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UNDERSTANDING POTABLE WATER STORAGE

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PREFACE

This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Maria Giannuzzi as editor, Suzanne Brooks handling typesetting and layout, and Margaret Crouch as project manager.

The author of this paper, VITA Volunteer Charles M. Ritter, is a project engineer with an engineering consulting firm in Wheat Ridge, Colorado. Mr. Ritter specializes in potable water treatment and distribution and wastewater disposal. The reviewers are also VITA Volunteers. Philip Jones has 15 years experience as a civil engineer working on water and sanitation projects. He has spent seven years working in East Africa and is presently a consultant based in Washington, D.C., specializing in environmental engineering for developing countries. Irving Starobin is a chemical engineer, specializing in plastics, who has worked as a consultant for UNIDO and has experience in Asia, Europe, and South America.

VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations. VITA maintains an international Inquiry Service, a specialized documentation center, and a computerized roster of volunteer technical consultants; manages long-term field projects; and publishes a variety of technical manuals and papers. For more information about VITA services in general, or the technology presented in this paper, contact VITA at 1815 North Lynn Street, Suite 200, Arlington, Virginia 22209 USA.

POTABLE WATER STORAGE

by VITA Volunteer Charles M. Ritter

I. INTRODUCTION

BASIC THEORY AND APPLICATIONS

Put simply, potable water is drinking water. Conversely, water that is not drinkable is termed non-potable. Water engineers use the terms in various ways. The term "potable water supply" can refer to water in a reservoir or river, for instance, that may be too contaminated to drink as is, but which will be treated to make it drinkable. It can also refer to the same water after it has been treated, or to other water such as from some bore-holes and springs, which is naturally pure and does not require treatment.

Treated or naturally pure water is a scarce and valuable commodity. Because of this, it is usually only produced in amounts necessary to satisfy short-term (i.e., over the next few hours or a day) demand, and so particular care is taken to ensure that it does not become contaminated. The term "potable water storage" refers particularly to storage of this water. The word 'potable' in this report therefore refers only to water that is considered fit to drink. It may have a wider meaning in other contexts.

In contrast, the storage of untreated (raw), possibly contaminated water is not usually subject to the same standards of protection, although reasonable precautions should always be taken to prevent access, for instance, by animals for drinking or by humans for washing, to a raw water storage dam that might hold several months supply.

The amount of potable water available from a supply source may not always be adequate to satisfy demand at a particular point in time. Therefore, it is frequently necessary to hold a sufficient quantity of water in storage, to be withdrawn during periods when consumption exceeds incoming supply.

In addition to supplying water during periods of shortage, water storage reservoirs perform other beneficial functions: (1) maintaining relatively constant water pressures in the distribution system; or allowing pumps and treatment processes to run at constant flow while demand varies; (2) alleviating the need for pumps to run continuously; and (3) improving system reliability.

It should be noted that potable water storage facilities are not always needed--or desirable. If the raw water source is itself drinkable, plentiful, and readily accessible, there is no advantage to be gained in extracting more than is required, and storing it. For example, an abundant spring to which people come to collect water, or a well fitted with a hand pump, does not require storage. In fact, the slight delay of waiting in line may be highly preferable to risk of contamination that would accompany the installation of a small well-head storage tank.

Potable water storage is needed, however, if the rate at which water can be extracted from the source varies greatly from the rate at which it is consumed. Pumps, treatment processes, and the carrying capacity of pipework are most efficient and simple to operate when working with a constant flow of water. Thus, it is good practice for raw water handling to be based on a constant average flow, and for excess potable water to be stored during periods of low demand, such as at night, to augment flows during periods of high demand, such as in the morning and evening. In this way, demand is evened out: storage used for this purpose is also referred to as balancing or equalizing storage. If pumps and treatment plants can only be operated for part of a day, say during daylight, or for one operator shift, then storage is required to maintain a supply at other times. Some extra storage may be provided to maintain a contingency supply in case of a breakdown. However, this should be considered as a short-term emergency supply only; in dealing with breakdowns, the main objective should be to repair the system quickly.

One special case, requiring the longer-term storage of potable water, is that of rain water, dealt with later.

Typically, potable water is stored after all treatment and pumping processes have been completed, usually at a point close to or within the distribution system, and at an elevation above the highest point of discharge. Thus, the stored water can continue to flow to consumers by gravity even if there is a breakdown in the treatment or pumping plant. The actual location of the storage will often be obvious, that is, on the nearest piece of high ground within or next to the consuming area. Where alternatives exist, the location may be governed by the location of the pump or intake (so as to avoid a long pumping main), by the location of the high use area within the community and by the the layout and type of distribution system being built. Figure 2A shows the scheme when pumping directly into a storage tank. Figure 2B demonstrates when the tank is filled from a more elevated source, the water then flowing by gravity through a separate outlet to the distribution system. Figure 3 illustrates the situation when water is to be pumped into the distribution system and

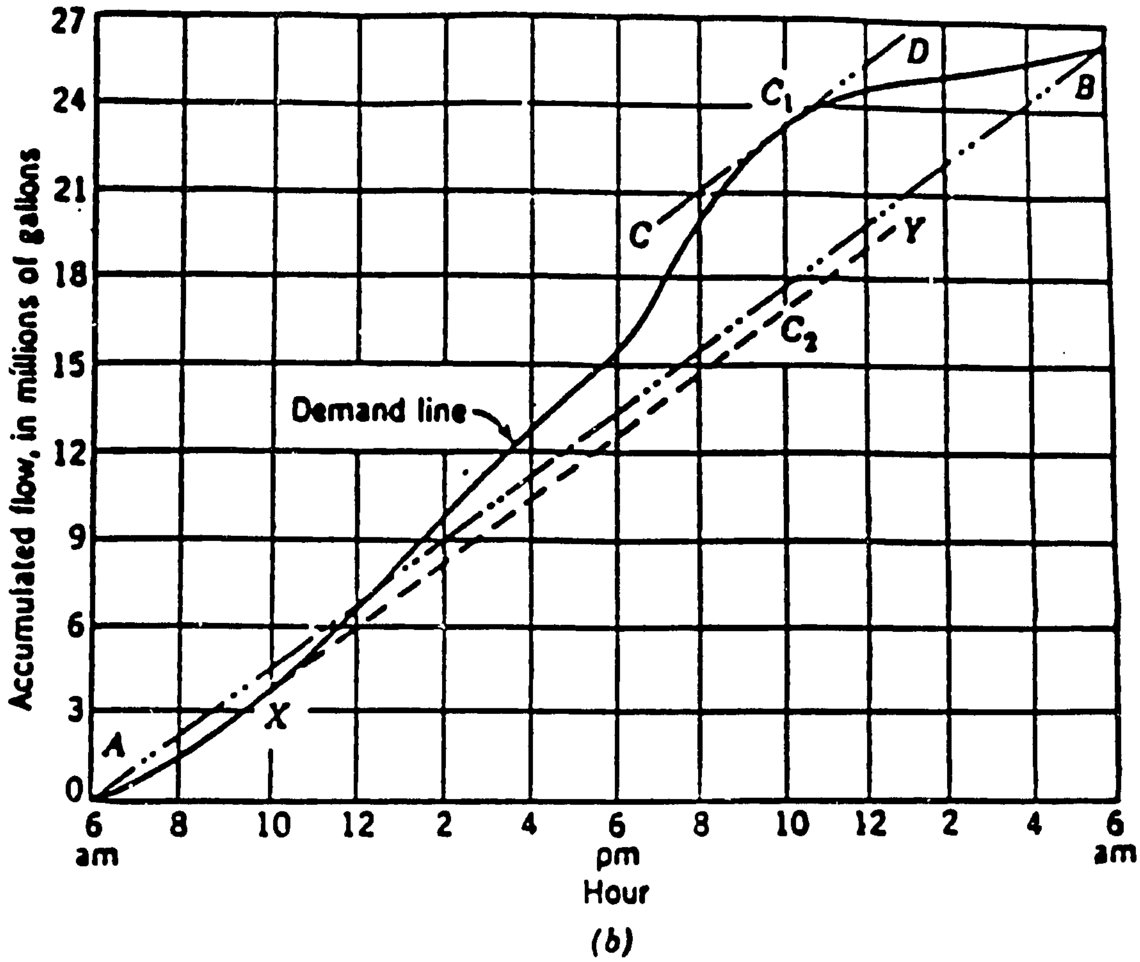

Figure 1. Mass diagram of storage requirements. The cumulative-demand curve is plotted from records or estimates, and the average-demand line, AB', drawn between its extremities. Line CD and XY are drawn parallel to line AB' and tangent to the curve at points of greatest divergence from the average. At C1--the point of maximum divergence--a line is extended down the coordinate to line XY. This line, C1C2, represents the required peak-hour storage: in this case, it scales to 6.44 mil gal. [From George G. Schmid, "Peak Demand Storage," Journal of American Water Works Association, 48, 378-386 (April 1956).]

Source: J.A. Salvato, Jr. Environmental Engineering and Sanitation. (New York: Wiley-Interscience, 1972).

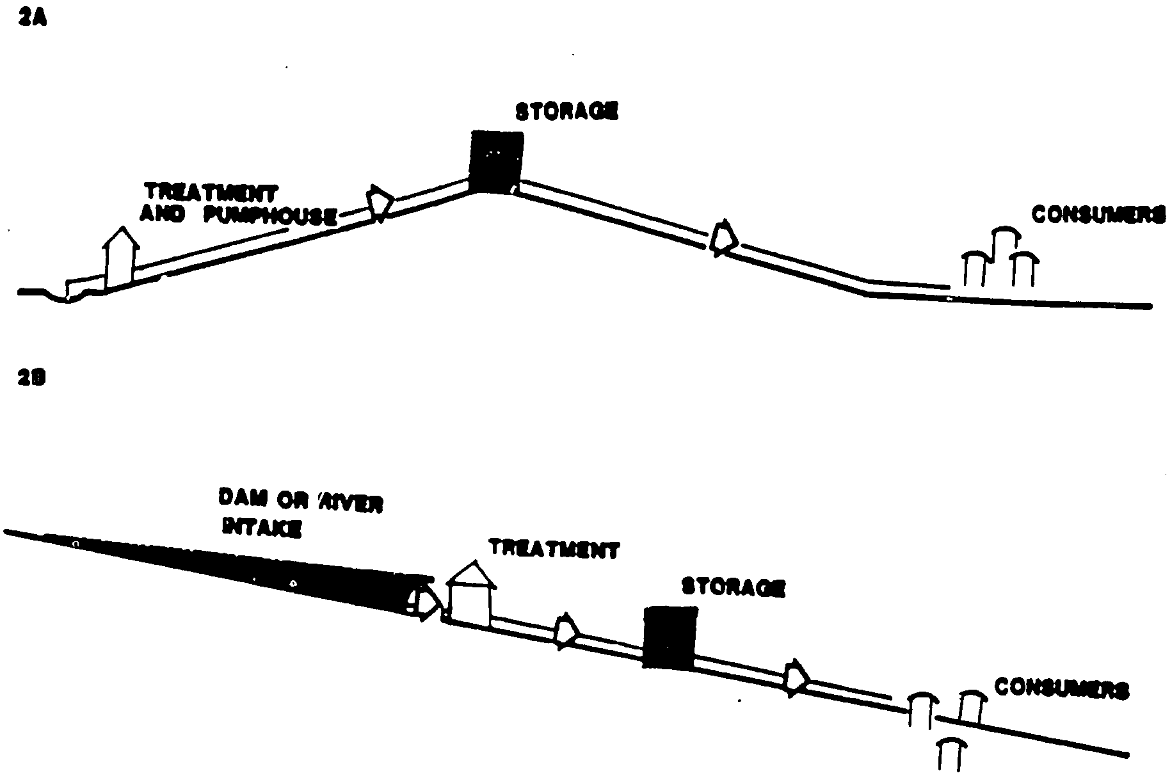

Figure 2.
Direct Pumping Into A Storage Tank

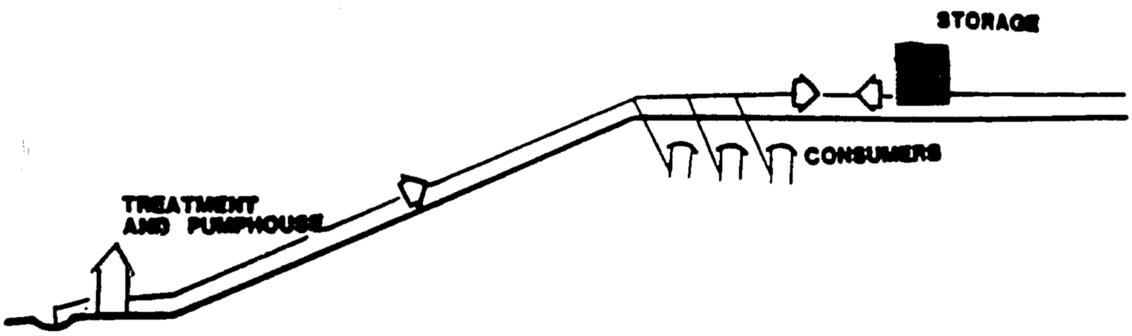

Figure 3.
Pumping Into The Distribution System and Storage

allowed to overflow into storage. In the latter case, some advantage may be gained by locating storage near the high usage area on the opposite side from which the supply enters the community. There is no rule as to which system is best; each has advantages and disadvantages and is more a matter of distribution design, local engineering practice, and possibly legal requirements. Obviously, the second system cannot be used if only intermittent pumping is done.

A shallow tank with a relatively large areal expanse is preferred to a deeper, narrower one. In piped distribution systems, locating distribution storage near the high usage area on the opposite side from which the supply line enters the community, has the advantage of satisfying peak demands through smaller-sized mains, and with the lowest pressure loss. The tank site should be high enough that maximum head losses can be overcome as water flows toward the point of demand, hopefully arriving there with an adequate positive pressure. However, a higher tank means a greater energy requirement for pumping. In addition, a higher tank will require higher pressure rated and more expensive pipe. It will also result in an increased water loss from leakage. Therefore, it is important to place the tank at the right height.

Depending upon the pressure rating of pipes within the distribution network, the vertical distance between storage and the low point in the community should usually not result in a sustained pressure greater than 100 pounds per square inch (psi) when the system is at rest, i.e., static head and pumping head at no-flow. The practice in the United States has been to ensure a residual pressure of at least 20 psi when the maximum demand, i.e., for fighting fires, is applied at critical spots in the service area. For all purposes except firefighting, a small system such as a school, mission, or hospital complex can easily make do with no more than three meters residual head.

If insufficient elevation difference exists in the terrain surrounding a community, construction of an elevated tank or standpipe that is taller than it is wide may be necessary. Globes, cylinders, and rectangles are some of the variations of this type of storage structure. The outsides of above-ground tanks and pipes are subject to weathering.

If suitably situated high ground is not available, the tank may be elevated on a tower. Specialist advice should be sought if the area is subject to earthquakes or strong winds. Below-ground tanks should be constructed above the water table as well as any sewage disposal systems in the area. The minimum lateral separation between water storage reservoirs and sewage disposal facilities should be about 30 meters. To provide good drainage, sur-

VOLUME REQUIREMENTS

One of the primary functions of a water storage structure is to provide a reserve capacity that can be utilized to meet demand when the normal supply rate is inadequate. It is, therefore, necessary to set forth some guidelines for determining how large the storage capacity should be.

Per unit water demand is generally used as the basis for sizing a tank. For instance, the average per person consumption multiplied by total number of people in a community yields one estimate of storage volume requirement when halved. Another recommended method is to multiply the average daily use by an appropriate peaking factor to yield the maximum demand over a one-day period, and subtract daily water production (i.e., treatment) capacity. In smaller communities, elevated storage should be at least equal to one (and preferably two or three) days' requirement during hot, dry periods.

A more precise method of calculating volume requirements is to construct a mass diagram of water usage on the peak day, and draw parallel pump supply lines tangent to the demand curve at its most divergent points* (see Figure 1). For this example, the reservoir is assumed to be filling when demand is low, and emptying when demand exceeds the production capacity. It may be necessary to make some assumptions about the demand curve configuration. The practice in the United States is generally to provide a fire fighting reserve over and above the peak demand equalization storage volume.

II. VARIATIONS IN TECHNOLOGY

CONSTRUCTION MATERIALS

Through the centuries, a variety of construction materials have been utilized as the basic element(s) in water storage structures. Small reservoirs formed by earthen embankments have supplied poor quality water to villages in India during the long dry season. In western Sudan, the hollowed-out trunk of the baobab tree is employed to retain water collected during the short rainy season. Brick, masonry, and concrete may be the most popular materials currently utilized. These and other modern-day tank construction materials are discussed below.

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*This method is discussed in greater detail in Environmental Engineering and Sanitation by J.A. Salvato, Jr. (see Bibliography).

Foundation pressure under a tank up to about 3 meters deep is not very great, and provided that about a foot of topsoil is removed (0.3 meters) or maybe .6 meters in soft ground, then no problems would be found. Solid rock is obviously a good foundation. A mixture of rock and soil is not good, as the soil will settle slightly, but the rock will not, resulting in a cracked floor and worse.

Elevated tanks have their weight concentrated over a small area, and extra care is then needed to choose a good firm site. As a rough guide, if you can park a truck overnight at a site, and see only a slight or no dent where the back wheel lay, then the ground bearing pressure is sufficient.

Typical size ranges suitable for various types of materials include:

- ferrocement, less than 1 cubic meter
- masonry up to about 20 cubic meters
- reinforced concrete, almost any size, but hardly worth the effort for less than about 5 cubic meters
- round corrugated galvanized steel, up to 2 cubic meters
- bolted sectional steel, fiberglass panels, 1 cubic meter up to almost any size
- welded steel, 20 cubic meters and up

Brick or Stone Masonry

Hard, dense material such as brick or stone masonry should be laid with full cement mortar joints. Pressed and dried bricks formed from laterite soils have a soundness comparable to lime-sandstone bricks. A 2-centimeter layer of rich cement mortar applied to the inside face will render the structure watertight.

A tank more than about a meter deep may need circumferential steel reinforcement, which can be laid in the horizontal mortar joints, or buttresses spaced around the outside. The mortar lining must be carefully cured, like the concrete, by being kept damp for several days to a week, otherwise it will crack. As a tank fills and empties, and as temperature differences occur from night to day, masonry and concrete will expand and contract. Sliding joints between floor, walls, and roof may be necessary.

Concrete

Water storage structures made of concrete require internal steel reinforcing to provide tensile strength. The two primary design methods revolve around (1) working stress, based on the British experience, and (2) ultimate strength design (limiting crack width).*

A dense, durable, and impermeable material that will not erode, crack, or otherwise permit water leakage that could cause contamination of the stored water, or corrosion of the interior steel is necessary. Watertightness of the finished structure is enhanced by a low water-cement ratio (0.45 maximum) within the limits of reasonable workability. A continuous waterstop made of polyvinyl chloride (PVC) or rubber is cast in the concrete at all breaks or joints to prevent the passage of water through them. The new concrete should be kept wet and allowed adequate time for curing before being placed in service. Post-tensioned, prestressed concrete is generally not cost-effective unless the tank is very large.

Building a watertight structure out of concrete is not easy, and a mortar-lined masonry tank is usually more successful. Concrete work requires a supply of formwork (molds to form the concrete shape), which is usually made of wood sheet or planks. This can be expensive and requires good carpenters to make waterproof joints, otherwise the concrete will not be watertight. Steel must be accurately fixed inside the formwork. Altogether, it requires a more skilled work force than masonry.

A concrete floor slab is relatively easy to build. The walls, especially if curved--as they must be for adequate strength--are the most difficult part. A flat slab roof requires support formwork that must be strong enough not to move at all during construction and subsequent curing, but otherwise is fairly easy to build. Most masonry-walled tanks have concrete floors and roofs.

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*Appropriate design procedures are detailed in the Handbook of Concrete Engineering and Concrete Sanitary Engineering Structures published by the American Concrete Institute and Design of Liquid-Retaining Concrete Structures by R.D. Anchor; also, the April 1981 issue of Concrete International published by the American Concrete Institute was devoted entirely to this subject (see Bibliography).

Ferro-cement

These containers are being built more and more in developing countries, especially in India. The technique involves applying a sand and cement mortar mixture over a framework of steel rods, mesh, pipe, chicken wire, etc., to form a lightweight, watertight structure. There is no need for complicated and expensive form-work, and thin-walled flexible ferro-cement is advantageous in curved structures such as circular or conical tanks.

Earthen Basins with Impermeable Liners

Plastic film or thin concrete liners can be used to make earthen reservoirs watertight. However, plastic film is very easily torn or punctured. The embankments are subject to some natural hazards such as erosion.

All systems using a flexible membrane should be designed so as not to fail structurally if the liner is punctured, and drains must be installed if ground water under the liner is a problem. For cases where a separate liner is not installed, various methods of compacting suitable soils or seeding with bentonite or chemicals can be employed to improve the soil's water retaining characteristics.* Care should be taken to prevent scouring by water of soil liners around the inlet pipe. A clay liner can be protected from drying out with 2.5 meter layer of sand or gravel.

The disadvantages of an uncovered reservoir described in the section on "Water Quality Considerations" can be overcome by spanning the basin with a reinforced concrete slab or corrugated metal roof. Other types of covers or methods of evaporation control include: (1) reinforced synthetic rubber supported on foam floats, (2) polyethylene sheets, and (3) ultra-thin layers of long-chain alcohols. The alcohols are, however, subject to dispersion by wind and waves.

One variation of the earthen basin is that, instead of being uncovered, the basin is filled with uniformly sized sand and acts as an artificial aquifer (water-bearing formation). Water still occupies between 30 and 40 percent of the volume of the basin, and purification takes place as the liquid filters through the sand. A gravel mulch layer on top of the sand enhances the operation of the artificial aquifer by improving percolation of rainwater (recharge characteristics) and suppressing evaporation.

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*See Methods of Creating Low-Cost Waterproof Membranes for Use in the Construction of Rainwater Catchment and Storage Systems by D. Maddocks.

Smaller artificial aquifers storing less than 25,000 gallons are probably easier to design and construct. To prevent contamination, such a system must be managed carefully, or it is likely to be used for irrigation or stock watering.

Steel Tanks

Several types of steel tanks are available. For small volumes, 1 cubic meter or so, round corrugated steel or square sheet steel (often used as internal roo tanks) tanks, galvanized and with a cover may be used. These are often available from stock at builders suppliers.

For larger volumes up to several hundred cubic meters, steel tanks are usually prefabricated in a factory, transported in sections and erected on site. The segments are welded or bolted together; this works best if it is done by the supplier as part of his duties in case it subsequently leaks. Welded tanks are often circular or have more complicated shapes. They require an experienced construction crew and skilled welders for a successful job. Bolted segment tanks can be erected by an experienced crew under the direction of an experienced foreman who can usually be provided by the manufacturer. Although the cost of steel tanks may appear high, they can often be transported in one truckload and become competitive when transport costs are considered. They come in standard size increments, and can be arranged to fit almost any requirement. They are relatively easy to construct as elevated tanks, either on a steel tower supplied as part of the arrangement, or on masonry pillars or walls.

Steel tanks tend to corrode, especially if storing rainwater or slightly saline water, or if subject to a salty atmosphere or sand-laden winds that wear away paintwork. A chemist or competent water engineer can advise on how corrosive your water is likely to be. Simple precautions, such as raising the tank a few centimeters off damp ground, careful choice of metal fittings and careful installation, and painting the inside and outside can significantly lengthen tank life.*

Silica glass-coated metal panels that are bolted together circumvent the periodic maintenance requirements. These structures are not suitable for placement below the ground, however.

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*The publication "AWWA Standard D-100-79 for Welded Steel Water Storage Tanks," issued by the American Water Works Association in 1979, sets forth the requirements for welded steel tanks (see

Steel grain storage bins have been converted to water tanks using PVC or other artificial liners.

Wood

A variety of woods, including cypress, fir, pine, and redwood, have been used for water storage structures. One such commercially available tank is made of staves with tongue-and-groove joints that are held together by galvanized or asphalt-protected steel tension hoops around the circumference. Like concrete, the wooden tanks do not require special maintenance, although their average life span is shorter. If wood preservations are used, they must not contain any toxic chemicals.

Fiberglass and Plastic

Man-made materials such as fiberglass or plastic can also be used in the construction of water storage tanks. However, these tanks are usually installed only on a very small scale.

Plastic, fiberglass, and various combinations are used to make bolted sectional tanks similar to steel tanks. Damaged sections can be repaired if suitable resins and fiberglass can be obtained, or, as with steel segment-bolted tanks, a complete segment can be replaced.

Small plastic tanks up to about 2 cubic meters made of polyethylene or poly vinyl chloride are available. They are light and easily handled, but are also easily damaged and difficult to repair properly. They may become brittle if exposed to light/sun and therefore should only be installed indoors.

Miscellaneous

When substandard construction or lack of the proper materials results in a tank that is not watertight, liners made from epoxy, vinyl, asphalt, or other materials that will resist leakage can be applied to the inside. Care must be taken that any such materials are safe for drinking water applications. A reputable local supplier of construction materials or the ministry dealing with water supply or public health should be asked for guidance.

INDIVIDUAL CISTERNS

Cisterns are used to catch and store rainwater. Especially in duction of an individualized water storage technology may be feasible. Cisterns should be covered to reduce evaporation and prevent entry of animals and debris. And since water quality is also an important consideration, it may be practical to filter the water leaving the storage reservoir after a lengthy detention period. The impermeable surface collecting precipitation (often the roof of a house) must be kept clean, or provision made to bypass initial flows around the storage cistern. Where possible, water should be extracted from the cistern using a pump or gravity pipe, and not by dipping a potentially dirty container into it.

Rainwater contains appreciable amounts of dissolved oxygen and carbon dioxide, which can significantly affect both taste and acidity (pH). It is also comparatively corrosive to iron or metal.

TANK ACCESSORIES

The addition of a few accessories to the basic storage structure will serve to make it more functional and fail-safe. Piped air vents are necessary to prevent pressure or vacuum buildup within the tank as it is filling or emptying. These openings should be covered with a screen material to keep insects, birds, and other small animals from entering the reservoir, and should always point downwards. The same is true for the outlet ends of drain or overflow pipes. These pipes should conduct water far enough from the tank so that the tank foundation is not adversely affected. Installing a valve in the drain line outside the tank will permit the discharging of the stored contents when desired. The drain pipe should never be connected to a sewer line.

A lockable access hatch and ladder permit entry into the structure. Like the vent pipe, the hatch should be raised at least one half meter above the top of a buried tank, and 5 or 6 centimeters above the top of a surface tank, so contaminated surface water flows around or underneath the opening, instead of entering through it. A lockable access hatch cover, and fencing around the tank site will discourage tampering, swimming, or vandalism.

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*A summary of the different types of cisterns that have been used over the years is contained in "Cistern Based Water Supply in Rural Areas in Low Developed Countries" by G. Schulze (see Bibliography).

Overflow pipes should be one size larger than the inlet, and never fitted with a valve. Outlet pipes raised several centimeters off the tank floor allow the accumulation of silt which can be flushed out during periodic maintenance cleanings.

WATER QUALITY CONSIDERATIONS

Water quality may be either beneficially or adversely affected by detention in a storage reservoir. Turbidity is often reduced as water passes through a basin. This process, known as sedimentation, could be responsible for removing significant numbers of bacteria and other particulates. Transmission of some parasites, which must contact the host organism within 24 to 48 hours to remain viable, is effectively prevented during storage and detention.

On the other hand, large uncovered reservoirs are susceptible to contamination because algae build up in the surface layer. If the incoming water contains a proper supply of nutrients, algae production will be enhanced by sunlight, and solids will accumulate at a faster rate than sedimentation can remove them. The bacteriological quality is then affected because algae and other solids protect various pathogens from the disinfecting chemical. Excessive algae growth can be controlled, to some extent, through regular applications of copper sulfate. However, this chemical is not always available, and building a roof over the tank is preferable to avoid the problem completely.

Other potential sources of pollution that pose a greater threat if the reservoir is uncovered are birds, animals, insects, humans, and windblown and atmospheric contaminants. Moreover, chlorine tends to dissipate faster in an uncovered reservoir, making maintenance of a sufficient residual impossible.

Proper construction of accessories and even the tank itself will reduce the potential for the introduction of contaminants into drinking water. For instance, vent pipes must extend above the flow level of any surface drainage, because it may be contaminated and drain lines should not be directly connected to sewers. The completed structure should be as watertight as possible, and situated above any underground seepage. Interior liners must be non-toxic and impart no taste to the water; this includes all interior paints, resins, compounds used for filling cracks, formwork releasing agents, and any additives mixed with the concrete.

Tanks should be drained as often as necessary (at least once per year) for maintenance. The operations technician should inspect the interior of the tank, repair any leaks, and remove any silt or plant life that has collected there.

Two different procedures for disinfecting a storage tank before placing it in service are described in the American Water Works Association's Standard D-105-80 (see Bibliography). One method involves filling the tank with a concentrated chlorine solution (10 milligrams per liter) and letting it stand full for 24 hours, after which time the disinfection water is drained as waste.

The second method is useful where water is scarce, and using rather than discarding the chlorine solution is desired. The steps in this procedure are as follows:

1. Thoroughly coat (with sprayer) interior of surfaces with a strong solution containing 200 milligrams per liter of chlorine.

2. Fill drain piping with 10 milligrams per liter chlorine solution.

3. Allow 30 minutes of contact between all surfaces and the chlorine solution.

4. Permit fresh water to enter the tank, and purge drain piping of the disinfection water.

5. Close drain valve and fill tank to maximum level.

With either method, the tank's inside surfaces should be thoroughly cleaned and swabbed before disinfecting. After disinfection, the water should be tested for proper bacteriological and aesthetic qualities to assess its suitability for public consumption. Because of the hazards involved in spraying the strong chlorine solution, the workmen must be adequately protected with the proper clothing and breathing apparatus. One person should remain outside, connected by a rope to a co-worker inside the tank. All workers should be free of intestional diseases. They should wash their boots--or feet--before entering the tank (and not wash them in the tank water through the access hatch). Different chlorine compounds and the amounts needed for preparing a 50 milligram per liter solution are given in Table 1.

III. CHOOSING THE TECHNOLOGY RIGHT FOR YOU

A number of factors should be considered in selecting the most appropriate storage structure for a particular location. Cost is

Table 1. Quantity of Disinfectant Required to Give a Dose of 50 mg/l Chlorine

Diameter of Well, Spring, or Pipe (inches)	U.S. Gallons of Water per foot of Water Depth	Ounces of Disinfectant/ 10-Foot Depth of Water		
		70 Percent Calcium Hypo-chlorite[a]	25 Percent Calcium Hypo-chlorite[b]	5-1/4 Percent Sodium Hypo-chlorite[c]
2	0.163	0.02	0.04	0.20
4	0.65	0.06	0.17	0.80
6	1.47	0.14	0.39	1.87
8	2.61	0.25	0.70	3.33
10	4.08	0.39	1.09	5.20
12	5.88	0.56	1.57	7.46
24	23.50	2.24	6.27	30.00
36	52.88	5.02	14.10	66.80
48	94.00	9.00	25.20	120.00
60	149.00	14.00	39.20	187.00
72	211.00	20.20	56.50	269.00
96	376.00	35.70	100.00	476.00

[a] $Ca(OCl)_2$ also known as high-test calcium hypochlorite. A heaping teaspoonful of calcium hypochlorite holds approximately 1/2 oz.

[b] $CaCl(OCl)$.

[c] $Na(OCl)$, also known as bleach, (brand names include Chlorox, Dazzle, etc.), can be purchased at most supermarkets, drug, and grocery stores.

Source: J.A. Salvato, Jr., Environmental Engineering and Sanitation (New York: Wiley-Interscience, 1972).

probably the most important consideration, because sufficient funds, either from a local source or foreign development aid, are necessary before anything of a permanent nature can be built. Since the unemployment rate in most developing countries is high, labor-intensive technologies offer certain advantages over more costly mechanization-based schemes.

In addition, materials used in construction should be available locally, whether imported from outside the country or produced indigenously. The purchase of locally-derived materials may boost a region's economy, and ensure that proper means for repair or replacement are available. If foreign goods are utilized, they should be simple, rugged, and reliable so that they will not require much maintenance attention or repair work. Because of the need to inspect and paint them regularly, metal tanks are probably not the best solution.

Local customs and cultural effects are other important factors to consider. If water has traditionally been collected by the women at a local gathering spot, it is probably advantageous to integrate them into the planning, and perhaps build a large communal system rather than individual storage cisterns. Conversely, if different segments of the community will not associate or work with one another, building a large public water storage facility may be difficult, not to mention pointless. This is unfortunate in light of its advantages--the inherent economies of scale, and the fact that it is easier to monitor and maintain water quality in a reservoir serving the whole community.

The choice of storage systems depends on community resources and needs. A well-built concrete or masonry tank should last for at least 20 years. A well-maintained steel tank may last for 10 years. Some low-cost simple but dependable technologies include:

1. Earthen basins with impermeable liners and whatever covers can be fashioned over the tops of them;

2. Ferro-cement containers constructed with a variety of possible materials available that will lend tensile strength to the cement;

3. Artificial aquifers may be the least resource-intensive, utilizing instead large amounts of cheap labor.

To choose the technology right for you, consider the following questions.

1. **How much storage do you need?**

2. Where do you need it?

3. What types of tank would satisfy (1) and (2)?

4. Which of the options from (3) do you have the resources to build and maintain?

5. From what is left, choose the cheapest.

Having made your choice, try to find someone else who has already tried it, and see what advice they have to offer. Their advice will probably be among the best you can obtain, but if they have any unsolved problems, VITA may be able to offer a solution. Attention to the points raised in this report, together with a more detailed investigation of your chosen technology will help ensure a long lasting and reliable storage system.

The lack of good, dependable, environmentally protected stores of water is a serious problem in many underdeveloped regions of the world. Improving this situation will require a substantial infusion of effort and money. It is hoped that the suggestions made herein will be valuable in stimulating new ideas, selecting the most suitable technology from among the various alternatives available, and applying the correct criteria to locate and size storage facilities.

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