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Selecting simple chlorinators for community water supplies

Brian Skinner, WEDC

A VARIETY OF devices can be used for chlorination of small-scale community water supplies in rural areas of developing countries. This paper focuses on ones that do not require chlorine gas or electricity. It offers guidance on the selection of such devices and it highlights some of the operational problems that need to be overcome when using them.

Disinfection by chlorination

Chlorine is the most widely used chemical for disinfection of water.

This paper deals with the chlorination of community supplies. However, the alternative of chlorination at household-level is proving to be a very successful approach in some countries (CDC, 2000).

The chlorination of drinking water takes place when chlorine is dosed into the water as a gas or as a liquid or solid compound. Most of the chlorinators mentioned in this paper dose chlorine solutions into the water.

Chlorine is most effective in disinfecting water that is free from suspended solids or organic matter. Surface water should therefore first be treated by sedimentation and filtration. These treatment stages are also important for removing some pathogens that are resistant to chlorine.

The effectiveness of chlorine is dependent on a number of factors including the concentration of the chlorine solution, the physical and chemical characteristic of the water, the type of pathogens present, and the time for which the pathogens are in contact with the chlorine. There is no space in this paper to discuss ways of successfully achieving disinfection and for relevant guidance readers should consult textbooks or obtain advice from people with appropriate experience.

In recent years there has been concern about the potential health risks from by-products of chlorination, although many of the alternative methods can also cause by-products. The generally held view, originally supported by WHO (1993 p93), is that the health risks from chlorination are minimal compared to the known risk of consuming water that has not been disinfected.

Sources of chlorine

Sources of chlorine used for water treatment are chlorine gas, sodium hypochlorite (a liquid), and various solids (powders or tablets) such as chlorinated lime (bleaching powder) and calcium hypochlorite (high test hypochlorite (HTH)). The solids are often dissolved in water to make appropriate strengths of chlorine solution suitable for dosing, but some dosers are designed to make direct use of solids.

Recent developments in equipment have meant that manufacture of sodium hypochlorite solution from the electrolysis of a solution made from common salt is now often feasible on a small scale. This means that it is now possible to de-centralise hypochlorite production to wherever electricity is available. (CDC, 2000)

Categories of chlorinator

The main categories of chlorinator other than gas chlorinators and electrically powered dosing pumps are briefly described in the following sections. Suggested selection criteria and applications for the different types are shown in Table 1. Sometimes only part of the water to be treated passes through the doser. This is acceptable as long as the two streams are subsequently thoroughly mixed together. Simplified sketches of a number of gravity-driven chlorinators are presented in Figure 1.

Water-powered devices

- *paddle-wheel dosers* are driven by a paddle-wheel that is partly submerged in water flowing in an open channel. The wheel drives a horizontal shaft, which rotates a number of small containers in and out of a tank of chlorine solution. The containers lift solution from the tank and tip it into the water in the channel;
- *float-powered chemical dosers*. In this type the water to be treated passes through a small tank, equipped with a fast-acting siphon that rapidly empties the tank each time it fills. As the water level rises in the tank, it lifts a float. The float is connected to a dosing cup that is submerged in a separate tank of chlorine solution. As the float rises, the cup is lifted out of the solution and is pushed onto a plunger that displaces a fixed dose into the water tank just before it empties;
- *hydraulic motor/piston driven dosers* are used where the water to be dosed is flowing in a pipe. The dosing pump is either a piston pump or a diaphragm pump. The pump's reciprocating movement is created either directly, by connecting it to a larger piston driven by the water, or through a cam driven by a small turbine rotated by the water;
- *venturi and orifice dosers*. When water flows through a constriction in a pipe the velocity of the water increases and its pressure reduces at the constriction. In this type of doser the difference between the upstream pressure and the pressure at the constriction is used to draw chlorine gas, or a chlorine solution into the pipe;
- *direct-suction dosers* can be made by connecting a small pipe to the side of the main suction pipe of a water

pump. Then, when the pump is operating, chlorine solution will be drawn into the water; and

- **displacement-bag dosers.** In this doser the chlorine solution is held in a flexible bag in a sealed cylinder. A little of the water that is being pumped flows through a small pipe into the cylinder, but outside the bag. This water slowly squeezes solution out of the bag into another pipe that discharges it into the water being pumped.

Diffusion chlorinators

- **pot chlorinators** use a perforated container full of a mixture of coarse sand and chlorine compound such as bleaching powder (chlorinated lime) or calcium hypochlorite. The container is then suspended in a stationary body of water such as a well. The chlorine slowly diffuses into the water. There is some doubt about the effectiveness of these devices;
- **floating diffusers** consist of a float which carries a vertical cylinder in which there is a stack of large diameter tablets of a chlorine compound such as calcium hypochlorite. The device is floated on the surface of the water to be treated. The bottom of the stack is submerged so that chlorine can slowly diffuse into the water. As these tablets dissolve away other tablets slip down the cylinder to ensure that a constant depth of tablets is always submerged. The effectiveness of this device is doubtful;
- **continuous flow diffusers** are similar to the floating diffusers but the device is stationary and the water to be treated flows across the device past the tablets at the bottom of the cylinder to collect a high dose of chlorine; and
- **intermittent-flow diffusers** are similar to the continuous flow diffusers but have a drain hole for draining the water away from around the tablets when the flow stops.

Gravity-driven chlorinators

If a fixed pipe is used to drain a tank of chlorine solution the rate at which it discharges solution will vary as the level of the liquid in the container falls. Gravity-driven dosers are normally required to give a stable dose so are designed to overcome this problem by providing a fixed 'head' (shown by 'h' on the diagrams in Figure 1). A valve, or a clamp on a flexible pipe, or a change in the height of the discharge end of the outlet can be used to adjust the flow on most of these devices.

- **Mariotte jar.** This doser consists of a large (e.g. 20-litre) sealed, rigid bottle that contains the chlorine solution. The jar is fitted with a vertical small-diameter air-inlet pipe, and a separate smaller diameter outlet pipe. Both pipes terminate inside the jar below the level of the liquid. Various arrangements can be used but the essential factor is that the level of the end of the air-inlet pipe in the jar is a little higher than the level of the end of the outlet pipe. As the solution flows out of the jar through the outlet pipe, the pressure of the air above the liquid reduces to below atmospheric pressure and air bubbles are sucked into the jar through the air-inlet pipe. This arrangement ensures that the pressure in the jar at the level of the end of the air-inlet pipe remains constant at atmospheric pressure, despite the fact that the depth of the liquid in the jar is falling. This maintains a constant discharge of the chlorine solution;
- **Inverted bottle with water seal.** This also uses a large rigid bottle full of the solution to be dosed. The bottle is inverted with its open mouth submerged in a small container. An outlet pipe slowly drains solution from the container, causing the level of the liquid to slowly drop. As soon as its level falls below the mouth of the bottle a bubble of air enters the bottle, displacing some

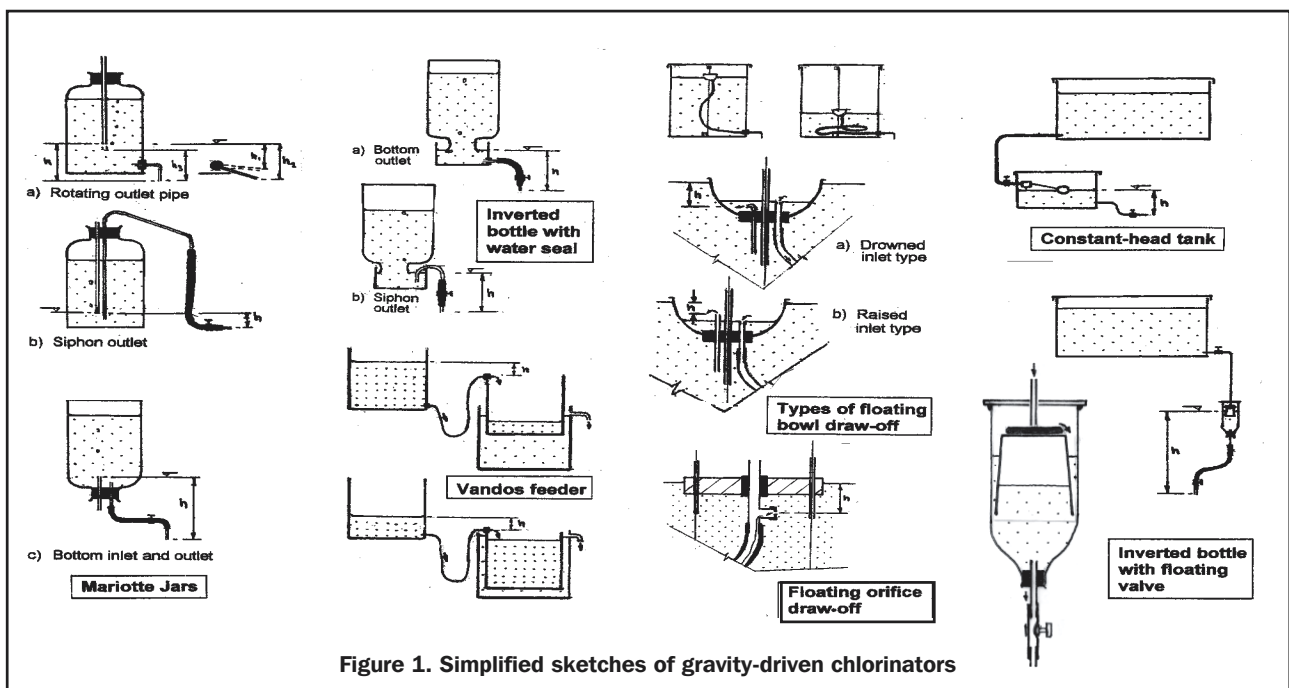


Figure 1. Simplified sketches of gravity-driven chlorinators

of the liquid which then flows into the container. This raises the level in the container slightly above that of the mouth of the bottle. The level then begins to fall again, until once more air can enter the bottle. This means that the level of the liquid in the container is relatively stable, resulting in a constant discharge through the outlet pipework;

- **Constant-head tank.** In this device, chlorine solution flows from one tank, through a float valve and into a smaller tank. This valve maintains the level of the solution in the small tank so that flow from it, through the dosing pipe remains constant;
- **Inverted bottle with floating valve.** This doser is described by Solsona (1990 p20). The bottle is a form of the constant-head tank just described. It is made from an inverted plastic bottle which has had its bottom removed so that an upside-down plastic cup can be inserted into it to float on the chlorine solution that partly fills the bottle. The cup, which has a soft piece of rubber glued to its base, acts as a valve, when it pushes against the end of the inlet pipe. As solution leaves the bottle the cup moves down slightly, allowing more solution to enter the bottle. This makes the cup rise again, which stops or reduces the flow once more. In this way a constant level of liquid is maintained in the bottle, resulting in a stable discharge.
- **Floating draw-off.** Floating orifice devices provide a submerged floating inlet in a tank of chlorine solution. This inlet is connected to a flexible pipe that passes out of the tank near to its base. The inlet is always a constant distance below the surface of the liquid, and the size of the inlet and its depth below the surface controls the discharge along the flexible pipe. The inlet point must control the flow so there should not be any flow control valve on the pipe. One or more vertical fishing lines, or another device is used to keep the float central in the tank.

Floating bowls can be used instead of a solid float but these have separate inlet and outlet pipes. The inlet pipe controls the flow. Small stones can be placed in the bowl to adjust the depth at which it floats in the water; and

- **Vandos chemical feeder.** Solsona (1990 p21) describes this type of feeder. It uses two identical cylindrical drums. The first drum is initially filled with water that flows into the second drum at a controlled rate through a flexible pipe. The second drum floats in a tank that contains the chlorine solution. As the water flows into the second drum it becomes heavier, so it sinks into the tank, displacing an equal amount of chlorine solution. This solution overflows through a high level outlet to the dosing point. Although the level of water in the first drum drops, it is falling at the same rate as the inlet to the second drum is sinking, so this maintains a constant level difference, and hence a constant flowrate. Periodically the water in the second drum is transferred back to the first drum and the tank is refilled with chlorine solution.

Avoiding problems

Precipitates, crystallisation and scaling

The use of solutions made from calcium hypochlorite and chlorinated lime can lead to problems, particularly with hard water. The production of calcium carbonate may result, which can block orifices. The formation of deposit at a drip feed nozzle can be reduced by enclosing it in a small, free-draining container that reduces air movement around the nozzle. The container should be transparent so that the nozzle can be observed.

When making chlorine solutions from solids or powders sufficient time must be allowed for the non-soluble solids to precipitate. Then the clear solution should be carefully decanted ready to be used for dosing. Simple filters can also be used on the outlet from the solution tank to hold back any particles that remain.

Deterioration of chlorine compounds

All chlorine compounds are prone to losing their effectiveness over a period of time particularly if they are exposed to air, light, moisture or heat. Hence compounds need to be as fresh as possible and be carefully stored. Assumptions made about the chlorine content of compounds needs to be regularly checked by testing the solutions that are made from them for dosing. Calcium hypochlorite is the most stable compound.

Variability of chlorine demand

The amount of chlorine solution that needs to be added to the water from a source to ensure proper disinfection may vary at different times of year. Sedimentation and filtration that precede chlorination of surface water sources should reduce the variability in the dose required, but adjustments to the dose are still likely to be required.

Testing effectiveness

Whatever the source of water and type of chlorinator being used, it is important to regularly test the actual level of 'free residual chlorine' in the treated water. This testing should take place after all of the water has been in contact with the chlorine for a sufficient period. If the pH of the water is less than 8.0, then after a contact time of at least 30 minutes, the concentration of free chlorine should be at least 0.5mg/litre to indicate successful disinfection (WHO 1993 p24). However this assumes adequate treatment of surface water before chlorination. The chlorination should only be considered to be reliable if the testing regime shows that the required residual is always being attained.

Coping with intermittent and variable flow

As shown in Table 1, only a few types of chlorinators can deal with variable and intermittent flow. Most simple chlorinators need an operator to stop the flow of solution. Suitable on/off features will be required for gravity-driven chlorinators that dose at a constant rate but only need to operate during part of the day or night (e.g. only when a pump is working).

Conclusion

Chlorination is still usually the most appropriate method of disinfecting water for community supplies. It is hoped that

this paper will contribute to the wider adoption of chlorination for the disinfection of small-scale water supplies in developing countries.

In this short paper only very limited information has been provided about each chlorinator. Further information can be found in Skinner (2001), a WELL Technical Paper funded by DFID. It includes many useful references to sources of printed and electronic information.

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BRIAN SKINNER, WEDC

Table 1. A comparison of small-scale chlorinators

Selection Criteria and Appropriateness for Different Water Sources		Key to letters used in boxes: y – yes, p – probably, u – unlikely, n – no l – low, m – medium, h – high															
		Gravity-driven					Water-powered					Diffusion					
		Marlotte jar	Inverted bottle	Constant-head tank	Inverted bottle + valve	Floating draw-off	Vandos-feeder	Wheel-feeder	Float-powered	Hydraulic drive	Venturi systems	Direct suction	Displacement bag	Pot/floating units	Continuous flow	Intermittent flow	
Needs moving water for power or for tablet erosion		n	n	n	n	n	n	y	y	y	y	y	n	n	y	y	
Suitable for dosing into flowing water		y	y	y	y	y	y	y	y	y	y	y	y	n	y	y	
Suitable for intermittent flows of water		p	n	n	n	n	n	y	y	y	y	y	n	n	y		
Suitable for dosing at high rates		n	n	p	n	n	n	p	p	y	y	y	n	p	p		
Suitable for dosing against water pressure		n	n	n	n	n	n	n	y	y	n	p	n	n	n		
Can be made locally		p	y	p	y	y	y	p	u	n	p	u	y	p	u		
Spares supply for moving parts may be a problem		n	n	n	n	n	n	p	p	p	p	n	p	n	n		
Level of skills required for major maintenance tasks		l	l	l	l	l	l	m	m	h	m	m	l	l	l	l	
Needs calcium hypochlorite tablets		n	n	n	n	n	n	n	n	n	n	n	n	n	y	y	
GROUNDWATER	Open well - bucket withdrawal Dosing into well	u	u	u	u	u	u	n	n	n	n	n	n	p	n	n	
	Well or borehole – handpump withdrawal							n	n	n	n	n	n	n	n	n	
	Connection to suction pipe												p				
	Dosing into well or borehole	u	u	u	u	u	u						p				
	Well or borehole – powered pump withdrawal, pumping directly into distribution pipework							n	n						n	n	
	Dosing into pipe near pump									y	y	p	y				
	Dosing into well or borehole	p	p	p	p	p	p							p			
	Well or borehole – powered pump withdrawal and pumping to elevated tank																
	Dosing into pipe near pump									y	y	p	y				
	Dosing into well/borehole	p	p	p	p	p	p							p			
Dosing at entry to tank							u	y	y	y		y	p	y	y		
SURFACE WATER (for pre-treatment)	Spring - gravity flow into pipework										n						
	Dosing into pipe							u	p	p		p					
	Dosing into spring box/storage tank	p	p	p	p	p	p		p					u	u	u	
	Dosed into gravity flow pipework								y	y	u		p				
	Dosed into pipe near pump								y	y	y	y	y				
	Dosed into flow in channel	u	u	p	u	p	p	y									
Dosed at piped entry into contact/storage tank								y	y	y		y	u	y	y		
RAINWATER (domestic systems)																	
Stored rainwater many not need treatment. If it does, none of these methods are really appropriate. Batch treatment in domestic containers is probably the best option.																	

Notes:

- Whatever dosing method is used it is important that there is sufficient contact time between the chlorine and the pathogens before the water is consumed.
- For all of these sources batch treatment at some stage is usually an alternative option. For all sources, other than those using buckets or handpumps for water withdrawal, this can be carried out in tanks of known volume. In these tanks the water can be mixed with a predetermined dose of chlorine. This tank can also conveniently act as the 'contact tank', in which the water is retained for the time necessary to ensure that it is in contact with the chlorine for sufficient period to kill any pathogens.
- For all sources batch treatment at domestic level in household containers is also an option.