I.J.S.N., VOL. 2(4) 2011: 850-855 ISSN 2229 – 6441

INTERNATIONAL JOURNAL OF SCIENCE AND NATURE
© 2004 - 2011 Society for Science and Nature(SFSN). All rights reserved
www.scienceandnature.org

APPROPRIATE WATER TREATMENT SYSTEMS FOR OWAN COMMUNITY, NIGERIA

[1]Akionbare W.N. & [2]Akhionbare S.M.O.
[1]Department of Project Management Technology, Federal University of Technology, Owerri, Nigeria.
[2]Department of Environmental Technology, Federal University of Technology, Owerri, Nigeria.

ABSTRACT
An earlier study revealed that the Owan community of Edo State of Nigeria is not adequately served by government-owned water supply facilities installed in the area. In this study, the quality of some alternative water sources (springs, hand dug wells and River Owan) in the community was assessed to determine appropriate, cost-effective and efficient technologies required to enhance their acceptability for domestic use. Results revealed that the colour of the spring (Aga) and the five hand-dug wells met the regulatory permissible levels while the river was deficient. pH for all water sources fell below the lower limit of 6.8. Waters were generally "soft" while iron and total solids content were within desirable limits. There was the presence of coliforms in all water sources signifying the need for disinfection. Treatment proposed for the water sources includes colour removal for rivers; pH correction for springs and wells; elevation of hardness values for all the three sources; and total coliform elimination for all sources. General source protection was recommended for preservation of quality of sources. Water treatment methods and technologies appropriate for this semi-urban community includes protection from storm runoff using infiltration galleries for river source, cisterns for spring and covered slabs for hand-dug wells. These obtained a fit between the people's water needs, attitudes, capacities, resources at their stage of development and regulatory standards for acceptable service delivery in simplicity, ease of maintenance and sustainability.

KEY WORDS*:* semi-urban, appropriate, quality deficiency, diffuser, infiltration gallery, regulatory standard, sustainability.

INTRODUCTION

Treatment of water in public waterworks is designed to adequately deal with changes in the quality of the raw water and produce a finished product of consistently high quality, however great the demand on the supply may be (Ohagi, 1983). The quality of the final treated water is largely dependent on the quality of the raw water particularly with regard to those mineral constituents that are not normally removed in conventional water treatment. The first step in determining the extent of necessary water treatment usually is to assess the quality of the raw water. The specific analyses include those parameters, quality characteristics and constituents known or suspected to be important in various uses of the finished water. The result indicates the areas in which deficiencies exist that must be corrected. When no deficiencies are found or are likely to occur, no treatment is necessary. When deficiencies are found, appropriate types of treatment must be undertaken to correct them. Selection of the specific treatment system to be used involves organizing a combination of processes appropriate for removing the undesirable constituents to produce a coherent whole that accomplishes the required overall performance reliably and economically (Akhionbare and Okieimen, 2003; Akhionbare, 2009).

In choosing a raw water source, the adequacy and reliability of the source are also considered, together with its capacity to meet existing and future demands. It is preferable to choose a source requiring a minimum amount of treatment, to the installation of elaborate water treatment plants for water sources of low quality (Hanidu and Ali, 1997). For rural areas, the desire is to move away from cost-prohibitive solutions that serve the need of a few to the adoption of proven, cost-effective technologies and approaches (such as hand pumps, spring protection, dug wells and upgrading of traditional water sources) that offer hope to all. Sanitary survey of a watershed detects the potential sources of pollution of a supply and assesses their present and future importance. For existing supplies, it enables the control of pollution hazards and the maintenance of the quality of the water. Reduction of contamination at source allows the use of more economical treatment processes e.g. the use of vegetable cover in rainwater collection areas can reduce erosion and hence reduce the amount of suspended solids in water; an intake could be sited to prevent the entry of suspended solids by removing its closeness to the river bed in order to remove the abstraction of sediment with the water; spring water could be protected by digging a ditch near the spring to divert surface water and providing a covered cistern to collect the spring water etc. Faniran (1982) suggests models for rural areas based on the sinking and protection of wells, perennial springs and rainwater-harvesting systems.

Among the priority needs of UNICEF in the 1990s are improved household technologies for protecting water quality from source to mouth for low-income areas

(UNICEF, 1995). There is little merit in providing water supply and related facilities if they are beyond the capacity of the community to use and sustain them properly (Feachem et al., 1977). This paper proposes appropriate designs of water treatment systems for the major water supply sources used in the Owan community based on available records of the quality characteristics of these sources from a previous study (Akhionbare and Okieimen, 2003).

STUDY AREA

The study area centres on the Owan East and Owan West Local Government Areas of Edo State of Nigeria. It is located in the northern part of Edo State bounded on the east by the Etsako East and Etsako West Local Government Areas, in the south by Ovia North East, Orhionmwon, Esan West, Esan Central and Igueben Local Government Areas. The major communities in Owan area considered in this study are Emai, Ora and Ozalla.

METHODOLOGY

The World Health Organisation (WHO) (1984) and the Federal Ministry of Environment (FMEnv, 1991) guidelines were used as standards to assess data on the following water quality criteria from the various water sources: colour, pH, total hardness, iron, total solids content, total coliform and *Escherichia coli* count.

Water Sources and Their Characteristics

Three major water supply sources considered are River Owan, which serves the Ora community, Aga spring which serves the Ozalla community and five hand-dug wells in the Emai community. The water quality characteristics of these water sources are summarized in Table 1. Table 2 shows regulatory limits for some chemical substances in raw water sources meant for abstraction prior to treatment. (FMEnv, 1991; WHO, 1984).

TABLE 1. Water Quality Characteristics for Some Water Sources in Owan Community(Akhionbare and Okieimen, 2003)

Quality Criteria	River Owan (Range)	Aga (Range)	Hand-dug Wells (Range)
pH	6.2 - 7.6	5.6 - 6.5	6.0 - 6.8
Colour (Hazen units)	10 - 220	5	5 - 50
Total hardness (mg/l as $CaCO_3$)	7.01 - 38.40	7.01 - 17.54	7.01 - 28.05
Total iron (mg/l)	0.10 - 0.40	0.00 - 0.10	0.10 - 0.27
Total solids (mg/l)	22.50 - 273.05	18.49 - 150.00	20.80 - 170.00
Total suspended solids (mg/l)	2.46 - 70.00	0.00 - 8.00	2.10 - 100.00
Total coliforms (MPN/ 100 ml)	17 - 2400+	28 - 920	6 - 2400+
E. coli (MPN/ 100 ml)	0 – 2	0	0

TABLE 2. Desirable and Permissible Concentrations of Chemical Substances and Properties Affecting Potability (FMEnv, 1991, WHO, 1984)

Substance or Characteristic	Undesirable Effects That May Be Produced	Highest Desirable Level (HDL)	Maximum Permissible Level (MPL)
Colour	Discoloration	5 units	50 units
pH	Taste, corrosion	7.0 - 8.5	6.5 - 9.2
Total hardness as $CaCO_3$	Excessive scale formation	100 mg/l	200 mg/l
Total iron	Taste, discolouration,	0.10 mg/l	1.0 mg/l
Total solids	turbidity, deposits	500 mg/l	1,500 mg/l
Total suspended solids	Taste Turbidity	5 units	25 units

WHO (1984) recommends that coliform organisms should not be detectable in any two consecutive samples of 100 ml. Table 1 indicates that the colour of water from springs and hand-dug wells meet the regulatory standards but the river values range fell outside the maximum permissible level (MPL) of 50 units. A means of colour removal is required for the river water. The lower range of pH for all water sources (rivers, spring and hand-dug wells) fell below the lower limit of WHO (HDL: 70 and MPL: 6.5). The spring and hand-dug well water pH ranges were particularly outside the HDL and slightly on the acidic side of the pH scale. A form of pH correction is needed. Records (Akhionbare and Okieimen, 2003) also showed that pH values for the rivers tended towards neutrality during the rainy periods of the year due to dilution of ions in the water body. All water sources recorded low hardness values typifying "soft" waters (hardness values below 50 mg/l). Soft waters usually present problems in distribution systems, as the buffering capacity of the water is insufficient (Lamb, 1993). There is the need to raise the values above 50 mg/l but below ranges that would produce hard water which is a problem in domestic laundry. Values fell within the MPL for all three sources of water; but the rivers had higher fluctuations. Values for total solids and total suspended solids contents for all the water sources fell within the WHO's HDL. The presence of coliforms in the water samples from all the sources calls for definite action for their elimination. Only the river had a confirmation of the presence of E. coli (coliforms of human origin) in the samples. This calls for action to remove/prevent the source of this pollution.

Appropriate Water Treatment Systems for the Water Sources

The treatment required for the various water sources are as follows: colour removal for rivers; pH correction for springs and wells; elevation of hardness values for all the three sources; and total coliform elimination for all sources as well as general protection and preservation of the quality of good sources. Appropriate water treatment methods proposed for these sources fall into the following groups:

Protection from storm runoff

Water from the spring had consistently high quality which can be preserved through protection. Two major types of protection are proposed namely: structural and chemical protection. Public education and sanitary awareness are non-structural means of protection. Structural means involve construction of infiltration galleries on the river, concrete covers for hand-dug wells and covered cisterns for the spring source. High quality water sources are protected by non-structural methods. The construction of boxes (cisterns) which require labour and fund commitment are justifiable to ensure that surface contaminants do not reach the water supply. When viewed against the bacterial quality of the spring water, the structural protection could represent an attractive substitute for other methods of disinfection, since to do both would appear uneconomical. Structural source protection is expected to have substantial costs in labour, capital expenses and even lowered water quality (Pojasek, 1977). It is advocated that structural and chemical alternatives follow, rather than have a quality problem. Water surveys of source watershed, elimination of all controllable sewage impacts, routing rails of waste away from watersheds, are encouraged. To guard against animal waste contamination of surface waters, deliberate efforts to discourage free ranging would help. Figures 1, 2 and 3 represent protection facilities for the river, spring and hand-dug well sources.

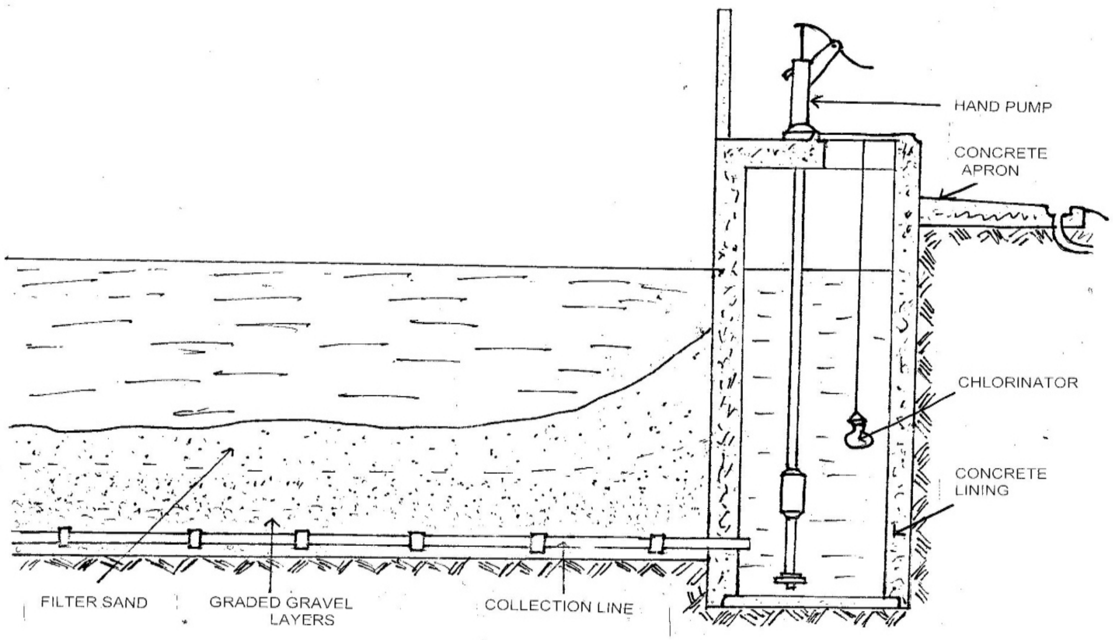

FIGURE1. An Infiltration Gallery for a Surface Water Source

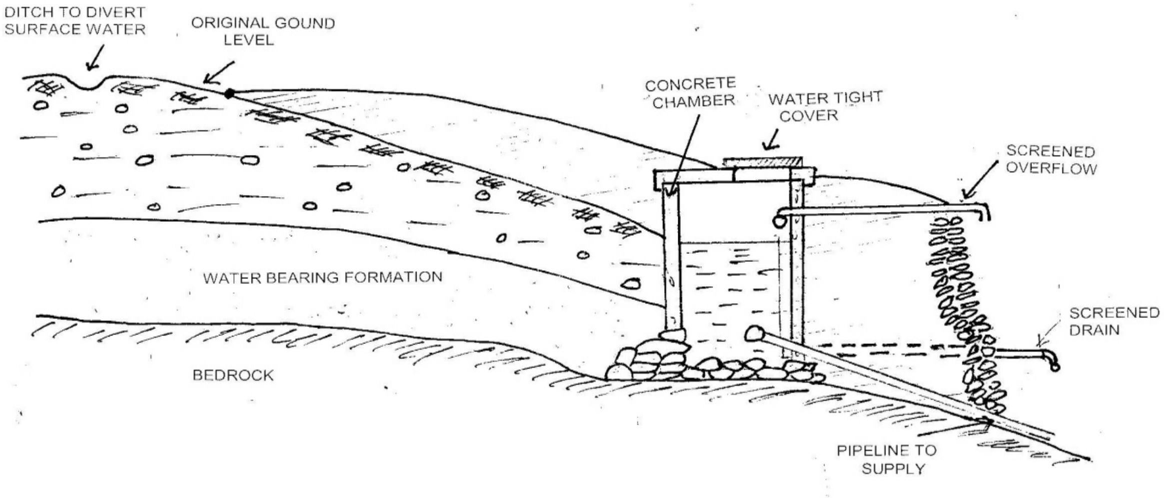

FIGURE 2: A Protected Spring Source

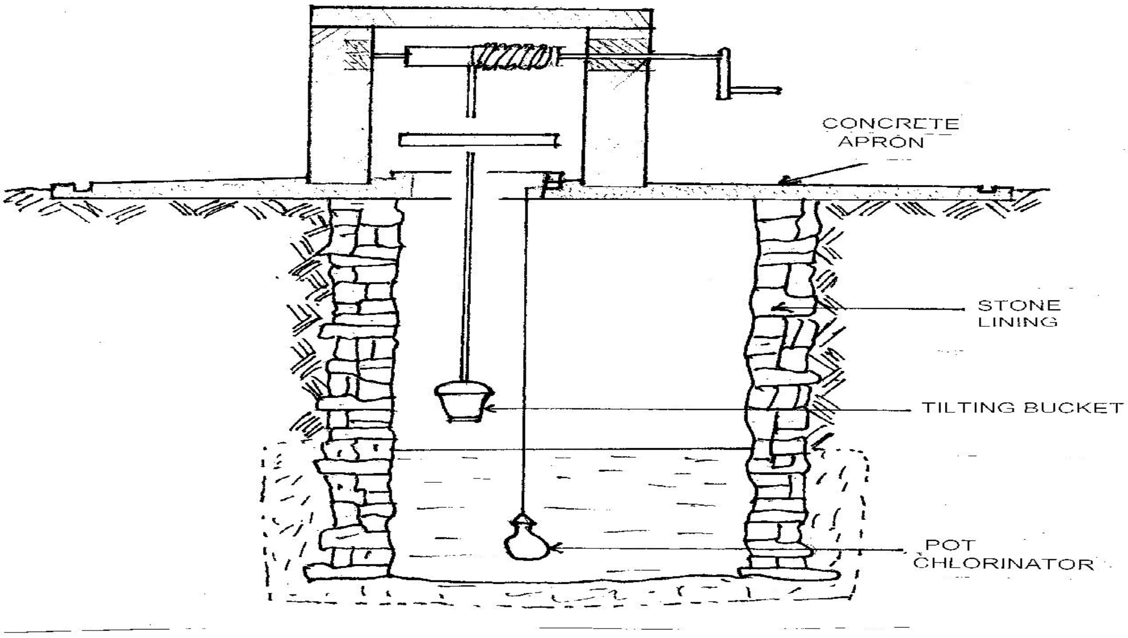

FIGURE 3: A Dug-Well with windlass

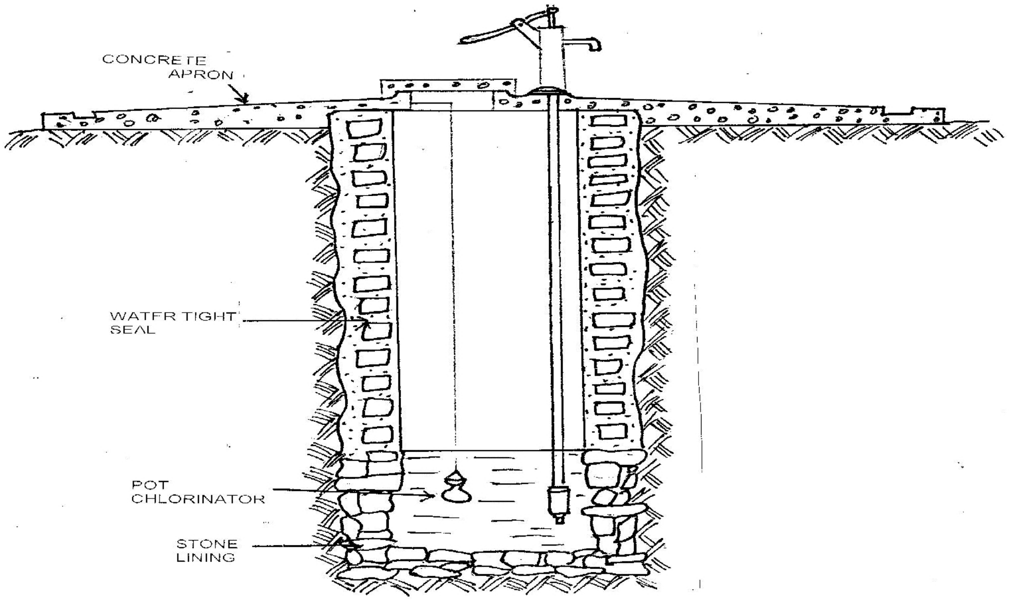

FIGURE 4: A Dug-Well with handpump

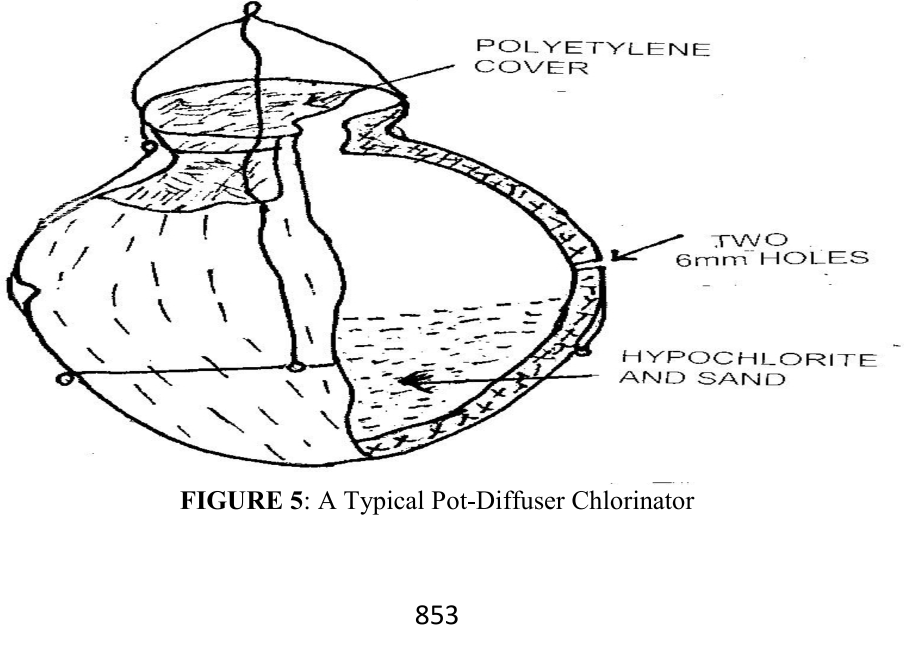

FIGURE 5: A Typical Pot-Diffuser Chlorinator

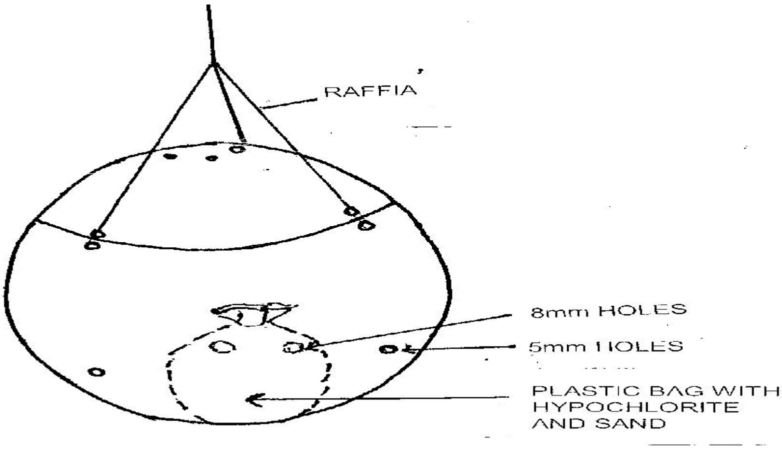

FIGURE 6: A Coconut-shell Diffuser Chlorinator

Galleries help to arrest the subsoil flow along their entire length with a comparatively lower draw down in a riverbed. In rivers, there are seasonal variations in surface flow, and depending on the nature (texture) of the subsoil layers, water can be abstracted by digging tunnels parallel to the river alongside the river. Water is filtered in passing through the bed material and can be made to deliver it into a well located at the margin of the river. The well can provide a safe supply through hand pumps. Sediments build up on top of the gallery and this may retard subsequent free passage of water. The surface silty layer is removed periodically. The cross-section and length of the gallery depends on the quantity and rate of flow of draw at the well; normally a gallery measuring 2.5m x 2.5m x 10m is able to provide about 10,000 litres per day.

Figure 2 shows a protected spring source. Sanitary measures are important in the area around the source to keep the supply safe. A masonry chamber is placed so as to intercept the flow. A diversion ditch is built to direct surface water and providing a covered cistern to collect the spring water. The supply is piped from a tap near the spring. An overflow drain is provided and led away by PVC drains. Domestic animals are excluded from the area around the spring by erecting a fence.

Figure 3 represents a method for protecting a hand-dug well. The safety of the water is ensured by covering the well with a watertight slab (with manhole and cover) constructing a concrete apron all around, and providing an impervious lining to a depth of 3 metres. A windlass comprising a common rope and a tilting bucket is proposed, the mouth of the well being covered as a sanitary precaution. An alternative can be the installation of hand-pump instead of the windlass.

Correction for pH and hardness

The most practical and economic method would be aeration and the application of hydrated lime to the water from all three sources. Natural groundwater from springs and wells usually has low pH values and is hence aggressive due to the presence of dissolved carbon dioxide (Lamb, 1993; Akhionbare, 2009). With lime application, the pH value can be raised to the desired level by introducing doses of lime. Aeration eliminates the CO_2 hence reducing the corrosiveness of the water. Lime addition will convert the free CO_2 to bicarbonate, thus increasing the alkalinity of the water and its buffer capacity.

Disinfection to remove bacteria

That the physico-chemical quality of a water source is satisfactory does not mean that the water should be consumed without disinfection. Disinfection is the treatment proposed to destroy any coliform bacilli present in the water sources. Physical and chemical methods of disinfection are proposed. The physical method involves boiling of the water but this is impracticable on a large scale. They are hence proposed for private household use. For community purpose, the use of chlorine (calcium hypochlorite) is proposed using such dosing facilities as shown in Figures 4 and 5. Apart from its germicidal effect, chlorine has several important secondary properties in water treatment: it oxidizes iron; it destroys taste and odour; it controls algae and slime organisms. Because of its oxidizing ability, any organic matter in the water uses part of the chlorine applied. Enough chlorine is applied therefore for organic matter and microorganisms leaving enough residual to deal with further infection of the water during distribution. The residual is measured after a contact time of at least 30 minutes. Using the brand of chlorine called OLIN BLUE DRUM - HIGH TEST HYPOCHLORITE (HTH) which contains 68-70% available chlorine, and which is commonly used in many municipal water supply facilities in this country, the following amounts will be required to disinfect the various quantities of water as shown in Table 3.

TABLE 3. Average Amounts of Calcium Hypochlorite Needed to Disinfect Various Amounts of Water for Drinking (Rajagopalan, 1974)

Volume of Water (m^3)	HTH (grams)
1.0	1.0
2.0	2.0
4.0	4.0
5.0	5.0
10.0	10.0
40.0	40.0
150.0	150.0
200.0	200.0
500.0	500.0

For household water containers, depending on the size of the containers for storage, Table 3 values are applied to obtain well-disinfected water for drinking for the family. The essence of the use of the table in calculating the requirement for various water volumes hinges on the need to minimize excess residual chlorine and consequent corrosion of the plumbing systems. To do this, tanks of sufficient size to retain a day's supply of water is installed; and rigorous free residual chlorine monitoring is done (determined with DPD tablet No. 1 to a faint pink colour) (APHA, 1985).

Figure 4 is a pot-diffuser used in chlorination. It is made up of a simple earthen pot filled with the appropriate moist mixture of the chlorine powder and sand; and suspended in a hand-dug well about one metre below water level. It is suitable for a daily withdrawal rate of 900 - 1300 litres (40 to 60 persons) for about a week, with residual chlorine levels in the range of 0.2 - 0.8 mg/l. The pot is about 12 - 15 litres capacity with two holes on opposite sides about halfway down the pot. A moistened mixture of the chlorine compound and 3 kg of coarse sand would not fill the pot above the holes. The mouth is covered with polythene and the pot is lowered in the well and suspended away from the points at which water is withdrawn. Figure 5 is another modification of the pot-diffuser where a coconut shell is used instead of earthen pot. A plastic bag containing a mixture of chlorine powder and clean sand in equal proportions is placed inside the lower part of the shell (the mouth of the bag being closed with a rubber band) and the two parts are then fastened together by rubber bands passed through staples at three peripheral points. Three holes (each 0.5 cm in diameter) bored through the container body and two holes (0.8 cm in diameter) punched in the middle of the plastic bag, enable the disinfectant to pass through the shell into the body of the water. Three cords of raffia passed through three staples hang the chlorinator about 30 cm below the water surface. This device can disinfect small domestic hand-dug wells with daily withdrawal rates of about 90 litres for about three weeks giving a residual chlorine level of about 0.2 - 0.1 mg/l. When the residual chlorine level falls below 0.1 mg/l, the plastic bag is refilled with fresh chemical or the whole unit is replaced.

CONCLUSION

The treatment proposed for the water sources would achieve objectionable colour removal for rivers; pH correction for springs and wells; elevation of hardness values for all the three sources; and total coliform elimination for all sources. General protection and preservation of the quality of good sources through watershed surveillance is also encouraged.

REFERENCES

Akhionbare, S.M.O. (2009) ***The Environment: Concepts, Issues and Control of Pollution***. MC Computer Press. Nnewi, Nigeria.

Akhionbare, S.M.O. and Okieimen, F.E. (2003) "Quality Assessment of Drinking Water from Hand-dug Wells in Emai Community of Edo State". ***Nigerian Journal of Applied Science***. 21:50 – 55.

American Public Health Association (APHA) (1985) ***Standard Methods for the Examination of Water and Wastewater***. NY.

Faniran, A. (1982) "The Perception of Water Quality Among Rural Communities in Southwestern Nigeria". A paper presented at the Third National Conference on Water Pollution. Port Harcourt.

Feachem, R., McGary, M. and Mara, D. (1977) ***Water, Wastes and Health in Hot Climates***. John Wiley and Sons. Chichester NY. p.75.

Federal Ministry of Environment (FMEnv.) 1991. National Guideline Standards for Industrial Effluent, Gas Emissions and Hazardous Waste Management. Federal Environmental Protection Agency.

Hanidu, J.A. and Ali, M. (1997) "Challenges in Rural Water Supply and Sanitation". A paper presented at the National Conference on Water Sector Reform. Abuja.

Lamb, J.C. III. (1993) Lecture Notes on Water Quality and Monitoring, University of Delft.

Ohagi, S.M.O. (1983) "Physico-chemical and Bacteriological Analysis of Ikpoba River". M.Sc. Thesis in the University of Benin.

Pojasek, R.B. (1977) ***Drinking Water Quality Enhancement Through Source Protection***. Ann Arbor Science Pub. Inc. Michigan.

Rajagopalan, S. (1974) ***Guide to Simple Sanitary Measures for the Control of Enteric Diseases***. WHO. Geneva.

United Nations Children's Educational fund (UNICEF) (1995) "Child Survival, Protection and Development (CSDP) in Nigeria, Key Social statistics".

World Health Organisation (WHO) (1984) "Guidelines for Drinking Water Quality". Geneva.