be able to store at least 20 litres of water at any given time. However, the ultimate goal of providing a storage capacity of at least 10 litres per person should be clear at the onset of emergency assistance operations (See 4.5). As household storage containers should not be used to transport water from watering points, enough containers to perform this task should also be provided. The best type of storage containers are narrow neck water bottles or jerrycans; they should have a lid. Water pollution is more difficult to avoid with open containers such as buckets or saucepans; their use for household water storage should, therefore, be discouraged. It is advisable to disinfect household storage containers at least once a week, as silt or other materials may collect in them.

10. Water Distribution Systems

- Water distribution systems are needed to convey the water drawn from the source, through treatment and storage facilities, to the points where it is delivered to the users.
- Water distribution systems should be kept simple. They should, however be designed and constructed in a proper way as they represent a substantial capital investment that should always be useful and cost-effective.
- An appropriate water distribution system should ensure an even coverage of water needs among the camp population.
- Under normal circumstances, water distribution in refugee camps should be carried out through public distribution standposts. Service and administrative buildings should be provided with house connections. Staff housing should, whenever possible, be provided with private connections.
- The design, construction, operation and maintenance of the water supply system should be carried out bearing in mind the need to minimize eater wastage. This is particularly important in systems based on low yield water sources or on those requiring treatment or pumping.

General

1. Water distribution systems (or *"reticulation"*) should be built to deliver the required quantity of water to individual users and under a satisfactory pressure. In refugee camps, water reticulations are always a major investment and as such require careful design, construction, operation and maintenance. Under normal refugee situations, distribution systems should cater for the domestic and sanitary requirements of the refugees, camp administration and service centres. Garden or livestock watering may be unavoidable cultural factors which should be covered, as far as possible, in many refugee camps. As the water demand in refugee camps varies considerably during the day, the pipeline network should be designed to supply the *"maximum hourly demand"*, usually estimated to be 30% higher than the estimated average hourly demand (daily water demand divided by 24) (See 3.1-9).

2. The main system components are the pipelines; other basic components are break pressure tanks (See 10.8), valves (See 10.6), service reservoirs (See 9.5-6) and watering points (See 10.9).

Types of Pipeline Systems

3. From a layout point of view, there are two types of piped distribution systems (See Figure 33):

i) *Branched systems* are those that convey water from a distribution main to different consumption points, following a treelike pattern; all their branches finish in dead-ends. Their design is straightforward but has a main disadvantage in the fact that it causes stagnant water pockets in all dead-ends. If repairs are necessary, large areas must be cut off from service. Head losses, due to heavy local demands - or during a fire - (See 7.13) may be excessive unless the pipes are quite large.

ii) *Looped network* systems usually have a ring mains to which secondary pipes may be connected. Their design is much more complicated; with them the possibility of stagnant water is reduced. If part of the pipeline needs cleaning or repair, it may be isolated from the rest of the system (with appropriate valves); all watering points outside of it may continue to be supplied.

4. Pipelines can be classified in accordance with the tasks they should perform:

i) *Trunk mains* convey water from the sources to other points in the distribution system over long or short distances. They may be *pumping mains* if the water is coming under pressure from a pumping system or *gravity mains* if gravity is the only force used to generate flow. *Distribution mains* are those to which standposts and other service connections are connected.

ii) *Service pipes* connect the mains to a camp's section, a standpost or a house connection.

iii) *Plumbing pipes* form the pipework within standposts, showers, houses, etc.

5. In refugee camps, the most commonly used pipe materials are polyvinyl chloride, known as *PVC* and high density polythene, known as *HDPE*; under special circumstances, especially when the pipeline has to withstand high pressures, galvanized iron *(GI)* pipes are used. The use of *asbestos-cement* pipes for human water supply should be avoided. The choice of pipe materials should be decided bearing in mind availability on local markets, the cost, the diameters available and their pressure ratings. Resistance to corrosion and mechanical damage, as well as transportation requirements to the project site should also be considered. Although both PVC and HDPE pipes are relatively easy to transport in view of their light weight (HDPE has the additional advantage of being provided in rolls for pipe diameters of 160 mm. or less, thus reducing the number of necessary joints), both have the disadvantage of being very easy to tap in unauthorized ways (illegal connections). This can be avoided to a large extent by laying the pipe in appropriate trenches and then covering them. This is, in any case, strictly required by PVC, which is a material that degrades when exposed to sunlight, losing part of its strength and becoming brittle; care should therefore be taken to cover PVC pipes when they are stocked in the open.

Valves and Taps

6. All pipeline systems require the use of valves to control flows and pressures as well as for closing or opening a pipeline or a section of it (Figure 34). As the pipeline must always follow the terrain's topography, some valves are used for the release of air that may be trapped at high points *(air valves)* and to facilitate emptying and scouring the pipeline to flush out sediments that may have been deposited at low points *(wash out valves)*. *Sluice valves* are fitted to the pump outlets in the case of pumped supplies, but are also installed to isolate pipeline sections during operation or maintenance activities; these valves are also known as *gate valves*. *Non-return valves* consist of a flat disk set pivoted within the pipe in such a way that it may be forced open by water flowing in one direction but also forced shut, thus impeding the flow, if water tends to flow in the opposite direction. *Float valves* function with the same principle; the driving force is given to the mechanism by the upwards movement of a floater or buoy, thus allowing the automatic closure of inlet pipes before tanks overflow. Other valves, such as the butterfly valves, screw plug valves or ball valves are also used for flow control tasks and are built on the principle of a plug, diaphragm or jumper which is forced into the pipe's opening, thus reducing or shutting off completely the flow; as their sealing device (gasket) wears down rather quickly, they require constant attention and periodical renewal; this may become an important maintenance problem if the valves have a frequent use; an additional disadvantage of these valves is that, due to their design, they cause considerable pressure-head losses, even when completely opened. *Stopcocks*, also known as water *taps* or *faucets*, used at water distribution outlets at public standposts or house connections, are normally designed in accordance with the same principles of screw plug valves. They therefore suffer from the same shortcomings related to the short working life of gaskets, thus creating a major maintenance problem, especially when distribution is carried out through public distribution standposts; these taps may be opened and closed hundreds of times during a single day; as their malfunctioning is one of the main causes of water wastage, this should be given close attention during the planning and implementation of a preventive maintenance programme. Recently, very sturdy, easy to repair and maintain self-closing taps (known as *water saving taps*) have been developed specifically to address these problems; their introduction in public distribution standposts at refugee camps has proven successful in minimizing water wastage and camp maintenance costs.

Other System Components

7. *Valve boxes* should always be built to protect control valves from undesirable tampering, which may upset the hydraulic behaviour of an entire water supply system or some of its components; valve boxes are to protect control valves-and the whole supply system-from this type of disturbance; they may be attached to other structures (e.g. storage tanks) or placed independently along the pipeline. They may be made from many materials, depending on local availability, but they should always be provided with a secure cover, adequate drainage, and a size large enough to allow easy operation and maintenance.

8. Whenever it becomes necessary to reduce hydrostatic pressures in gravity pipelines, *break-pressure tanks* are used. These tanks permit the flow to discharge into the atmosphere, thus reducing pressures to zero; a new static level is, therefore, established. Strategic placing of break-pressure tanks minimizes capital costs, as the need to use GI pipes or more expensive, higher grade plastic pipes is reduced (See 10.5). Cement masonry, concrete or any other suitable material may be used for their construction.

9. The most common water distribution facility used in refugee camps is the *public distribution standpost* or *tapstand*. These structures should be designed and built bearing in mind that no other component in the water supply system will suffer more abuse and that they should always be adapted to social and cultural needs of the beneficiary refugee population. This is particularly important in view of the fact that standposts are more than a physical structure; they will normally become a social gathering point where several day-to-day activities (water collection, clothes washing, bathing) will take place (See 6.29). This means that, as part of their design, enough attention should be paid to their location and to the additional facilities necessary to make them sanitary and attractive. The control of water wastage at standposts should also be given importance. Users should never fail to turn off the taps and constant maintenance should be ensured to avoid leaky or broken taps; self-closing, water saving