Ife Journal of Agric. Vol. 2(2).

Treating rural water without introducing harmful substances

O. OGEDENGBE
Department of Agricultural Engineering,
University of Ife,
Ile-Ife, Nigeria.

Abstract

The coliform count on the stream water studied was high. The water is a direct source of drinking water to some rural communities. A previous study established that about 100 ppm of chlorine in the form of chlorox was sufficient to bring the coliform Most Probable Number (MPN) from about 11,000 per 100ml down to within allowable standard of one per 100ml of water sample. There is some concern that turbid water contains organic matter which when chlorinated could give rise to formation of cbloroform and possibly other chlorine-based compounds of the trihalomethane family which conceivably could be carcinogenic. This prompted design and contruction of a simple system of turbidity removal and chlorination. With this system the required chlorine dosage even went down to about 50 ppm.

Introduction

In an earlier work, Ogedengbe and Adeniji (1978) presented the results of an investigation in which some rural water supplies and the people who used them were studied. It was found that the coliform count Most Probable Number (MPN) in these stream waters and shallow wells ranged from 2,100 per 100ml to 11,000 per 100ml in comparison with the World Health Organisation's (WHO's) allowable count of one coliform per 100ml for potable water. The authors furhter presented some hospital records which showed that the users of these water supplies frequently suffer from (and sometimes die of) water-borne diseases such as guinea-worm, typhoid, cholera, dysentry, infectious hepatitis and gastroenteritis.

Following these water-supply-disease inter-relationships in the area of study, the authors used liquid chlorine in the form of commercial bleach – (chlorox) to treat the water, and found that by adding about 10 tablesponfuls of chlorox into a 10 liter jar of the water, the coliform count then consistently met the WHO standard.

The present study introduces a new dimension to the problem of rural water supplies presented in that study, namely, the concern that whereas the addition of chlorine to the water will bring the coliform count down and possibly reduce occurrence of water born diseases, it could give rise to formation of a number of chlorine-based organic compounds which could be harmful to humans.

In the past few years there have been some serious discussions at conferences, seminars, as well as some published and unpublished bulletins and papers on the potential carcinogenicity of chlorinated organics in water supplies meant for human consumption. Dallair (1977) has presented a documented review of conditions of finished waters in the United States, especially in relation to the presence of chlorinated organics in drinking water and against the background that these substances could cause cancer in humans.

In a review of European water treatment practices, Miller and Rice (1977) looked into the problems of organics in water, and showed a special interest in the tendency by European water technologists to use disinfectants such as Ozone, chlorine and activated carbon in contrast to U.S. water works in which chlorine is the major water disinfectant used.

Both studies cited above have one common focal point; namely that organic matter in water, upon coming in contact with chlorine form new compounds that could cause cancer in humans.

As stated earlier, the present study is a follow up of an earlier study in which some rural waters in Nigeria, when treated with chlorine (chlorox) in measured dosages were found to have their coliform counts brought down from a high value of about 11,000 per 100 ml. to within the recommended WHO standard of 1 coliform per 100ml. The high turbidity values recorded on the stream water (90 NTU to 145 NTU), and the colour which was as high as 50 APHA units clearly suggest presence of organic matter. Chlorinating these samples without first drastically reducing the turbidity level could lead to formation of chlorinated organics, and the attendant problem of potential carcinogenicity.

The purpose of the current study is to institute a simple modification to the earlier study (Ogedengbe and Adeniji, 1978) in the form of turbidity removal before chlorination, without losing sight of the financial and educational constraints of the users.

Materials and methods

General background: In a study referred to earlier (Ogedengbe and Adejini, 1978) a familiarisation survey had been made into several rural communities near the University town of Ife for an on-the spot assessment of their water problems. The survey had shown that the problems of water supply to many of the rural communities were basically similar, justifying the selection of one of the supply sources (a stream in Alakowe Village) for an in-depth study. The current investigation was carried out on the same stream.

Experimental investigation: The experiments were carried out along the following general steps:

1. A large plastic container with a screw-on cap was washed, rinsed thoroughly with tap water; then washed with a chlorine solution and finally rinsed several times with distilled water. The (germ-free and chlorine-free) container was used to collect water sample from the stream under study. The sample was immediately taken to the laboratory for analysis.
2. The turbidity of the raw water was taken several times and the average recorded.
3. Portions of the raw water dosed with varying amount of chlorine and the chlorine residual was determined after 30 minutes of contact time in some of the samples.
4. The chlorinated samples were then subjected to coliform counting procedures.
5. Next, a portion of the original stream water sample was dosed with alum, allowed 60 minutes to settle, and the clear supernatant decanted. Its turbidity was taken and recorded.
6. A portion of the clean water was subjected to coliform counting, (no prior chlorination).
7. Other portions of the clear water were then subjected to tests of chlorination, chlorine residual determination and coliform counting as per steps 3 and 4.

In essence the experiment was set up to reveal :

1. how much suspended matter and colour (turbidity), is in the water in its natural state.
2. the coliform count (an internationally accepted indicator of pathogenic organisms) in the stream water.
3. how much chlorine is needed to reduce the coliforms in the water to acceptable levels.
4. to what extent and at what dosage alum reduces the turbidity of the water.

5. how much chlorine is needed to effectively disinfect the stream water after its turbidity has first been reduced with alum.
6. the chlorine residual (chlorine remaining in the water, which is the difference between the amount originally put in and the amount used up in killing germs and in reacting with organic matter in the water).

Turbidity measurement: Hack Turbimeter Model 2100A (produce of Hach Chemical Co., Ames Iowa, USA) was used to measure turbidity. Calibration of the instrument was based on Formazin, and the unit of measure is the Nephlometric Turbidity Unit (NTU) although it could also be referred to as the Formazin Turbidity Unit (FTU).

Coliform counting:. The multiple tube fermentation technique was used to establish the coliform index based on the Most Probable Number (MPN) principle.

For each water sample on which coliform counting was to be made three sets of the tubes with 3 tubes per set were used, each tube containing lactose broth to promote growth of coliform organisms. The first set of three tubes was incubated with 1 ml. of the water sample per tube, the second set with 0.1 ml, and the third with 0.01 ml. All three sets were then incubated at 37°C and examined for gas production at the end of 24 hours and at the end of 48 hours. The presence of gas was taken to indicate positive "presumptive" tests, whereupon the samples were then subjected to "confirmed" tests and finally to "completed tests" as described in the "Standard Methods" (APHA 1965). Table 40 of the Standard Methods was used to obtain the corresponding MPN index except that the result from the table had to be multiplied by 10 to compensate for the dilution factor (1 ml: 0.1 ml: 0.01 ml) used in this experiment as compared to the standard (10 ml: 1 ml: 0.1 ml). However in the case of the heavily chlorinated samples in which low coliform counts were anticipated, the standard (10: 1: 0.1) inoculation was used and so the MPN-values in the table were used without modification.

Chlorination: Liquid bleach (chlorox), perhaps the commonest source of chlorine, was obtained, tested and found to contain 2.5% chlorine by weight. A 1% chlorine solution was made by mixing 400 ml of the chlorox with 600 ml of distilled water. One ml of this solution dosed into a liter sample of water approximately corresponds to a 10 ppm dosage.

Determination of chlorine residuals after a 30 minute contact time was made using the Hach procedure.

Results and discussion

The results of turbidty measurements, chlorination and coliform counting are summarized in Tables 1 and 2. The results show that

1. the turbidity of stream water varied with season. In the middle of the rain season turbidity was lowest 15 (NTU). The highest turbidity (90 NTU was recorded at about the peak of dry season. That stream water turbidity should vary with season is understandable. By the middle of rain season, much water has moved down the water course producing a cleansing effect, in contrast to dry season when the little water remaining is generally static, creating a natural environment for decomposition of leaves and other organic matter.
2. when samples of raw water were treated with varying dosages of chlorine (chlorox), the coliform counts (MPN) were found to decrease generally with increasing chlorine dosage, and with decreasing sample turbidity. For the stream water collected during the rain season (with 15 NTU) about 50 ppm of chlorox appeared to be sufficient to bring coliform counts to acceptable standard. When original turbidity was 75 NTU, 100 ppm of chlorox was needed to produce the desired result. The 90 NTU samples were not adequately treated for coliforms even at 100 ppm chlorine dosage.
3. For water samples treated with 80 ppm of alum and settled for 30 minutes, the turbidities of the decanted supernatants were low (35 NTU reduced to 9 NTU, 90 NTU to 12 NTU, 75 NTU to 13 NTU and 15 to 4 NTU). The slight non-proportionality of turbidity removal (e.g. 80 ppm dosage reduced turbidity from 90 to 12 in one set of samples and from 75 to 13 in another set) could be explained in terms of possible differences in characteristics of water samples collected at different times. Moreover, the stream samples were treated with alum under their natural pH conditions which were generally between 6.8 and 7.2. Preliminary studies to establish optimum alum dosages had shown that the optimum pH for alum treatment was about 10 - a condition under which about 60 ppm were found adequate to reduce all sample turbidities to 5 NTU or less. However, pH adjustment was not made since the use of lime would introduce added expenses and technical complexities beyond

the reach of the intended users.

4. Without any chlorination, the coliform counts of decanted alum-treated-and-settled samples were considerably lower than those of unchorinated (or even slightly chlorinated) raw samples, although none of the counts were low enough for the decanted samples to be considered "biologically safe" for drinking purposes.
5. When decanted samples were treated with varying dosages of chlorine, and the chlorinated samples were tested for coliform a dosage of 50 ppm was found adequate, reducing coliform counts to acceptable levels.
6. The maximum chlorine residual in any sample after 30 minutes, (room temperature 22°C to 26°C) was less than 5ppm even when the initial chlorine dosage was 100 ppm.

One major handicap in the use of alum in reducing turbidity is that it lowers the pH of the water. For example, about 80 ppm alum dosage was found to reduce water pH from 7 to 6.2. Such (slightly acid) water would have a peculiar taste which could be offensive to the user. To the extent that use of a pH booster (such as lime) is not being recommended here, use of alum dosages lower than 80 ppm is suggested. Further insight into use of the correct quantity is provided in the following section.

TABLE1 : COMPARISON OF COLIFORM COUNTS IN RAW WATER AND IN WATER PREVIOUSLY TREATED WITH ALUM (FOR TURBIDITY REDUCTION)

Runs	Turbidity (NTU)	MPN Index* (Coliformy) 100ml	Turbidity (NTU)	MPN Index* (Coliform/ 100ml)
	Raw water		*Water after treatment with 80 ppm alum*	
1st Set Nov. 1977	35	4,600	9	210
2nd Set (Peak of dry season) Feb. 1978	90	11,000**	12	240
3rd Set March 1978	75	11,000	13	460
4th Set (Peak of rain season) July 1978	15	240	4	210

* According to internationally accepted standards, the coliform count in water intended for human consumption should not exceed one per 100ml of water sample.

* The number of tubes in which gas was produced exceeded that which corresponds to 11,000 coliforms. Hence it was assumed that the count in the sample was greater than 11,000.

TABLE 2: EFFECT OF CHLORINATION ON COLIFORM COUNTS IN RAW WATER AND IN ALLUM–TREATED WATER

Runs	Chlorine dosage (ppm)	Raw Water: MPN idex (Coliforms/ 100ml)	Raw Water: Chlorine residual (ppm)	Alum-Treated Water: MPN index	Alum-Treated Water: Chlorine residual
1st Set	10	240	0.0	120	0.0
Nov. 1977	20	240	0.0	23	
	50	11	0.5	3	1.0
	100	Nil	2.2	Nil	1.0
2nd Set	10	11,000	0.0	75	0.0
Feb. 1978	20	11,000	0.0	39	-
	50	4,600	0.0	Nil	2.0
	100	4,600	0.0	Nil	5.0
3rd Set	10	11,000	0.0	120	-
March 1978	20	11,000	-	39	0.0
	50	4,600	0.0	Nil	1.5
	80	11	0.0	-	-
	100	Nil	0.0	Nil	3.8
4th Set	10	210	-	7**	2.3
July 1978	50	Nil	3.2	Nil	-
	80	Nil	3.8	Nil	4.4

* Each dash (-) represents data missed during analysis or deliberately left out from analysis.

** It is difficult to explain why, inspite of a chlorine residual as high as 2.3 mg/1, coliforms were still found in the sample.

Suggested form of application

The results of the experiments performed in this study as discussed in the preceding section have shown that in terms of aesthetics (clarity) chlorine dosage requirements, and reduction of coliforms, it is better to first reduce turbidity of water before treating it with chlorine.

Turbidity in stream water is caused by suspended inorganic and organic matter. The inorganic component derives from fine clay and silt which are the natural consituents of the soil over which the stream flows; and of the watershed to which the stream belongs. The organic components are contributed by farming operations that disturb the top soil, vegetable decay, human (and possibly industrial) wastes; plankton and other microorganisms (Clark and Viessman 1966, Babbit *et al.* 1967,Sawyer and McCarty 1967).

Thus, there is evidence that turbidity in stream waters is contributed in part by suspended organic substances. And although no experimental data are available with respect to relative carcinogenicity of chlorinated water, the point can be made that the lower the turbidity in a water sample, the less the amount of organic and consequently, chlorinated organic substances in it following chlorine treatment of the water. Thus if chlorinated organic substances do indeed cause cancer in humans, reduction of amount of organic matter in the water prior to chlorination will definitely reduce the concentration of chlorinated organics and consequently reduce the level of potentially harmful substances in the water

The plan and elevation of a small tank that can be used to effect turbidity reduction and chlorination are shown in Fig. 1. Made of galvanised iron sheets, the tank is divided into two compartments, with dimensions and appurtenances as shown. Each compartment has a volumetric capacity of 45 liters (or 3 bucketfuls of water using a 15 liter bucket). The system can be put to use as follows:

1 The tank is thoroughly washed, rinsed and drained using the drain-valve at the bottom of each compartment. The lid is also cleaned.

2. It is placed at a convenient location on a suitable support to facilitate draining of tank. (The location should, preferably, be cool but not dark).
3. To start, with the tank in place, close in decanting valve, the drain-valves and the tap.

4. Place a small quantity of alum (experience will teach how much, but many of the e people for which this is intended have experience in the use of the right quantity) in compartment A (the inlet end of the tank).
5. Fill compartment "A" with water, but not to the brim. Pouring the water should be rapid (though not splashy) to create turbulence for proper contact between alum and water. (Raw water should never be poured into compartment B).
6. Allow to settle for at least one hour. And if suspernatant is 'clear' open the decanting valve (which is located at 2/5 of the tank height measured from the bottom), and so let clear water into compartment B, until equilibrium of water levels in compartments A and B is established.
7. Close the decanting valve, add some more alum to compartment A and fill it up again with the raw (stream) water.
8 While settling is going on again in compartment A, add about 5 tablespoonfuls of chlorox (or one tablet of HTH chlorine which can also be easily obtained) into B. As a general rule, chlorine should not normally be added to compartment A.
9. Open the decanting valve again (after at least one hour of settling in tank A) and let more clean water into B until equilibrium is reached. Each compartment should now be about ¾ full
10. The clear, chlorinated water is now ready for use, through the tap.

As the tap and the decanter from A to B are located at the same level (0.2 meter from bottom) water ceases to come out of the tap when the level in compartment A falls just below the invert of the decanter. If water is really needed (a near-emergency situation) it could be drawn through the drain at the bottom of compartment B though this is not recommended on routine basis. The tap is the normal supply route while the drain is for cleaning.

As soon as there is enough space in compartment A to take a bucketful - about 15 liters - but not before, (in any case there should be a minimum of one hour time lag between successive additions of raw water to compartment A to allow for proper settling) water and alum are added, with decanter closed, and corresponding amount of chlorox (2 spoonfuls per bucketful of water) or ½ tablet of HTH chlorine, added to B, the system continues.

Every week or whenever clarity of decanted water starts to suffer (but generally not longer than two weeks) the tank should be washed, drained and 'recharged.'

It may be useful to have the tank painted black on the outside to make water cooler and to prevent rust.

The tank size illustrated in this paper is considered adequate for supply of safe drinking water for an average rural family. In general, there is no reason to chlorinate water for cooking, washing or bathing although it would be good to reduce water turbidity for these uses. A separate arrangement (larger container of course) could be made to take care of alum treatment of water for this set of uses.

If properly set up and operated, this water system is capable of producing (from raw stream water) drinking water which is clean, germ-free, low in concentration of chlorinated organic susbtances and consequently (should be) low in potential carcinogenicity.

Concluding remarks

There is ample evidence (Ogedengbe and Adeniji, 1978 that people in rural and to some extent in urban areas of Nigeria still do get sick from (and sometimes die of) diseases such as infectious hepatitis, cholera, gastroenteritis, etc., at a time when these diseases are virtually extinct in the developed world. Evidence also exists that these diseases derive largely from the water that the people drink.

Since neither community self-help efforts nor government effort is likely to provide pipe-borne water to all rural areas in the foreseeable future, stop gap measures are required to arrest the occurrence of water borne diseases. This is important because there is a chance that the apparent decline in productivity (especially in farming practices) is somewhat related to the state of water that people use.

The current study, as well as an earlier one (Ogedengbe and Adeniji, 1978), has shown that the coliforms, and consequently, germs in our rural stream waters can be killed by chlorination. The fear raised (Dallair, 1977 and Miller and Rice 1977) that chlorinating water which contains organic matter gives rise to formation of chloroform ($CHCl_3$) and many other chemicals of the trihclomethane family which – having caused cancer in laboratory animals – could cause cancer in humans, may or may not be justified. The fact is that no one can say for sure at this time. The safe position is to reduce the level of organics in water before adding chlorine.

The simple system presented in this paper allows turbidity, and consequently organic matter, to be reduced prior to chlorination.

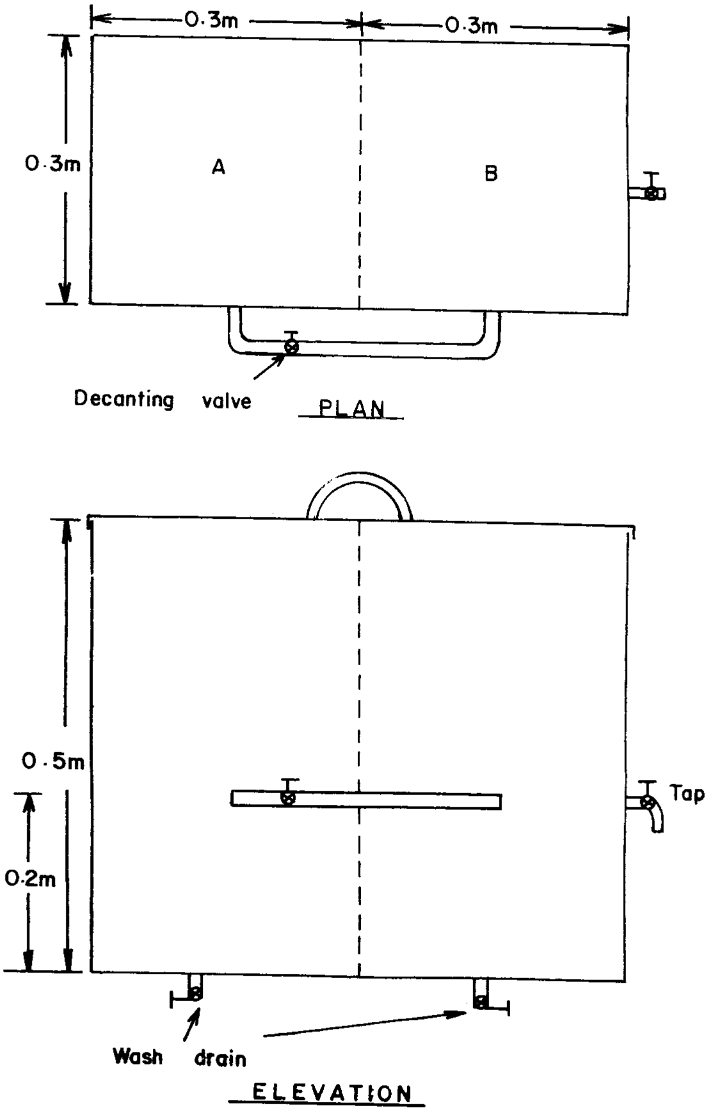

FIGURE 1 : A simple tank constructed for accomplishing water turbidity removal and chlorination

References

American Public Health Association – APHA (1965). Standard Methods for the Examination of water and Wastewater 12th ed. (American Public Health Association Inc.).

Babbit, H.E. , Doland, J.J. and Cleasby, J.L. (1967). Water Supply Engineering. McGraw-Hill Book Company, New York.

Clark, J.W. and Viessman, W. (1966). Water Supply and Pollution Control. International Textbook Company. Pennsylvania.

Dallair, G. (1977). Are Cities Doing Enough to Remove Cancer-causing Chemicals from Drinking Water? Civil Engineering – ASCE 47:88.

Miller, G.W. and Rice, R.G. (1977). European Water Treatment Practices – and What We Can Learn From Them. Civil Engineering – ASCE 47:46.

Ogedengbe, O. and Adeniji, F.A. (1978). Quality Assessment of a Typical Rural Water Supply System in Nigeria. India J. Med. Res. 67: 638-646.

Sawyer, C.N. and McCarty, P.L. (1967). Chemistry for Sanitary Engineers. McGraw-Hill Book Company, New York.