TECHNOLOGY MISSION ON DRINKING WATER IN VILLAGES AND RELATED WATER MANAGEMENT

TECHNOLOGY PACKAGE ON

DISINFECTION OF DRINKING WATER

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JUNE 1987

1. INTRODUCTION

In a developing country like India, biological water supplies is a major concern. It is mainly due to lack of sanitation and waste water treatment facilities and personal hygiene. The water sources by sewage or fecal matter results in entry of disease producing microorganisms making water unfit for human consumptions.

Table - I : A classification of water related diseases.

Sr.No.	Category	Disease	Remedy
1.	Water borne infections	Typhoid, Cholera Jaundice, Dysentery	Microbiological improvement in water quality
2.	Water washed infection (skin, eyes)	Scabis, Trachoma	Greater volume of water for use
3.	Water based infection	Schistosomiasis Guinea worm	Protection of user and source
4.	Water related insect vectors Breeding in water	Sleping sickness yellow fever Malaria	Water piped from sources

2. PATHOGENIC MICROORGANISMS :

Different groups of microorganism which cause water borne diseases are shown in Table - II

Table - II : Pathogenic microorganisms causing diseases

	Organism	Disease
Bacteria :		
	Salmonella	Enteric fevers (Typhoid, paratyphoid) Gastroenteritis
	Shigella	Dysentery
	Vibrio cholerae	Cholera
Viruses :		
	Infectious hepatitis B	Jaundice
	Polio virus	Polio
	ECHO, Coxackie	Gastroenteritis
Protozoa :		
	E. histolytica	Amoebic dysentery
	Giardia	Giardiasis
	Endamoeba coli	Gastroenteritis
Helminths :		
	Tape worm	Gastroenteritis
	Round worm	

3. DISINFECTION :

It is the process of destructions or at least complete inactivation of harmful pathogenic microorganism present in the water. The chemical or agent used in this processes is termed as Disinfectant.

3.1 Types of Disinfectants

Two types of disinfectants

1) Chemical 2) Non-chemical.

3.1.1. **Chemical Disinfectants :**

Requirement :
- Effective in killing pathogenic microorganisms
- Readily soluble
- Not imparting taste, odour or colour to water
- Not toxic to human life
- Easy to detect
- Easy to handle, transport apply and control
- Readily available

3.1.2. **Types of Chemical Disinfectants :**

a) Chlorine and Chlorine compounds :

It is mostly used because
- It destroy microbes quickly
- Widely available
- Cost is moderate

b) Iodine :

It is not used mostly because of its limitations like :
- High doses (10-15 mg/L) requirement
- Not effective when water is coloured or turbid
- High volatality in aqueous solution

c) Potassium Permangnate :
- It is a powerful oxidizing agent
- Effective against cholera and not against other pathogenic microbes
- Leaves stains in container

d) Ozone :
- Effective against compounds that give objectionable test or colour
- leaves no measurable residuals
- High installation and operational cost
- Needs continuous power supply

3.2. **Non-chemical Disinfectants :**

3.2.1. **Boiling :** It is safe and time honoured which destroys pathogenic microorganisms. It is effective at household level but not at community level.

3.2.2 **U.V. & Gamma radiation :** Light irradiation is effective for clear water and not for turbid water. It is ineffective when water contain nitrate, sulphate, ferrous ion. It does not produce any residual.

4. **CHLORINATION :**

Chlorine, in one form or other, is the most common disinfectant. Its action is to destroy the enzymes essential for the existance of microorganisms. In addition to its germicidal ability, chlorine oxidizes iron, manganese and hydrogen sulphide. It destroys taste and colour producing constituents and controls algae and slime. It also aids coagulation.

Chlorine as disinfectant can be applied in following forms :

Chlorine gas :
- Greenish yellow, toxic
- Heavier than air
- Dry gas non-corrosive
- Soluble 1% by wt. at $10^{o}C$.

Chlorinated lime (Bleaching powder) :
- Easily available source of chlorine, cheap, easy to apply.
- Chlorine content is 33%.

High test hypochlorite :
- 60-70 percent available chlorine granular or tablet form.

Sodium hypochlorite :
- Available in solution form 12-15 percent available chlorine.

Chlorine dioxide :
- Strong oxidizing and bleaching agent.

4.1 **Reaction of chlorine in water :**

a) **Chlorine demand** : When chlorine is added to water it reacts with chemical constituents present in it such as ammonia, sulphurdioxide, iron and manganese, making less available for germicidal effect. Hence it is necessary to add sufficient chlorine, so that it should be in residual form after realising with different chemical biological constituents. Chlorine demand is the difference between the amount of chlorine added to water and the amount of free combined available chlorine remaining at the end of specified contact period.

b) **Chlorine chemistry** : In water chlorine hydrolyzes and form hypochlorous acid (HOCl)

$$Cl_2 + H_2O \quad \text{--------} \quad HOCl + H^+ + Cl$$

The hypochlorous acid undergoes further ionization to form hypochlorite ions (OCl)

$$HOCl \quad \text{--------} \quad H^+ + OCl.$$

Chlorine may also be applied as calcium or sodium hypochlorite. These compounds readily dissolve in water and contain approximately 70 percent available chlorine.

$$2\ Ca\ OCl_2 + 4H_2O = 2\ Ca\ (OH)_2 + 2\ HCl + 2HOCl$$

$$2\ HOCl \quad \text{----------}\rightarrow \quad 2H^+ + 2\ OCl^-$$

Equilibrium concentration of HOCl and OCl^- depends on the pH and temperature.

Both HoCl and OCl^- are important for disinfection. The theory says that HOCl is more active than OCl^- ion for killing microorganisms as it diffuses more effectively through cell membranes and form nascent oxygen which is toxic. The enzyme attacked is triosephosphate dehydrogenase found in most cells and is essential for digesting glucose.

c) **Reaction with Ammonia :**

Chlorine is a very active oxidizing agent and is highly reactive with readily oxidized compounds such as ammonia. It reacts with ammonia to form chloramine.

$$HOCl + NH_3 \dashrightarrow H_2O + NH_2Cl$$
(monochloramine)

$$HOCl + NH_2Cl \dashrightarrow H_2O + NH\,Cl_2$$
(dichloramine)

$$HOCl + HN\,Cl_2 \dashrightarrow H_2O + NCl_3$$
(Trichloramine)

The specific reaction products formed depend on the pH of the water, temp, time and the initial chlorine to ammonia concentration ratio. In general both monochloramine and dichloramine are generated in the pH range of 4.5 to 8.5. Above pH 8.5 monochloramine exists. However below pH 4.4 trichloramine is produced.

d) **Break point chlorination :**

When chlorine is mixed with water containing ammonia, initially chlorine will be consumed by forming chloramine resulting in no free residual chlorine (HOCl or OCl). Further additions of chlorine, results in breaking down chloramine and NH_3 to nitrogen and HCl in which case there is no residual chloramine. The point at which minimum concentration of chloramines are observed is called breakpoint chlorination. Further addition of chlorine after breakpoint chlorination results in formation of free residual chlorine.

These reactions are shown in Figure 1:

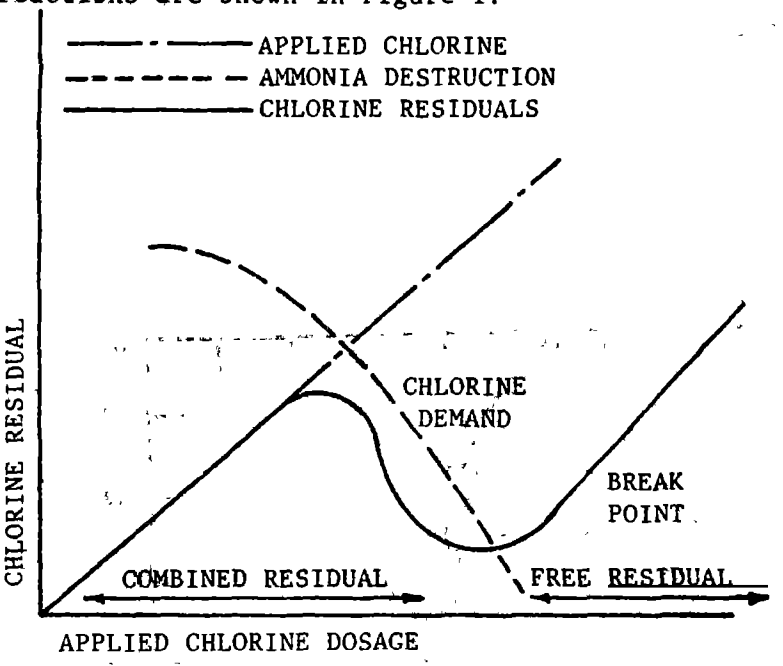

FIG. 1 : Characteristic breakpoint chlorination curve.

Break point curves are unique for different water samples, since the chlorine demand is a function of the concentration of ammonia, presence of other reducing agents and the contact time between chlorine application and residual testing.

e) Effect of Contact time, pH and temperature :

Efficient disinfection of water with chlorine depends on Type of chlorine residual, contact time, Temperature & pH.

4.2 Type of chlorine residual :

Free chlorine : Hypochlorous acid (HOCl)- more effective
Hypochlorite ion (OCl^-)- less effective

Combined chlorine : Monochloramine - Most effective
dichloramine - less effective
Trichloramine - least effective

The pH of water decides the formation of HOCl and (OCl^-) as shown in Figure 2.

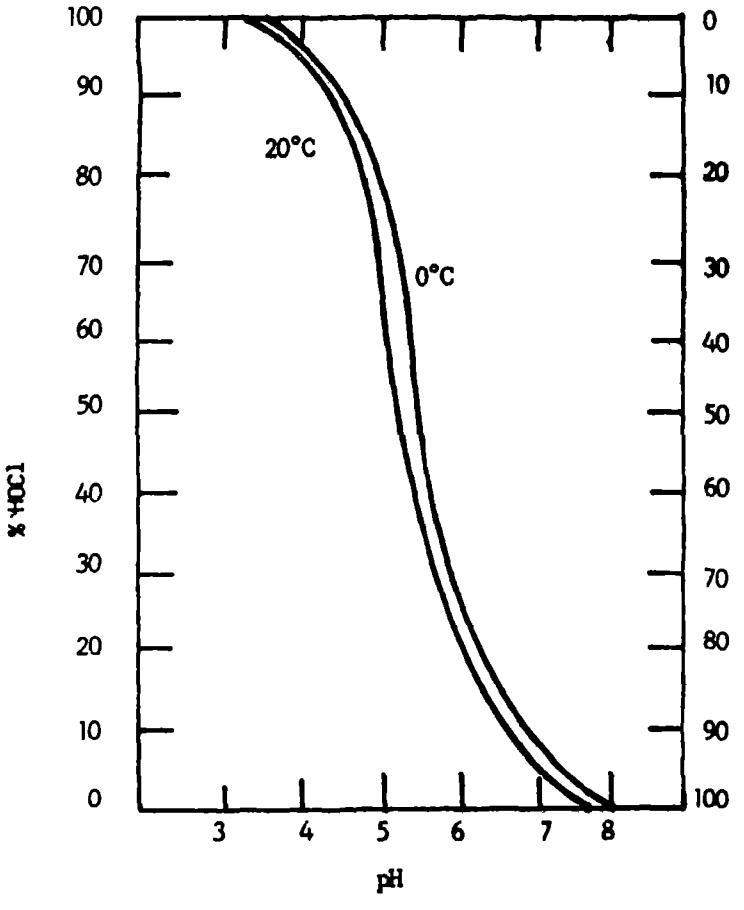

FIG. 2 : Shows relative amounts of HOCl and OCl^- formed as function of pH (3).

4.2.1 Combined available chlorine known as chloramines are slower than free chlorine in killing microorganism. For identical conditions of pH 6-8 it takes 25 times more combined chlorine to produce the same germicidal efficiency as that of free chlorine. The concentrations of these residuals required for 99 percent kill of *E.coli* are shown in Figure 3.

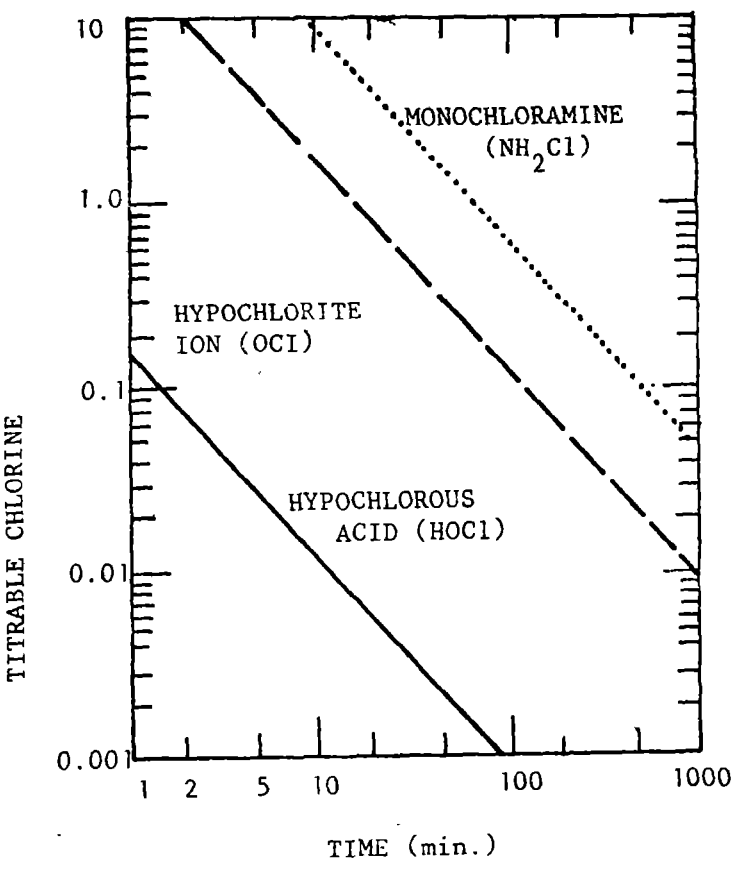

FIG. 3 : Shows the realationship between concentration and time for 99% destruction of Escherichia coli by different forms of chlorine at 2-6°C, as reported by Chambers (5).

4.2.2 Inactivation of Viruses :

The different groups of microorganisms behave differently towards residual chlorine. For example, viruses are more resistant to chlorine than bacteria. The effect of hyprochlorous acid on survival of different viruses and bacteria is shown in Figure 4.

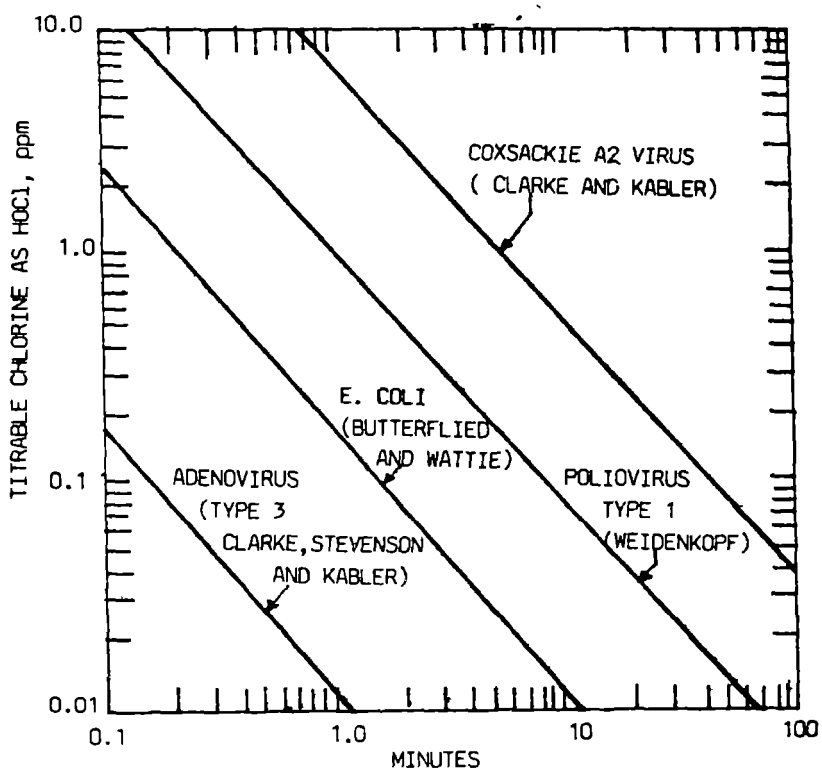

FIG. 4 : Concentration-time relationship for 99% destruction of Escherichia coll and several viruses by HOCl at 0 to 6°C.

5) CHLORINE ESTIMATION :

1) DPD method (Dl-ethyl para phenylene diamine)

   DPD + Cl_2 ---------- Red colouration.

2) Orthotoludine method.

   Orthotoludine + Cl_2 --------- Yellow colour.

6. NEERI DISINFECTION TECHNIQUE :

6 1. Bleaching powder quality :

- Calcium oxychloride
  ($CaOCl_2$ - Mol. WT - 127) 62.5 percent
- Molecular wt. of chlorine = 71
  (Cl_2)

- Actual wt. of chlorine present = 35 percent.
- Useful for small communities.
- ISI Standards (ISI - 1065 - 1957) Bleaching power should contain 33 percent available chlorine

6.2. Drip type chlorinator :

a) It was developed by this Institute in the form of container made of cement mortar (2.5 cm thick with chiken mesh reinforcement) which could be mounted on the parapet wall of well and from which the chlorine solution was fed by gravity through a special dropper in the out let tube (Fig 5). In the initial stage it was provided near the bottom of the container but was found to get choked frequently.

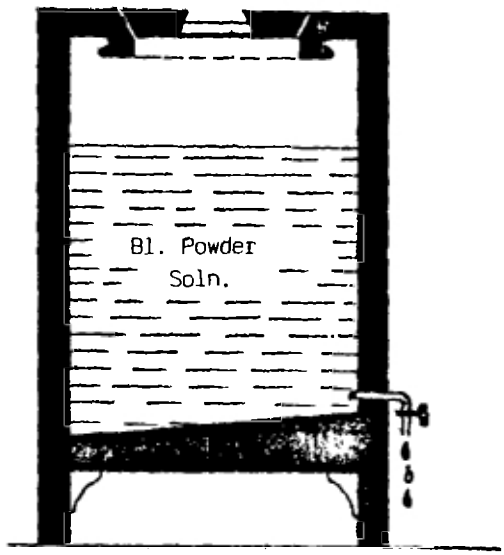

FIG. 5

b) The position of the out let was then shifted to the surface of bleaching powder solution by using a plastic float with an glass orifice inlet. (Fig. 6). This arrangement ensured a constant head discharged but the inlet orifice was getting chocked within two days run which was due to deposition of calcium carbonate in the orifice, owing to the interaction of atmosphere carbon dioxide with bleaching powder solution.

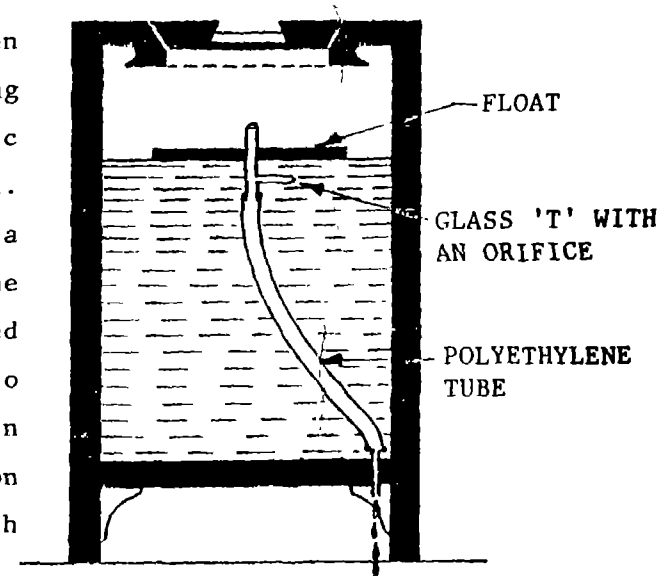

FIG. 6

c) To avoid chocking the inlet orifice was replaced by a larger diameter glass tube which acted only as a collector and control of the feed rate was done by providing a stop cock made up of plastic in the out let tube (Fig. 7). It was failed due to depositing calcium carbonate on either side of the stop cock.

d) In order to obviate this difficulties, a special glass dropper similiar to one used in medical transfusions was inserted in the outlet tube which was carried right down into the well and dipped into water (Fig. 8). It worked for a period of 6.8 days after which it was chocked in the stop cock and cleaning readjustment was necessary. The container was capable of holding enough chlorine solution for a weak period.

Before starting the chlorinator sufficient quantity of bleaching powder may be added to the well water to satisfy its initial chlorine demand which has been found to be generally in the range of 0.5 to 1.5 pm. 1 percent bleaching solution is made and kept overnight for settling. The supernatent is used for charging the chlorinator.

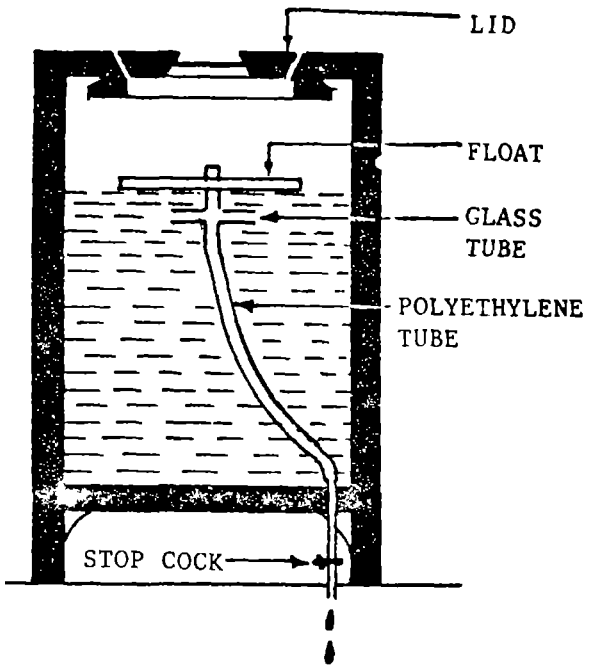

FIG. 7

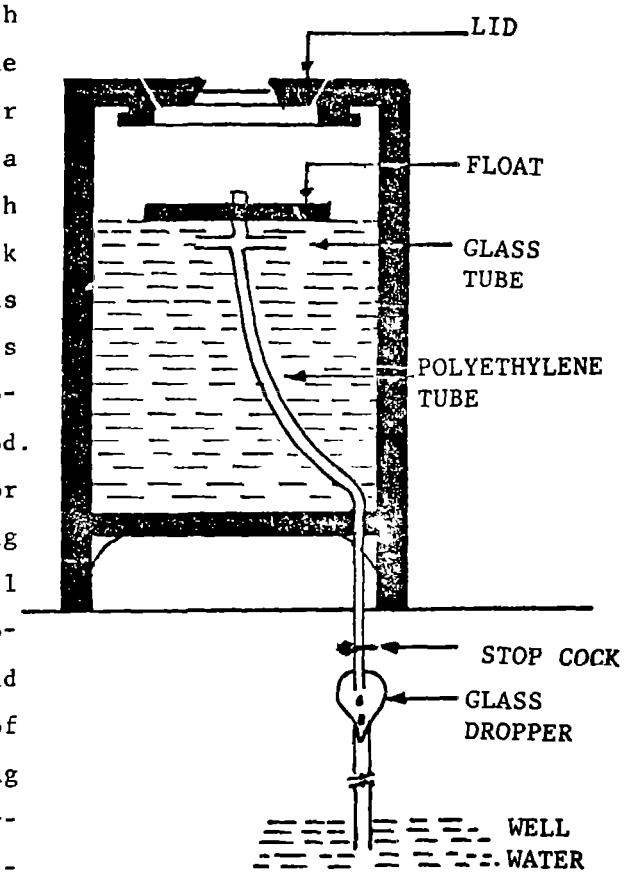

FIG. 8

6.3. Pot chlorinator :

In rural areas most of the people depends on well water as source of drinking water. In order to make water potable it should be disinfected continously.

a) **Single pot chlorinator :**

Pot chlorination where bleaching powder is used as chlorine source was developed. Its salient features are as follows (Fig. 9).

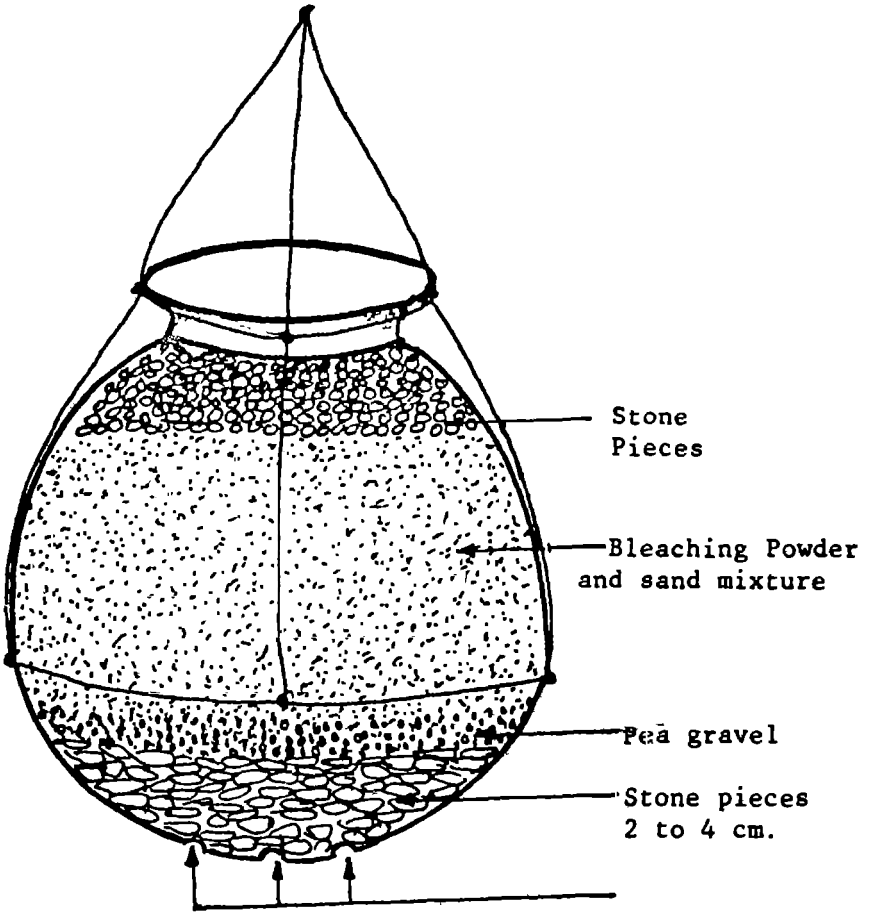

FIG. 9

- A earthen pot of 12.15. liter.
- Two 0.6 cm diameter holes in middle.
- 1.5 kg Bleaching powder and 3 kg of coarse sand - a moist mixture.
- Covered with poly ethylene paper.
- Lowered in well 2 ft. below the surface water.
- Chlorinate well of 9000 - 13000 liters water content having withdra wl. of 900 - 1300 liters per day.
- Works for a period of atleast one weak.
- Residual chlorine 0.2 to 0.8 p.pm.

b) Double pot chlorinator :

When a single pot with holes either in the middle periphery or at bottom is used in small household wells (400 litres) having withdrawl rate of 360 to 450 litres of water per day, it over chlorinate such wells. For this purpose a unit consisting of two cylindrical pots as shown in (Fig. 10). was developed.

- Two cylindrical pots one inside the other.
- Moist mixture of 1 kg beleaching powder and 2 kg of coarse sand in innerpot little below the level of holes.
- Outer pot covered with polyethylene paper.
- Outer pot had a hole at bottam.
- Lowered in well with the help of rope 1 metre below the level of water.
- Work for a period of 2-3 weeks.
- Residual chlorine in the range of 0.15 to 0.5 p.pm.

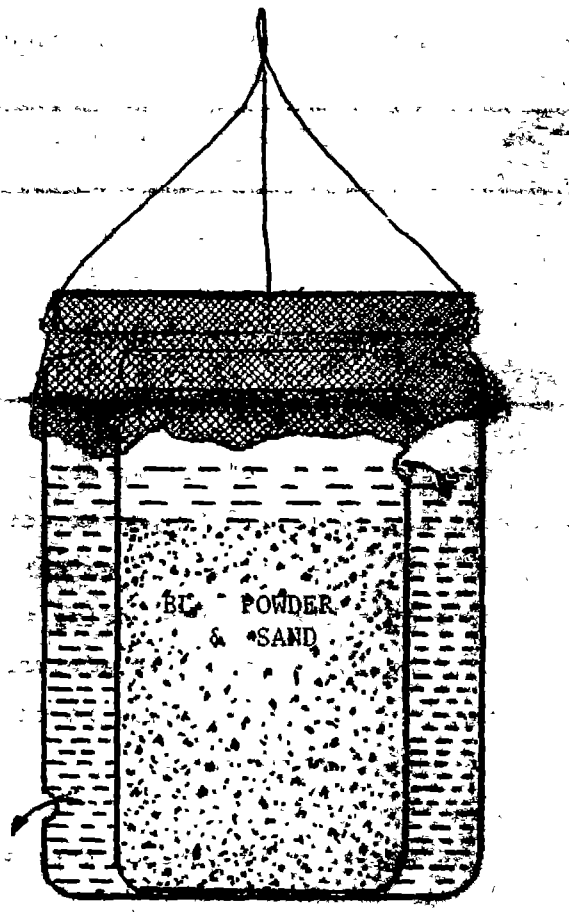

FIG. 10

6.4. **Chlorine Ampules :**

- Glass ampules with 1,5,10 and 20 ml chlorine solution content.
- Bleaching powder is used to prepare chlorine solution.
- 1 ml of chlorine solution contain 5.00 mg of chlorine.
- Shelf life of ampule is about 2 years.
- Available in amber colour bottle also.
- Used in emergency disinfection like floods travel earthquake.
- Process patented.
- Available with NRDC.

6.5. **Chlorine Tablets :**

Available in four sizes. Each size is providing a fix range of chlorine in the quantity of water recommended to be treated as follows :

Mass of Tablet (gms.)	Amount of Chlorine (mg)	Volume of water (Lit)
2.5 ± 0.125	300 ± 60	240
0.5 ± 0.025	25 ± 5	20
0.25 ± 0.013	5 ± 1	4
0.125 ± 0.005	1.25 ± 0.5	1

- Ingredients are soluble in water.
- Tablated at 1.5 to 2.0 kg per sq. cm. pressure.
- Tablet does not desintigrate quickly.
- Powdering of tablet before adding to water is perferable.
- Slow stiring for a minute is advisable.
- Dose should be 2 mg. per lit. to unknown water.
- Contact period 30 minutes.
- Patented through NRDC.
- Patent released to 15 parties through NRDC.

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