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Rural Potable Water Chlorination

World Water Resources, Inc, Bethesda, Md

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Rural Potable Water Chlorination

William E. Hanford Jr.
Alfred Long

WATER WASTE AND SEWAGE TREATMENT SEMINAR

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16. Abstract (Limit: 200 words)

The paper addresses two questions: (1) What is the most desirable form of sanitizing chemical for use in rural water supplies; and (2) What is the best overall means of getting this sanitizing agent into rural water supplies. Several chemicals and hypochlorinators are described and evaluated. In conclusion, a low-cost, dependable feeding device suitable for use in disinfecting marginal waters in the rural areas of developing countries is presented. The operation and maintenance of this device is easy for the unskilled labor in these areas; no sophisticated power source is needed to provide continuous, automatic operation; the device uses a readily available, commercial chlorine chemical that can be economically shipped, stored, and used at these points of need. An appendix is also included giving technical specifications and performance data.

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RURAL POTABLE WATER CHLORINATION

Up to this point of the seminar we have heard some excellent ideas on solutions to problems for large water systems. Most of this information has been extremely useful for metropolitan areas but because of high cost, locality and labor it probably is not applicable to rural areas. Yet, the water problem in rural areas is a substantial problem. It is a pressing problem! It is a problem of life and death! In the rural areas, water borne disease often becomes rampant. For example, in Thailand over 30,000 villages, each having between 500 and 10,000 inhabitants, are in need of safe water for drinking and cooking. In these locations, 40% of the mortality is due to dysentery, cholera and typhoid fever caused by water borne diseases, while 60% of the morbidity can be traced to infected water. Obviously, this problem must be corrected for reasons of political stability and economic development as well as humanitarian considerations. Therefore, while it is desirable to develop in these areas effective systems for delivering water, systems for removing turbidity, and even perhaps means for softening water, the most pressing problem is to make the water safe for drinking. Rural water must be made safe to drink in an effective, inexpensive manner!

With this in mind, I shall be considering two questions. The first question is: What is the most desirable form of sanitizing chemical for use in rural water supplies; and second, what is the best overall means of getting this sanitizing agent into the rural water supplies.

Returning to the first question - What is the most desirable form of sanitizing chemical for use in rural water supplies. There are literally dozens of possible chemicals for sanitizing water. Most, if not all of them, are probably familiar to you, but you may not have considered their effectiveness and overall economics or relation to the rural water chlorinating problem. In analyzing the various agents for consideration, I have established an eight point criteria. They are:

1. The chemicals must be a powerful sanitizing agent.
2. The chemicals must not be harmful or irritating when used as directed.
3. The chemicals must impart little objectionable taste, color or odor.

These three of the characteristics are important for the community which uses the water.

The next three criteria deal with how easily and inexpensively the chemicals can be used by a group in the rural area. These are:

4. The chemicals must be safe and easy to ship, handle and dispense (this would include equipment cost, the skill of the employees and the overall difficulty of developing the system).
5. There must be an easy test for determining how much of the chemicals should be added to the water to make sure the water is properly disinfected.
6. The chemicals must have good shelf life so that it can be stored for a reasonable period of time.

The final two factors deal with cost. They are:

7. The cost of shipping the material to the rural use point as compared to its effective disinfection rate.
8. The overall cost as determined by the cost of the material plus all the other factors. Assuming a demand of 50,000 gallon per day. This is often the most important question.

Figure A-1 shows a chart rating the elemental sanitizers, chlorine, bromine and iodine according to these criteria. Let me discuss these elemental sanitizers in more detail.

Figure A-1

	FORMULA	EFFECTIVENESS	NOT OBJECTIONABLE OR IRRITATING	EFFECT ON TASTE, COLOR & ODOR	EASE OF HANDLING AS A COST & SAFETY FACTOR	TESTABILITY	SHELF LIFE	SHIPPING COST % EFFECTIVE	OVERALL COST
CHLORINE LIQUID	Cl_2	A	B	B	F	A	B	100% B	C
BROMINE LIQUID	Br_2	B	B	B	F	B	B	100% B	D
IODINE CRYSTALS	I_2	B	D	C	B	C	B	100% C	D

ELEMENTAL SANITIZERS

Chlorine

Chlorine gas - as we all know - is the oldest, best, and most widely used sanitizing agent. Let us compare it to the eight criteria in order to establish a frame of reference.

1. Chlorine gas is an extremely powerful sanitizing agent.
2. It is not harmful or irritating when used as directed, but it is extremely irritating if it is allowed to escape, or is over-supplied.
3. Chlorine has a proven residual capable of easy testing.
4. Chlorine imparts little objectionable taste, color or odor.
5. The chemical is dangerous. It is difficult to handle, and requires expensive technical equipment which must be constantly monitored by skilled personnel.
6. The chemical has good shelf life if properly stored.
7. The chemical is 100% active but the containers are heavy which substantially raises shipping cost.
8. The chemical is expensive for rural use.

Bromine

Bromine has excellent sanitizing and algaecidal properties. The use of elemental bromine, although available, has gained little acceptance because of difficulty in handling. It is expensive for rural use.

Iodine

Although iodine has excellent disinfection properties, its slower rate of solubility and slower reaction with organic compounds make both chlorine and bromine more desirable sanitizing agents. Iodine residuals are generally more stable and persist longer in the presence of organic matter and other oxidizable matter than do chlorine and bromine residuals.

Iodine does not react with ammoniacal compounds that may be in the water, which generally means that water treated with iodine compounds produce less eye and skin irritation problems. If improperly used, however, there can be a noticeable color change in the water. Even though iodine residuals are measurable it is more difficult to test in the field. Iodine is expensive.

There are still some questions regarding medical ramifications with long term use of iodine. Although tests have been in progress for 18 months, longer tests are needed to prove that there are no harmful effects to the endocrine system. There have been reports that iodine may cause loss of hair.

HYPOCHLORITES

The next area we will discuss is the hypochlorite material. Figure A-2. First in this class is chlorinated lime.

Figure A-2

	FORMULA	EFFECTIVENESS	NOT OBJECTIONABLE OR IRRITATING	EFFECT ON TASTE COLOR ODOR	EASE OF HANDLING AS A COST & SAFETY FACTOR	TESTABILITY	SHELF LIFE	SHIPPING COST % EFFECTIVE	OVERALL COST
CHLORINATED LIME	$CaCl\,OCl + Ca(OH)_2$	A	A	F	D	A	A	±25% D	C
SODIUM HYPOCHLORITE	$NaOCl$	B	A	B	A	A	F	12–16% D	B
LITHIUM HYPOCHLORITE	$LiOCl$	B	A	B	A	A	D	35% C	F
CALCIUM HYPOCHLORITE	$Ca(OCl)_2$	A	A	C	A	A	A	70% B	A

Chlorinated Lime

Chlorinated Lime is an impure product containing ± 25% available chlorine. Although it is an effective sanitizer, the amount required to produce good disinfection causes objectionable turbidity and involves higher handling and shipping costs.

Sodium Hypochlorite

Chlorinating swimming pools with sodium hypochlorite (liquid bleach) is quite common in certain parts of the United States. The product sold for swimming pool use contains from 12-16% available chlorine when shipped. The product generally sold in stores for household bleach purposes contains approximately 5% available chlorine.

How then, does sodium hypochlorite meet the criteria for rural drinking water. Even though sodium hypochlorite is widely used as a source of chlorine sanitation, it has not always proved capable of performing the function for which it is prescribed. The reasons are:

(a) Regardless of how produced, sodium hypochlorite solutions are relatively unstable and deteriorate more rapidly than dry hypochlorites. Most manufacturers limit the shelf life of sodium hypochlorite to 60 days.

(b) Because of the relative instability of the available chlorine in sodium hypochlorite, the actual available chlorine content may be lower than that shown on the label.

(c) Sodium hypochlorite can be safely handled and it can be practically applied.

(d) The economics of sodium hypochlorite are not always as attractive as the purchaser may assume because of the relative instability of the product. For example, if sodium hypochlorite is purchased as 16% available chlorine, but decomposes to 8% available chlorine, the effective cost doubles. Other costs, of course, are incurred in the handling of bottles (glass or polyethylene) which may have to be returned for re-filling.

(e) One advantage of sodium hypochlorite is that no insolubles are added to the water when using this product. However, the use of sodium hypochlorite can cause turbid water if the water itself contains a considerable amount of calcium. The free caustic soda in sodium hypochlorite solutions greatly increases pH of the water.

Lithium Hypochlorite

Lithium hypochlorite when added to water forms hypochlorous acid (HOCl) similarly to chlorine and other hypochlorites, and complies with most of the criteria. Lithium hypochlorite, a dry product, however has two disadvantages. First, while lithium hypochlorite has good chlorine stability at temperatures below 27°C, at temperatures exceeding 27°C lithium hypochlorite has a tendency to lose its available chlorine content at a much faster rate than calcium hypochlorite or the chlorinated isocyanurates. Second, it is costly. Commercial lithium hypochlorite has only 35% available chlorine. It is about twice as expensive as calcium hypochlorite, based on available chlorine content.

Calcium Hypochlorite

Commercial calcium hypochlorite is a dry compound containing a minimum of 70% available chlorine. Calcium hypochlorite is the most widely used dry chlorine compound. The product is sold by Olin under the trade name of HTH. HTH dry chlorine is by far the leading product in this field.

How does calcium hypochlorite stand up to the eight point criteria? It has proved capable of performing the function for which it is prescribed. In fact, HTH dry chlorine has been sold for water chlorination for 35 years and was the first product of its kind in the field.

It is not harmful or irritating to humans under recommended use conditions.

When added to water, calcium hypochlorite forms hypochlorous acid and, therefore, has a proved residual which is capable of measurement by simple field tests.

Calcium hypochlorite does not impart objectionable tastes, colors or odors to water under use conditions. In fact, it is used to eliminate objectionable odors and colors in water. It is extremely stable under storage conditions.

This form of chlorine can be handled safely and applied practically. It is a strong oxidizing agent. If contaminated while in the dry state with combustible organic material a fire may result. This is minimized when tabletted.

Tabletted HTH dry chlorine is available at reasonable cost.

Calcium hypochlorite products contain a small amount of insoluble material. There is no calcium problem as long as the pH of the water is kept below 7.8.

ISOCYANURATES

Some of the more recent compounds which are being used for chlorinating water are the N-chloro organic compounds, but these are not normally used for potable water. As shown in Figure A-3, the primary ones in this field are the chlorinated isocyanurates.

Chlorinated Isocyanurates

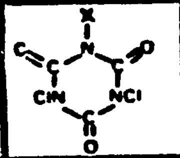
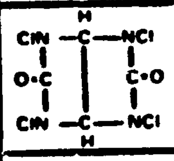
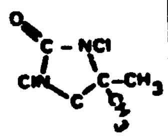
These are available as dry chloroisocyanuric acid, potassium salt and sodium salt. The sodium and potassium salts are used for swimming pool use. How do the chloroisocyanurates compounds compare with our eight point criteria?

There is still considerable debate over the ability of the chemical to perform the function for which it is prescribed. Competent authorities are still undecided as to exactly what happens when chloroisocyanurates are added to water. It is accepted that hydrolysis does take place to form hypochlorous acid. However, there is considerable discussion as to how much of the available chlorine residual is free and how much is combined.

There is still considerable debate as to the ultimate toxicity of waters which use chlorinated cyanurates as the chlorinating agent. Most public health authorities have not yet approved these products for potable water sanitation.

Because of the question of free available chlorine versus combined chlorine, there is doubt of proved residual activity capable of measurement by simple field tests.

Figure A-3

	FORMULA	EFFECTIVENESS	NOT OBJECTIONABLE OR IRRITATING	EFFECT ON TASTE, COLOR & ODOR	EASE OF HANDLING AS A COST & SAFETY FACTOR	TESTABILITY	SHELF LIFE	SHIPPING COST % EFFECTIVE	OVERALL COST
CHLORINATED ISOCYANURATES if X= Cl, H, Na, K		C	D	C	A	B	A	60-65% B	C
TETRACHLORO GLYCOLURIL		C	D	D	A	B	A	92% A	D
DICHLORO DIMETHYL HYDANTOIN		C	D	D	A	B	A	66% B	D

They can be handled safely and applied practically.

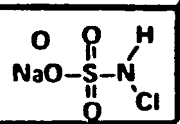
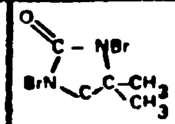
The chemical has good shelf life.

The chemical is more expensive than calcium hypochlorite.

The glycourils and hydantoins have no commercial significance for potable water applications. This also applies to the compounds shown in the next slide.

Figure A-4 is a chart showing other chemicals which should be mentioned with regard to rural sanitation. They are Sodium N-Chloro Sulfamate (mono), Chloramine (mono), Brominated hydantoin, Hypobromite and Silver. While I have prepared a chart on these materials, each one suffers from some drawback which make them undesirable. However, I mentioned them for the sake of completeness.

Figure A-4

	FORMULA	EFFECTIVENESS	NOT OBJECTIONABLE OR IRRITATING	EFFECT ON TASTE, COLOR & ODOR	EASE OF HANDLING AS A COST & SAFETY FACTOR	TESTABILITY	SHELF LIFE	SHIPPING COST % EFFECTIVE	OVERALL COST
SODIUM N-CHLORO SULFONATE (MONO-)		F	D	C	B	B	A	F	D
CHLORAMINE (MONO-)	NH_2Cl	F	D	D	C	B	B	F	D
BROMINATED HYDANTOIN		C	D	C	A	B	A	B	D
HYPOBROMITE	NaOBr	B	B	B	A	B	F	D	D
SILVER	Ag	C	C	B	A	F	A	C	F

In summary, what is the most desirable form of sanitizing agent for use in rural water supplies? There is no pat answer. Each of the chemicals we have discussed have advantages and disadvantages. But, I believe we can see that in most cases Calcium hypochlorite rates as an excellent, inexpensive agent for rural water applications.

This now brings us to the second question. <u>What is the best overall means of placing this sanitizing agent in the rural water supply?</u> For this discussion I have selected a more limited area. The devices we seek should have the following requirements:

1. Reliable performance in delivering continuous, uniform dosages of sanitizer.
2. Simple construction with a minimum number of moving parts.
3. Ease in making dosage rate changes to accommodate rapid changes in demand.
4. Simple installation requiring minimum changes in piping arrangements.
5. Shut-down provisions to prevent contact between water and sanitizer during off periods. (Midnight until dawn)
6. Sturdiness, durability, corrosion-resistance.
7. Compactness, and
8. Low cost

The basic class of devices which meet these criterion are the hypochlorinators - which dispense a solution of sanitizing agent.

There are several different types of hypochlorinators. The most common is the positive displacement, diaphragm type. It has a small pump which alternately sucks hypochlorite solution into its head, then on the reverse of the stroke forces this solution into the water to be chlorinated; a "Precision" Chemical Pump is an example of this type. A second type, the "interrupted feed" type, is that which uses the suction from the suction line of a circulating system to pull chlorine solution into the water to be chlorinated, interrupting the solution flow on a time cycle; an "Ever-Clor" is an example of this. A third type is the "aspirator" type which uses the suction created by an ejector to suck chlorine solution from a plastic tank or crock into the ejector, from which it is forced into the water to be chlorinated; a "Sure-Clor" is an example of this.

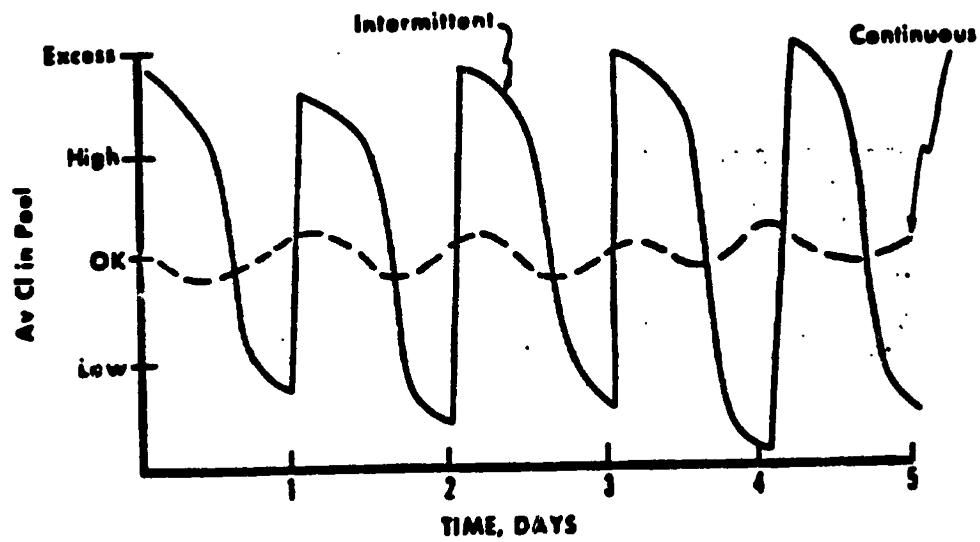
These three types of hypochlorinators may be unsatisfactory because:

1. They require pre-mixing of the chemicals with an exact amount of water and this solution ejected in accurate amounts.
2. These devices require electricity.
3. These devices may yield an uneven flow because of jamming of the feed line or pressure variations in the system.
4. These devices tend to give high and low points in chlorine addition. This is undesirable.

Figure 5 shows how continuous feeding of sanitizer keeps a reservoir within a safe available chlorine range compared to the wide fluctuations resulting from intermittent feeding. Adding sanitizer just prior to drinking does not necessarily produce acceptable water. Algae, organic residues, dirt, and debris accumulated during the down time consume the sanitizer, thereby reducing bactericidal action. With contamination entering the water constantly, it is a continuous job to combat the pollutants and obtain the water quality one should have for drinking.

Figure 5

Intermittent vs Continuous Feeding



A fourth type of hypochlorinator is the tablet hypochlorinator. There are a number of these erosion feeders on the market today.

Each of these feeders are designed around the properties of the sanitizers to overcome the inherent disadvantages of the previous types of feeders.

Products with high solubility rates have relatively short lives. These can be modified to give controlled release by densification, compounding with insolubilizing agents, or selection of product form such as tablets or cartridges.

Products having low solubility rates may be unable to deliver sufficient sanitizer when high rapid demand is encountered. This can be compensated by providing more surface in the form of smaller particles, or supplying more product in larger dissolving vessels.

Designers have cooperated with chemical producers in adapting products to the feeder, and vice versa, with varying degree of success.

Since all erosion type feeders are designed for the same purpose, of dissolving sanitizer, and since the same physical laws apply, the major differences between designs lie in the mechanical means provided for introducing and withdrawing water, the control mechanisms used, and the geometry of the unit to provide the desired contact between water and sanitizer. Feeder designers have been ingenious in developing a multiplicity of modifications to achieve this end. Typical approaches used by these designers are illustrated in the simple line sketches to follow.

The simplest design is the dissolving type illustrated in Figure 6. Slowly - soluble sanitizer is placed in a container with water inlets and outlets located at different levels. Choice of the inlets and outlets used depends on the solubility of the sanitizer and the feed rate desired. This type of feeder is suitable for chloroisocyanurates, glycouril and hydantoins. A major problem with this feeder is that the product remains in contact with water during off periods. In some cases, prolonged contact can induce product instability and generate gases in amounts sufficient to burst the container. This hazard can be eliminated by using a dependable relief valve, or by making provisions for draining and venting the feeder during down time, i.e. midnight to dawn.

Figure 6

Dissolving Type Erosion Feeder

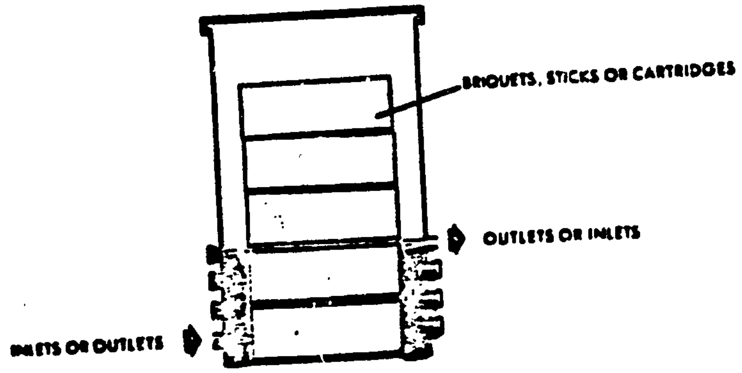
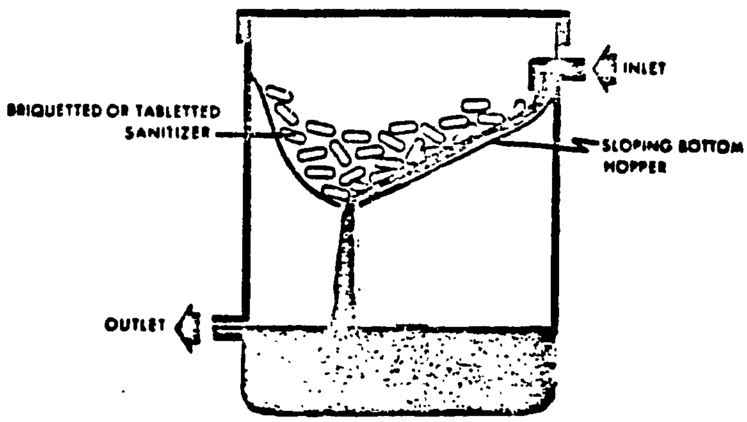


Figure 7 illustrates a design which overcomes excessive submergence of the sanitizer by water and strives to control dissolving rate by limiting contact with water to the lower surfaces of the chemical. The sloping bottom can be perforated or have a discharge slot. Additional control over dissolving rate can be gained by regulating the water inflow with orifices, sprays, valves or float control devices. Tabletted forms of moderately soluble sanitizers such as calcium hypochlorite are suited to this type of feeder.

Figure 7

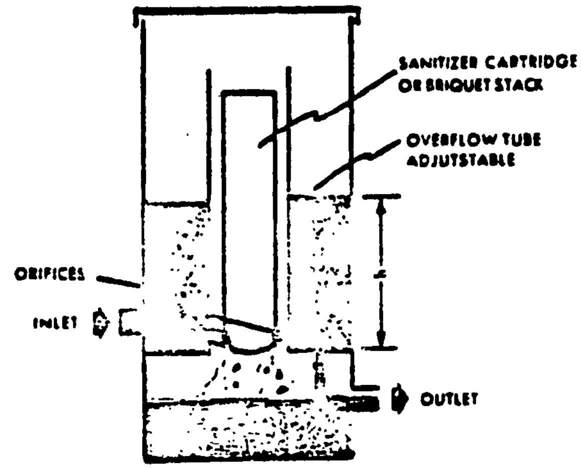
Sloping Bottom Type Erosion Feeder



A true erosion type feeder is shown in Figure 8. A jet of water is used to erode the lower end of the sanitizer charge. Control is obtained by moving the overflow tube upward or downward, thus changing the head of water over the orifices. Sanitizers that can be made in cartridge or briquette forms are usable in these feeders.

Figure 8

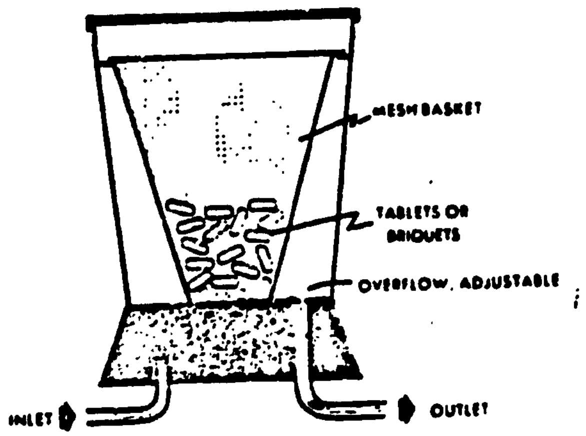
Impingement Type Erosion Feeder



The more soluble sanitizers can be dispensed conveniently from suspended basket-type feeders as shown in Figure 9. In these, only small surface area is exposed to water at any given time. Greater exposure is obtained by raising the overflow tube to increase the water level in the dissolving chamber.

Figure 9

Suspended Mesh Basket Type Erosion Feeder



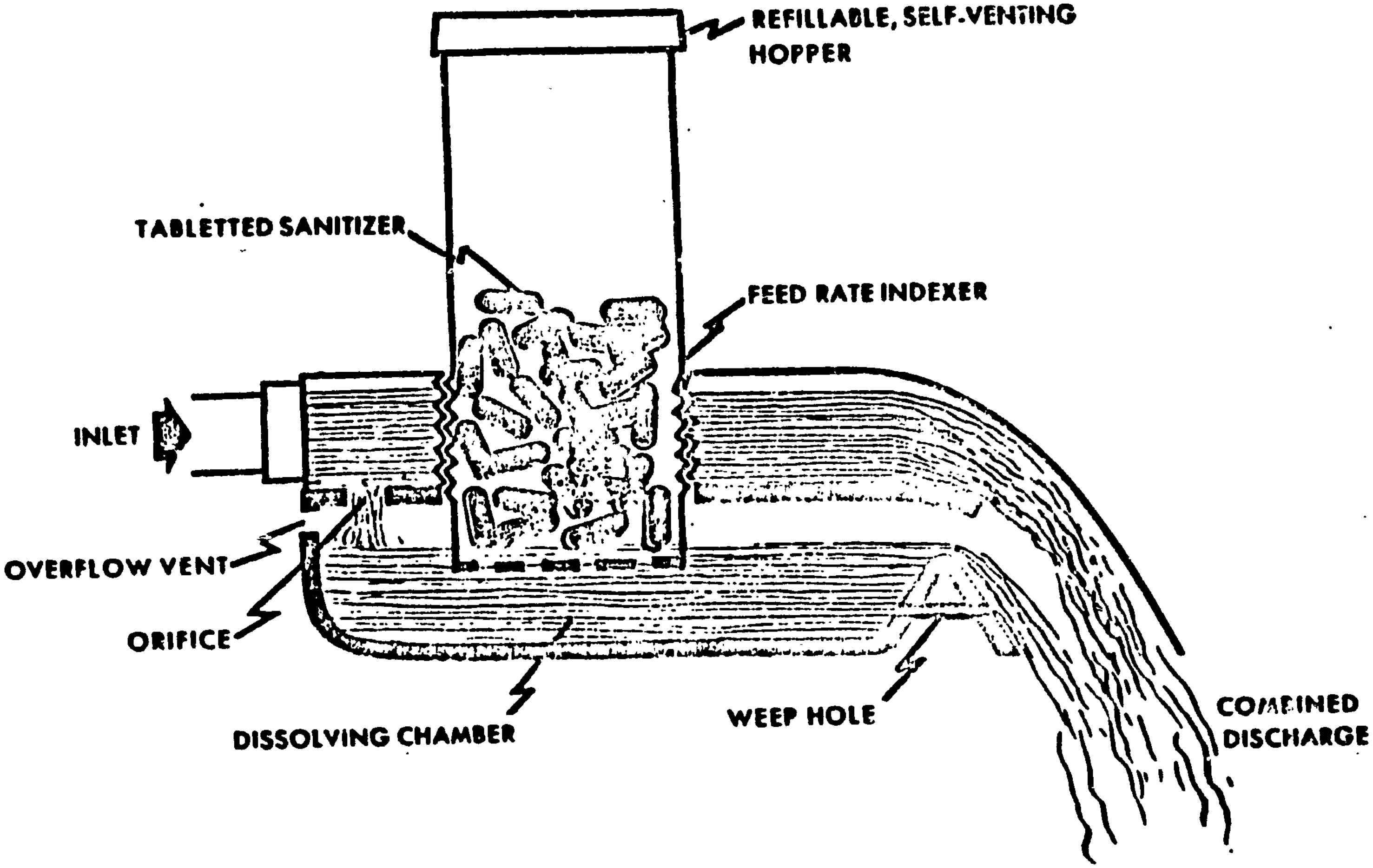
In Figure 10, an erosion feeder is illustrated having design features which satisfy most if not all of the requirements for a dependable, marketable feeding device. Features included are:

1. Capability of taking the total flow of the circulation stream without need for a special by-pass line and the associated fittings.
2. Constant level in the dissolving chamber to provide a fixed reference point for setting and providing uniform dissolving rates.
3. Adjustable control of dissolving rate by merely rotating the hopper to move it up or down to match simple index points.
4. Simple construction and compactness.
5. Automatic draining of the dissolving chamber through a weep hole to prevent contact between water and product during shut-down.
6. Overflow vents to prevent flooding of sanitizer if the discharge spout is accidentally blocked.
7. Corrosion-resistant, simplicity of operation and low cost.

Figure 10

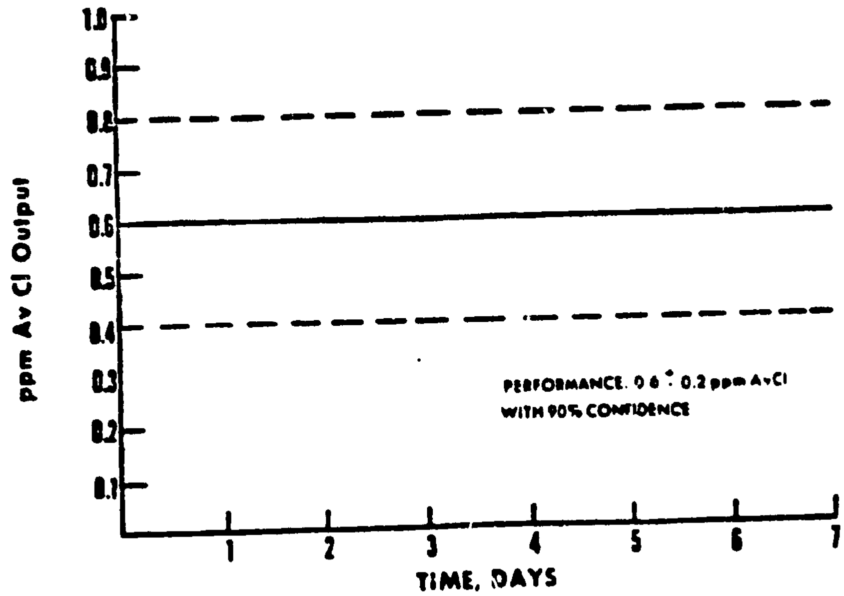
Erosion Feeder for Chemicals

TOTAL FLOW, CONTROLLED FEED RATE, SIMPLE OPERATION



This feeder is capable of handling tablets, briquetts or cartridges; however, solubility properties must be tailored to match the dissolving characteristics of the unit. Using tabletted calcium hypochlorite, developed for this feeder, good performance is obtainable, as shown in Figure 11. Uniform dissolving rates of 0.6 ppm AvCl ± 0.2 ppm with 90% confidence are achievable.

Typical Performance of Well-Designed Erosion Feeder



It is a feeder of this design which has been adopted by World Water Resources as the most reliable and realistic feeder for use in rural areas. I highly recommend it. When this feeder is connected to an automatic flow which provides accurate overall control, it becomes a device for use in rural systems which meets all of the aforesaid requirements.

In review, what is the best overall means of placing this sanitizing agent in the rural water supply? Once again, there is no pat answer. The hypochlorination concept is assuredly the best. The erosion type using tabletted chemicals is the best and the most practical.

In conclusion, the problems of rural water sanitation are small on an individual city to city basis but they are immense in their cumulative effect. Much can be done for the people of your countries by chlorinating the rural water. We have seen that there are a number of chemicals and a number of devices which can reduce the magnitude of this problem.

I have described a simple, low cost, dependable feeding device suitable for use in disinfecting marginal waters in the rural areas of developing countries. Operation and maintenance is easy for the unskilled labor in these areas. No sophisticated power source is needed to provide continuous, automatic operation. The device uses a readily available, commercial chlorine chemical that can be economically shipped, stored and used at these points of need. The end result is potable water for those who have suffered so long for want of help from us.

I hope the information I have given you on chemicals and devices will help you to make an informed choice on how you can best solve the problem in your area. Thank you.

115 Wisconsin Ave., Bethesda, Maryland, U.S.A. 20014 • Telephone (301) 986-0550 • Cable: WATERSURE WASHDC

Appendix 1(a)

World Water Resources Inc.
Data Sheet

WATER-SURE® 050
DESIGNED FOR DEPENDABILITY

USE:

The WATER-SURE® 050 is a simple, low cost, yet efficient means of chlorinating effluent from septic systems or sporadically delivered water supplies. It is designed to dispense calcium hypochlorite with the accuracy necessary for drinking water, at a cost low enough for septic systems.

ADVANTAGES:

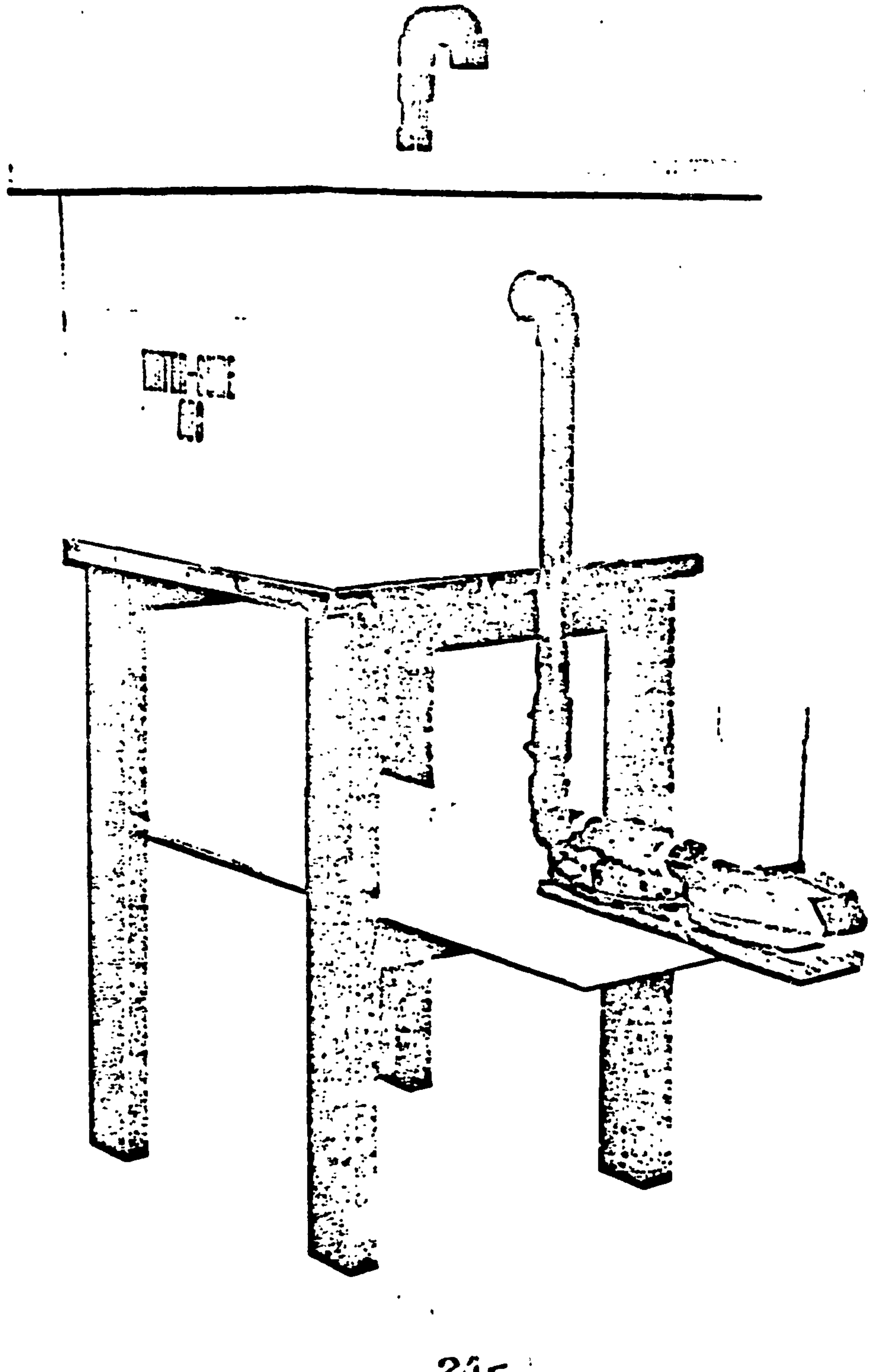
a. Simplicity: No moving parts. Nothing to go wrong.
b. Safety: No organic material or gaseous chlorine is used. Dry chlorine is accurately dispensed, killing the organisms in the water or effluent.
c. Maintenance: Requires filling every two months, no tools, or knowledge necessary.
d. Automatic control: The unit automatically turns on when an acceptable level of liquid is reached and turns off when empty.
e. High Surge Capacity: Units are made to handle excessive amounts of water in short periods of time.
f. Durability: All plastic, non-corrosive, unbreakable unit.
g. Low Price: Contact your local representative for the best buy in WATER-SURE sanitation equipment.

CHARACTERISTICS:

1. Weight: 4 lbs
2. Flow Rate: 20 gallons per minute with 20 inches of pressure
3. Starting Point. 30 to 60 gallons
4. Surge Capacity. 25 to 140 gallons per minute
5. Activation. 1¼" self-starting syphon, complete with bulk head fittings
6. Chlorinator: Unit holds 2½ lbs of calcium hypochlorite tablets for immediate use and dosage is adjustable from 2 ppm to 600 ppm
7. Inlet size. 4"
8. Exit size: Open
9. Options: Various sizes holding tanks, contact tanks and filters are available to supplement your WATER-SURE® 050

CONSUMPTION:

The unit comes packed with calcium hypochlorite tablets. The amount of chlorine consumed depends on the contamination in the water and the amount of water used. Generally, 2½ lbs of calcium hypochlorite will do 40,000 to 50,000 gallons of soiled water.



315 Wisconsin Ave., Bethesda, Maryland, U.S.A. 20014 • Telephone (301) ... • Cable WATERSURE WASHDC

Appendix 1(b)

World Water Resources Inc.
Data Sheet

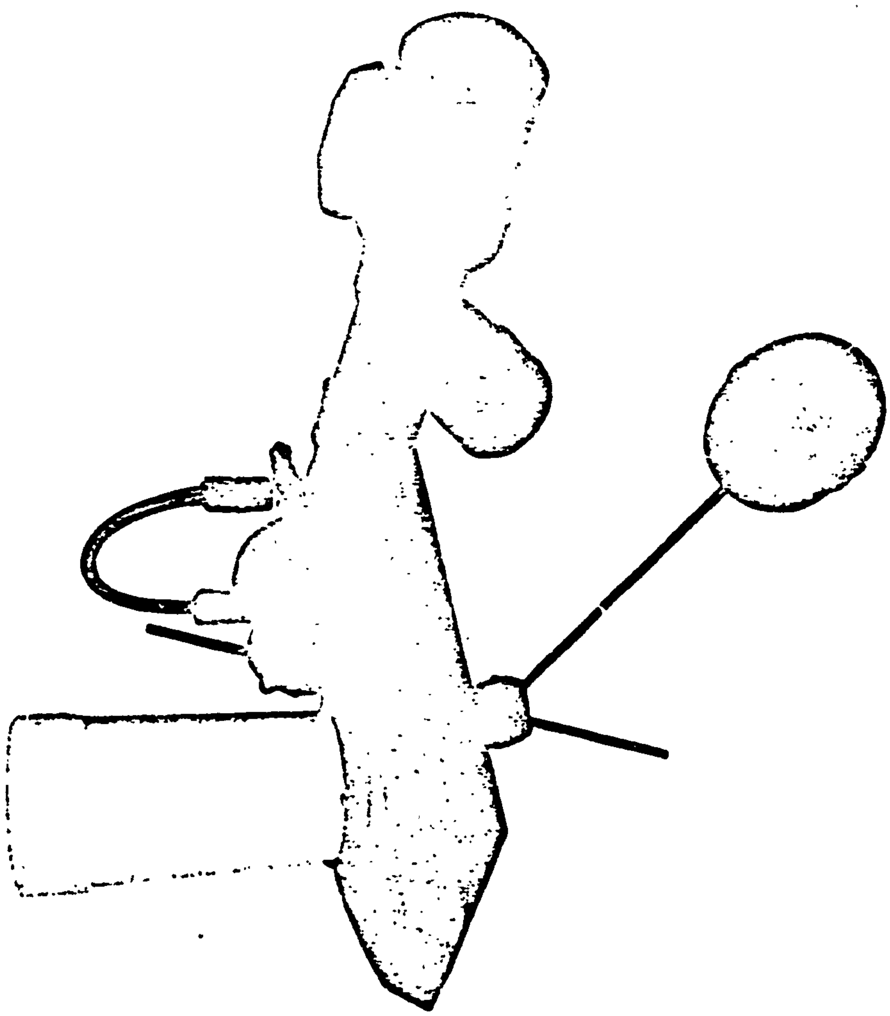
WATER-SURE® 101
MAKE WATER PURE WITH WATER-SURE

USE:
The WATER-SURE® 101 is an easy and accurate system for chlorinating water using Calcium Hypochlorite tablets as the disinfecting agent. The WATER-SURE assures that drinking water is safe and sanitary and is perfect for rural application, i.e. villages, farms, homes, etc.

ADVANTAGES:
a. Ease of transport: One box
b. Durability: 3 year guaranty on all parts
c. Low maintenance cost: An average 5¢ a person per year
d. Accuracy: Uniformly measured chlorination
e. Simplicity: No special tools or knowledge are required for installation which takes only 20 minutes
f. Safety: No chlorine gas or dangerous powder are added to the water
g. Low Purchase Price: Compares most favorably with other chlorinators on the market

CHARACTERISTICS:
1. Weight: Approximately 3 kilos
2. Structure: Totally plastic (composed of PVC and ABS)
3. Movable parts: A diaphragm, made from polyester and nitrite with resistance of 1600 cubic inches, is the sole moving part
4. Functioning: Operates exclusively by gravity, requiring a minimum head of one meter of water with an estimated flow of 45 liters per minute
5. Dimensions:
   Length: 60 cms
   Width: 40 cms
   Height: 40 cms
6. Inlet size:
   3 1/4 cms
7. Exit Size:
   Open

CONSUMPTION:
The WATER-SURE® 101 is a non-electrical, demand operated system, capable of chlorinating from 50 to 100,000 gallons of water per day. The amount of Calcium Hypochlorite consumed depends upon the quantity of water and the extent of contamination; however, we consider 1 kilo for each 180,000 liters of water as an average for chlorination.



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Yale University New Haven, Connecticut 06510

SCHOOL OF MEDICINE
Department of Epidemiology
and Public Health
60 College Street

Appendix 2

REPORT OF THE EVALUATION OF WATER PURIFICATION SYSTEM

Evaluator: Eric W. Mood, M.P.H., LL.D.
Associate Professor of Public Health
Yale University School of Medicine
60 College Street
New Haven, Connecticut 06510
(203) 436-8903

Date and
Location of
Evaluation: March 28, 1973
Premises of Diaclear, Inc.
1070 Sherman Avenue
Hamden, Connecticut

General

An evaluation of a water purification system which had been designed, developed and assembled by World Water Resources, Inc. of New York, N.Y., for the University Corporation for Atmospheric Research and for installation at the solar eclipse observation station to be established on the southeastern shores of Lake Rudolf, Republic of Kenya, was made on Wednesday, March 28, 1973 with supplementary laboratory tests being conducted on March 29 and 30, 1973.

The evaluation of the system consisted of three phases, namely 1) a critical review of the functioning of each individual unit of the system, 2) the performance of simple chemical tests and physical observation of the quality of the water, and 3) microbiological examination of samples of water at various strategic points.

Prior to the evaluation, the system had been assembled on a tract of open land in rear of the premises of Diaclear, Inc., 1070 Sherman Avenue, Hamden, Connecticut, by personnel from World Water Resources, Inc., and had been in operation for about twenty-four (24) hours. The source of water was from a small stream adjacent to the test site.

Functioning of Individual Units

Each operating unit was made functional and operated independently to observe the characteristics of the unit. Then the total system was made operational and functional as a complete system.

At the time of this evaluation, each operating unit functioned well and in accordance the general specifications of the contract. Similarly, the system as a complete system functioned well and in accordance with the general specifications of the contract.

Chemical Tests and Physical Characteristics of Water

Tests of residual chlorine using the ortho-tolidine colorimetric method were made several times at several sampling points. The residual chlorine levels in the first storage tank and after pre-chlorination and the addition of alum was consistently in excess of 0.50 p.p.m. and averaged about 0.6 p.p.m. free available residual chlorine.

The discharge from the second chlorinating unit showed consistently a free available residual chlorine in excess of 2.0 p.p.m. (the upper limit to the residual chlorine test kit used in this evaluation).

The final effluent was clear and colorless and had a free available residual chlorine content averaging 0.5 p.p.m. There was no chlorinous taste or odor to this water.

Microbiological Examination

Microbiological examinations of four (4) samples of water were conducted in accordance with the methods prescribed by 13th edition Standard Methods for the Examination of Water and Waste Water. The following tests were made:

1) standard agar plate count; 35°C; 24 hrs.
2) standard agar plate count; 20°C; 48 hrs.
3) confirmed tests for coliform bacteria

Samples were collected from the following three (3) sampling locations:

a) untreated water from stream
b) from the first storage tank after pre-chlorination and the addition of alum
c) final effluent (two samples collected from this location at two different times)

Samples for microbiological examination from locations b) and c) were dechlorinated with sodium thiosulphate.

Results of Microbiological Examinations

The results of the microbiological examinations have been tabulated and are found in Table No. 1, attached herewith. These data are self-explanatory.

Interpretation of Results of Microbiological Examinations

The results tabulated in Table No. 1, attached, indicated the average efficiencies of the water purification system under evaluation are as follows:

efficiency in inactivating bacteria as measured by the 35°C Standard Plate Count	better than 99.1%
efficiency in inactivating bacteria as measured by the 20°C Standard Plate Count	better than 99.8%
efficiency in inactivating coliform bacteria	better than 98.3%

If the untreated (raw) water had had a greater density of bacteria, all of the above efficiencies would have been considerably higher. Samples #2, #3, and #4 did not show any biological growth under laboratory conditions. They appeared to be sterile.

General Conclusions

From this evaluation, it may be concluded that this water purification system installed and operated in the manner similar to the conditions of evaluation is a very efficient system and that it has the capabilities of producing a high-grade, microbiologically safe drinking water that should be free of common pathogenic bacteria capable of producing water-borne disease, e.g. bacillary dysentery (shigellosis), chlorea, leptospirosis, paratyphoid fever (salmonellosis), tularemia, and typhoid fever. The system appears to have the capabilities of inactivating water-borne viruses, e.g. the agent of infectious hepatitis, and water-borne protozoa, e.g. E. histolytica, by increasing the dosage rates of both the pre- and post-chlorinators. Further, this system is capable of producing a drinking water that has good physical characteristics, i.e. water which is clear and colorless. With the installation of a deionizing unit on the final effluent line, this system has the added capabilities of removing some of the excessive dissolved mineral matter, which under selected conditions may cause disease or adverse physiological reactions.

Addendum

Additional Considerations

The reports of the chemical analyses of samples of water collected on September 6 and October 22, 1972, at various depths from Lake Rudolf indicate a very high dissolved solids content. These dissolved solids initially may cause some mild adverse physiological reactions, i.e. mild diarrhea, among some individuals who drink this water, particularly water that may not be deionized or demineralized. Therefore, all water that will be used for human consumption should be taken from the effluent of the deionizer.

Schistosomiasis does not seem to constitute a public health problem in the Republic of Kenya, but there is some data to suggest that it may be a problem in Mauritania. From data available to the World Health Organization of the results of epidemiological surveys conducted between 1959-1968 and reported in Vol. 22, No. 3, 1969, World Health Statistics Report, there is no evidence of endemicity of this disease in Kenya, but there are data which indicate a level of infection of schistosomiasis among children in Mauritania from an unknown source.

Evaluation conducted by

Eric W. Mood

Eric W. Mood, M.P.H., LL.D.
Registered Professional Engineer
Connecticut Registration No. 2474

April 2, 1973

Sample Number	Location from Which Sample Was Collected	Time of Collection	Residual Chlorine (before dechlorination) in p.p.m.	Standard Agar Plate Count (organisms per 1.0 ml) 35°C 24 hrs	Standard Agar Plate Count (organisms per 1.0 ml) 20°C 48 hrs	Most Probable Number (M.P.N.) of Coliform Bacteria per 100 ml
#1	untreated water from stream	2:05 pm	-	120 113	680 740	110
#2	from first storage tank	2:20 pm	0.6	0 0	0 0	less than 1.8
#3	final effluent	1:55 pm	0.5	0 0	0 0	less than 1.8
#4	final effluent	2:30 pm	0.5	0 0	0 0	less than 1.8

Tabulation of results of microbiological examination of samples of water collected on March 28, 1973 in connection with evaluation of water purification system provided by World Water Resources for University Corporation for Atmospheric Research.

Table No. 1

Equip Tips

Appendix 3
2300, 7400
JULY 1977

U. S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE EQUIPMENT DEVELOPMENT CENTER – SAN DIMAS, CALIFORNIA

NON-ELECTRICAL, GRAVITY FEED, LOW-FLOW, LOW-PRESSURE CHLORINATORS

Many Forest Service water systems are difficult to disinfect because electricity may not be available, the sites may be remote, and/or there may be low flow and pressure. The San Dimas Equipment Development Center tested World Water Resources Water-Sure ® chlorinators, models 050 and 101, to determine if these devices could provide a satisfactory level of chlorine residual at various conditions of low flow and pressure.[1]

MODEL 050

The model 050 (fig. 1) has numerous applications. It can be used to disinfect water supplies that are delivered on a sporadic, continuous but variable, or low-flow continuous basis. Also, adding a bag filter (fig. 1) to the system to catch suspended solids allows this chlorinator to disinfect septic tank or treatment plant effluent.

The 050 works on a siphon principle; as the siphon tank empties, the water flow and pressure fluctuate uniformly through the system. There are no moving parts nor any internal method to shut off incoming flow. The canister that contains the chlorine tablets is threaded; adjustment up or down permits the

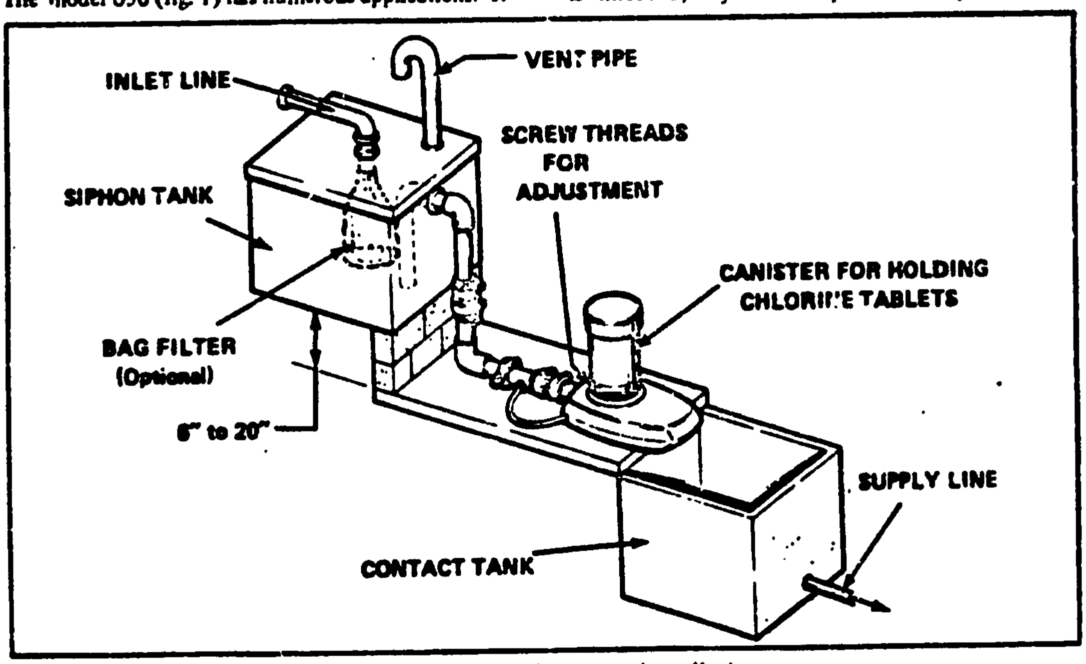

Figure 1. Model 050 chlorinator installation.

[1] See ED&T Report 7400-1, "Iodine Dispenser for Water Supply Disinfection," January 1976. This ED&T Report presents information on a device that, compared to the chlorinators, is less expensive, easier to install, maintains a more constant disinfection, and requires less attendance. On the other hand, this Equip Tips presents information on devices that can be used for permanent-use sites where the iodine dispenser is not recommended, and at sites where the use of iodine for potable water is not authorized.

No. 7723 1301

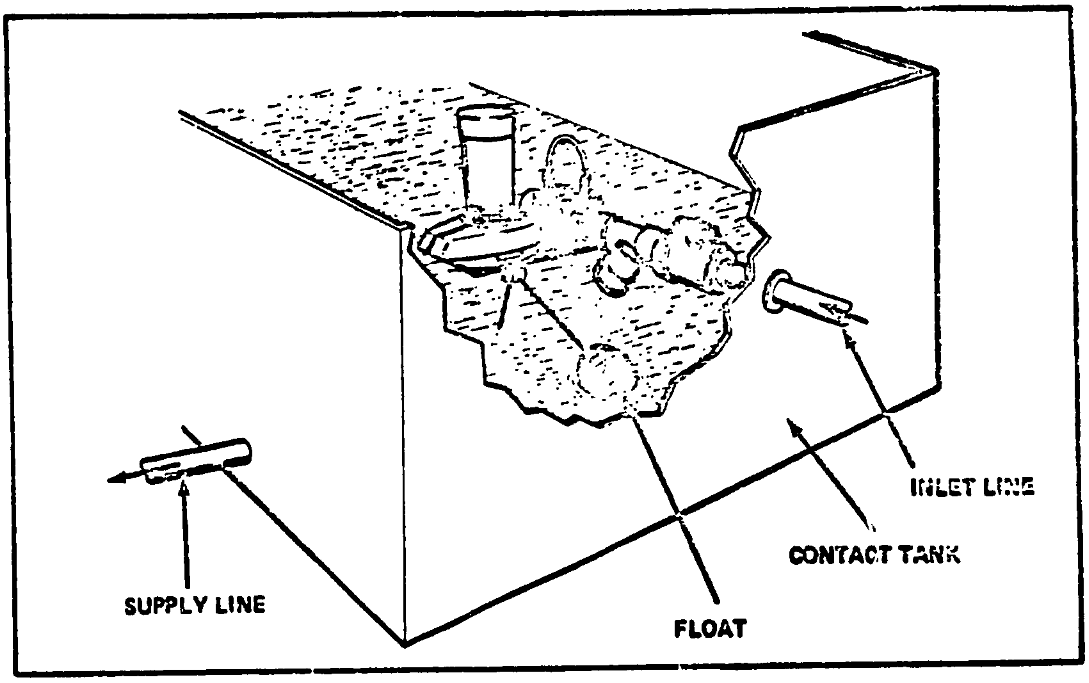

Figure 2. Model 101 chlorinator installation.

desired amount of chlorine to be dispensed. (The model 101 also has this feature.) Once the canister is set for the desired amount of chlorine, no further adjustments are necessary to maintain a relatively constant dosage of chlorine.

When the model 050 is installed, the siphon tank (size depends on application) is put in place first, then the chlorinator itself, and finally the chlorine contact tank. At remote locations, it is best to place a small enclosure around the chlorinator to prevent vandalism.

MODEL 101

The model 101 (fig. 2) can dispense chlorine to disinfect water supplies that have a maximum pressure of 20 psi at the chlorinator. Its only moving parts are a float control assembly, for on/off operation, and a diaphragm, which is activated by a minimum pressure of approximately 1.5 psi. The 101 is relatively easy to install; but cannot be installed in line. It has to be installed within or immediately over the chlorine contact tank so that after the water supply flows through the chlorinator, the water falls by gravity into the contact tank. If it is installed within the contact tank, an access area must be provided for chlorine tablet resupply.

When the water level in the contact tank (size depends on application) reaches a predetermined height, the float valve activates the diaphragm and stops the inflow. After initial calibration, an acceptable level of chlorine can be dispensed, as long as the water flow and pressure remain constant.

CHLORINATOR TESTS

Each model was initially adjusted to produce approximately 1.0 mg/l of free residual chlorine. Each was run through at least 20 test cycles, at the 1.0 setting, to determine how reliably they could accurately dispense chlorine. Free chlorine was determined after each cycle, using a spectophotometer. During the first cycle, the chlorine concentration was low because of the dryness of the chlorine tablets. During subsequent cycles (same canister setting), as the tablets dissolved, the chlorine concentration increased and then fluctuated.

Model 050

To simulate a variety of field conditions, the model 050 was cycled 28 times, at the same canister setting, using intermittent rest periods that ranged from 30 minutes to 24 hours between cycles. The

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Table 1.—*Model 050 test results*

No. of cycles	Low reading (mg/1)	High reading (mg/1)	Mean	Standard deviation
28	0.45	2.60	1.17	0.67

Table 2.—*Model 101 test results*

Water pressure (psi)	Flow rate (gpm)	No. of cycles	Low reading (mg/1)	High reading (mg/1)	Mean	Standard deviation
1.2	7	6	0.50	1.00	0.63	0.18
3.1	10	10	0.70	1.35	0.93	0.20
9.8	12	9	0.80	2.00	1.14	0.37

results of these tests are shown in table 1. The chlorine concentration fluctuated from cycle-to-cycle; nevertheless, all levels recorded were within an acceptable range.

Model 101

Again simulating a variety of conditions, the model 101 was tested using various flow rates and pressures to reflect the 101 mode of operation. At any given canister setting, the water flow and pressure must remain the same to produce the least variation in chlorine concentration. The results are presented in table 2. The model 101 does not dispense chlorine accurately; however, throughout the testing, the concentration differential was acceptable for potable water.

RECOMMENDATION

Forest Service field units should request assistance from Engineering in reaching decisions pertaining to the purchase and installation of these chlorinators.

AVAILABILITY

The models 050 and 101 are available from the following manufacturer

Manufacturer
World Water Resources 7315 Wisconsin Avenue Bethesda, Maryland 20014 *Telephone:* *FTS*—900/986-0550 *Commercial*—301/986-0550

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