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Comparative Analysis of Water Quality of Water Stored in Concrete, Steel and Plastic Storage Facilities

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Abstract— *In Nigeria it has been a common practice to construct water storage tanks with steel, plastic and concrete materials. With this scenario, there has been unpalpable concern and worry due to the uncertainty of the effects of these storage materials on the quality of the water in them. The study investigated the effects of steel, plastic and concrete storage tanks have on quality of water stored in them. The analytical method was used in this assessment of samples by analyzing the water samples collected before storage and the water stored in the three different storage facilities for seven days. The results were compared with World Health Organisation standards. The pH of the water samples before storage was 4.66 and after storage, it was 4.91, 6.87 and 4.84 for plastic, concrete and steel containers respectively and these are still within WHO limits. Metal like iron (0.239mg/l) was detected in steel, manganese (0.122) in concrete storage facilities. The conductivity of water in the original water sample before storage was 39µS/cm while that in the three storage facilities were discovered to be 49µS/cm, 72µS/cm and 92µS/cm for plastic, concrete and steel storage tanks respectively after storage; thus proving that there are more dissolved metal ion in steel storage tank caused by corrosion and more dissolved minerals in concrete storage tanks than plastic storage tanks. The result of the research showed that the physical, biological and chemical characteristics of the stored water were within the acceptable limits of W.H.O. standards except the total heterotrophic bacteria which were detected in outrageous amounts in the water stored by the different tanks. This is the only parameter that was significantly affected by the type of storage facility and which renders the water unacceptable according to World Health Organization (WHO) Standard.*

I. INTRODUCTION

1.1 Background of Study

Water has always been a very important and life-sustaining resource to humans and his related activities and is essential to the survival of all organisms and animals. It is vital in metabolic processes in living things and serves as a solvent for many solutes needed in the body. Current focus on water quality issues has been on physical and chemical contamination occurring within the distribution systems and storage facilities (Dodoo, et al., 2006). Where piped water supply to the household operates occasionally, storage facilities are commonly used to ensure that there is sufficient water for the society needs throughout the day. Definitely in rural areas, many people rely on rainwater tank storage for water provision, both for domestic and agricultural purposes. The storage and re-use of rainwater and other sources of water can reduce demand on the municipal water supply, particularly for non-potable uses such as toilets, laundry and gardening. Many people are now opting to invest in water storage tanks to collect water from different sources for domestic use or for commercial purposes. Tanks were used to provide storage of water for use in many applications, drinking water, irrigation agriculture, fire suppression, agricultural farming, both for plants and livestock, chemical manufacturing, food preparation as well as many other uses (Walski, 2009).

Duer(2006) indicated that the importance of water as a mechanism for the spread of disease has long been recognized as seen by the large amount of peer reviewed articles concerning the relationship of health to water quality and sanitation. Often in developing countries with high morbidity and death numbers, the health problems are related to poor water quality, limited water availability, limited sanitation and/or poor hygiene practices. Most interventions in these situations include: improving access to water, providing household treatment options, improving sanitation, good storage facilities and hygiene education (Kennedy, et al., 2004). There is also a growing body of evidence that storage systems can cause a decrease in the quality of water.

As published by Pradhan, (2012), Water quality problems in storage facilities can be classified as microbiological, chemical or physical. Excessive water age in many storage facilities is probably the most important factor related to water quality deterioration. Long detention times, resulting in excessive water age, can be conducive to microbial growth and chemical changes. The excess water age is caused by underutilization (i.e., water is not cycled through the facility), and short circuiting within the storage facility. Poor mixing (including stratification) can aggravate the water quality problems by creating zones within the storage facility where water age significantly exceeds the average water age throughout the facility (Rokade, and Ganeshwade, 2005). Distribution systems that contain storage facilities where water cascades from one facility to another (such as pumping up through a series of pressure zones) can result in exceedingly long water age in the most distant tanks and reservoirs. Though the storage facility is normally an enclosed structure, numerous access points can become entry points for debris and contaminants. These pathways may include roof top access hatches and appurtenances, sidewall joints, vent and overflow piping.

Good water quality is needed to maintain viable aquaculture production; poor water quality can result in low profit, low product quality and potential human and aquatic health risks. Production is reduced when the water contain contaminants that can impair expansion, growth, reproduction, or even cause death to the cultivated species (Stone and Thormforde, 2003).

Concrete tank, metal tank and plastic tank (a synthetic material affected by heat or pressure shaped into a water tight container), are among the storage vessels used to collect and store water for its various uses (Jonathan, 2010). High concentrations of heavy metals could be significant if corrosion is evident in the tanks. Many studies over the past decades investigated the corrosion and controls of metals in water distribution systems. The galvanized steel water storage tanks contain variable levels of heavy metals such as: Fe, Pb, Mn, Ni, Cu, Zn and many others. This contributes to the increasing concentration of these heavy metals in the drinking water.

Numerous studies have been done focusing on physical, chemical and microbial water quality of water in storage containers in situations where water is collected at a community source and then transported to the home. For example Kerneis et al., (2005) and Tokajian and Hashwa, (2003) performed studies that show how water quality degrades when supply is intermittent and as the residence time associated with distribution and storage increases. However, few studies have been performed on qualities of water in storage tanks. In addition, no peer reviewed articles were found by the author on field studies evaluating water quality of storage tanks commonly found in the developing world. The enthusiasm for this study results from the need for more research into water quality in modern water distribution systems and the causes of contamination of water in concrete, plastics and steel storage tanks. This study examines the effects of tank material, tank water temperature and other factors on water quality in storage tanks in the city of Port Harcourt, Rivers State, Nigeria. The overall objective is to determine how the materials used to construct water storage tanks impact physical and chemical quality of water in household storage tanks as well as document the water quality. Most of the previous research works were not specific at water quality. Therefore not much effort has been made to investigate the impact of storage vessels on the quality of water stored in them. This study will investigate the effect of different storage vessels on water quality.

1.2 Factors Leading to Water Quality Deterioration

A study by Sobsey, et al (2003) shows that water storage facility, after-water treatment, and the pipe network in a community that transports water from the water storage location(s) to supply point of consumption, constitutes a complex network of entrapped water where uncontrolled chemical and biological reactors can produce significant variations in water quality in both time and space. The primary factors of water quality deterioration in distribution systems as described by Meride, (2016), Sobsey, et al., (2003), Sawane, et al., (2005), and Rokade and Ganeshwade (2005) include the following: contamination via cross-connections or from leaky pipe joints; corrosion of iron pipes and dissolution of lead and copper from pipe walls and joints; loss of disinfectant residual in storage facilities with long resident time (this can also occur from long resident time in water mains where the flow velocity is inadequate to keep all of the water moving); bacterial regrowth and harboring of opportunistic pathogens; supply sources going online and offline; reactions of disinfectants with organic and inorganic compounds resulting in taste and odor problems; increased turbidity caused by particulate resuspension; and new formation of disinfection byproducts, some of which could be suspected carcinogens. The driving factors affecting water quality in a distribution system: the quality of the treated water fed to the system; the material and condition of the water pipes, distribution system valves, and storage facilities that make up the water system; and the amount of time water is retained in the system. With reference to the last item, it is most important to understand that on a looped pipe network system, the water reaching any particular consumer is actually a blend of water parcels that may originate from different sources at different points in time and follow different flow paths (Sawane, et al., 2006).

i. In Nigeria, focus on water quality issues has been on physical/chemical contamination occurring within the storage system. Evidence has been found indicating that the switch from chlorine to chloramine for disinfection increases corrosion of steel tank, which leads to elevated ion concentration levels in the water (Edwards and Dudi, 2004). Lagerblad, (2007) discovered that the presence of chlorine has also been implicated in higher rates of copper corrosion (Boulay and Edwards, 2001). Another study has shown that maximum corrosion rates occur at 30°C, which coincides with maximum bacterial growth (Arens et al., 1995). In developing countries, the focus has been on improving the chemical water quality of drinking water supplies. Although the presence of a water storage system is often seen as a sign of improved water quality, it does not imply that the water is free of chemical pollution and therefore adequate for application without negative effect (Lee and Schwab, 2005). Luck, (2008) report that oftentimes, water leaving treatment systems or arriving at community storage facilities is chemically safe; however contaminants may enter a storage system after treatment or during advance environmental condition such as increase in temperature (Nath et al., 2006). According to Craun and Calderon, (2001), in the United States alone approximately 18% of waterborne disease outbreaks were linked to contaminants entering the storage system after storage. Worldwide, contaminated water has been transported through storage systems and has been drawn-in in the spread of outbreaks of typhoid fever, cholera and diarrheal diseases. These pathogens have been found to be present in unimproved as well as improved water storage facilities (Gundry et al., 2004).

II. Materials And Methods

2.1 Materials

The analysis was carried out in the Laboratory. Several materials were used to carry out the analysis raging from the apparatus, reagent and instruments. The apparatus used include; different sized beakers, measuring cylinders, micropipette, volumetric flasks, burettes, funnel, test tubes, thermometer, Stopwatch, oven, electronic-mill, plastic bottles, Erlenmeyer flask (different sizes), refrigerator, filter papers and stirrer.

Digital analytical balance was used to determine the weight while FAAS was used to determine the concentrations of metals. Other apparatus used included a potentiometric digital pH meter and Conductivity meter. The main reagent that will be used are listed below; Buffer solution, $Pb(NO_3)_2$, HCl, $KMnO_4$, Distilled water, Nitric acid (HNO_3)

2.2 Methods

The analytical method was used in the assessment of the water samples before and after storage in the different storage tanks. The results of the analysis were compared with respect to the medium of storage. The results were also compared with World Health Organization standards.

Water samples were collected from one source and analyzed before storing in the three different storage tanks and were collected after storage at a specific storage period and tested. Prior to this, the plastic bottles were rinsed with 0.02M HNO_3 to maintain the constant pH and minimize loss of sample because of variation in PH, evaporation, precipitation and other relevant physical, biological and chemical properties. The sampling bottles were filled and then sealed tightly to avoid head space that could cause loss of samples because of oxidation. The physical, chemical and biological characteristics of the samples were analysed according to laid down standard methods.

III. Result And Discussion

3.1 Result: The result of the analysis is bifurcated into Pre-Storage Result and Post- Storage Result as presented below;

3.1.1 Result of water quality test before storage

The quality of water before storage is shown in Table 3.1.

Table 3.1: Result of the quality of water before storage

S/N	Parameters	Water before Storage
1	pH	4.66
2	Temperature (^oC)	30.6
3	Conductivity (µS/cm)	39
4	Turbidity (NTU)	0.03
5	Salinity ($^o/_{oo}$)	0.02
6	Total Dissolved Solid, TDS (mg/l)	20
7	Total Hardness (mg/l as $CaCO_3$)	18.3
8	Calcium as Ca (mg/l)	0.9
9	Iron as Fe (mg/l)	<0.001
10	Manganese as Mn (mg/l)	<0.001
11	Chromium as Cr (mg/l)	<0.001
12	Lead as Pb (mg/l)	<0.001
13	Zinc as Zn (mg/l)	<0.001
14	Faecal Coliform Bacteria (MPN/100ml)	Nil
15	Total Coliform Bacteria (MPN/100ml)	Nil
16	Total Heterotrophic Bacteria (cfu/ml)	0.3 x 10

3.1.2 Result of water quality test after storage

The result of water quality analysis carried out in the laboratory for the three different storage tanks is shown in Tables 3.2, 3.3, 3.4 and the comparative assessment is shown in Table 3.5;

Table 3.2: Table showing the test for water quality in plastic storage tank after storage

S/N	Parameters	Plastic
1	pH	4.91
2	Temperature (^oC)	31.1
4	Turbidity (NTU)	0.10
5	Salinity	0.02
6	Total Dissolved Solid	34
7	Total Hardness	19.2
8	Calcium as Ca (mg/l)	6.2
9	Iron as Fe (mg/l)	0.182
10	Manganese	<0.001
11	Chromium	<0.001
12	Lead as Pb (mg/l)	<0.001
13	Zinc as Zn (mg/l)	<0.001
14	Faecal Coliform Bacteria (MPN/100ml)	Nil
15	Total Coliform Bacteria (MPN/100ml)	Nil
16	Total Heterotrophic Bacteria (cfu/ml)	4.5×10^3

Table 3.3: Table showing the water quality of concrete storage tank after storage

S/N	Parameters	Concrete
1	pH	6.87
2	Temperature (^oC)	31.1
4	Turbidity (NTU)	0.13
5	Salinity	0.03
6	Total Dissolved Solid	51
7	Total Hardness	3.8
8	Calcium as Ca (mg/l)	1.5
9	Iron as Fe (mg/l)	<0.001
10	Manganese	0.122
11	Chromium	<0.001
12	Lead as Pb (mg/l)	<0.001
13	Zinc as Zn (mg/l)	<0.001
14	Faecal Coliform Bacteria (MPN/100ml)	Nil
15	Total Coliform Bacteria (MPN/100ml)	Nil
16	Total Heterotrophic Bacteria (cfu/ml)	6.5×10^3

Table 3.4: Table showing the water quality in steel storage tank after storage

S/N	Parameters	Steel
1	pH	4.84
2	Temperature (^oC)	31.4
4	Turbidity (NTU)	0.09
5	Salinity	0.04
6	Total Dissolved Solid	65
7	Total Hardness	13.4
8	Calcium as Ca (mg/l)	3.8
9	Iron as Fe (mg/l)	0.239
10	Manganese	0.062
11	Chromium	<0.001
12	Lead as Pb (mg/l)	<0.001
13	Zinc as Zn (mg/l)	<0.001
14	Faecal Coliform Bacteria (MPN/100ml)	Nil
15	Total Coliform Bacteria (MPN/100ml)	Nil
16	Total Heterotrophic Bacteria (cfu/ml)	4.0 x 10

3.5 Comparing Laboratory Physico-chemical Analysis with WHO Standards

The result of water quality carried out in the laboratory is compared with that of the World Health Organization (WHO) and is shown in Table 3.5;

Table 3.5: Comparism of water samples in plastic, concrete, steel and WHO standards

S/.No	Parameters	Plastic	Concrete	Steel	WHO Standard
1	pH	4.91	6.87	4.84	6.5-8.5
2	Temperature (°C)	31.1	31.1	31.4	Ambient
3	Turbidity (NTU)	0.10	0.13	0.09	<1.5
4	Salinity (o/oo)	0.02	0.03	0.04	Function of TDS
5	Total Dissolved Solid TDS (mg/l)	34	51	65	1000
6	Total Hardness (mg/l)	19.2	3.8	13.4	100-300 mg/l
7	Calcium as Ca (mg/l)	6.2	1.5	3.8	100-300 mg/l
8	Magnesium as Mg (mg/l)	3.159	0.56	2.33	100-300 mg/l
9	Iron as Fe (mg/l)	0.182	<0.001	0.239	0.3
10	Manganese as Mn (mg/l)	<0.001	0.122	0.062	0.4
11	Chromium as Cr (mg/l)	<0.001	<0.001	<0.001	0.05
12	Lead as Pb (mg/l)	<0.001	<0.001	<0.001	0.01
13	Zinc as Zn (mg/l)	<0.001	<0.001	<0.001	0.01
14	Faecal Coliform Bacteria (MPN/100ml)	Nil	Nil	Nil	Not detectable in 100ml of sample
15	Total Coliform Bacteria (MPN/100ml)	Nil	Nil	Nil	Not detectable in 100ml of sample
16	Total Heterotrophic Bacteria (cfu/ml)	4.5×10^3	6.5×10^3	4.0 x 10	Not detectable in 100ml of sample

3.2 Discussion

The water quality in the three storage facilities is quite good as they meet most of World Health Organization (WHO) Standard except that they promote heterotrophic bacteria. This can be as a result of the storage period of the water samples in the three different storage tank. The pH value of water samples from plastic and steel storage tank is lower compared with that of concrete storage tank. The cause of water sample from concrete tank increased pH compared to rest of the storage tank might be due to the content of material of construction (i.e limestone).The temperature of the water samples were not affected by the type of storage tank but rather, the solar energy absorbed by the storage tank and this varies between materials for construction. The temperature for the three storage tank are negligibly different.

The turbidity of water in the three storage tank are within the acceptable limit of WHO standard. The result signifies that storage tank did not have significant effect on turbidity of water samples. However, comparing the turbidity of water from the three storage tank; that of concrete is insignificantly higher than the others. The reason could be that concrete storage tank promotes. The conductivity of water in steel tank is higher than the conductivity of water in plastic and concrete tank. This could be as a result of dissolved metal ion caused by gradual corrosion in steel. The higher the metal ion concentration in water, the higher the conductivity of water. Likewise the conductivity of water in concrete tank is higher than that of plastic tank. The TDS value in steel tank is higher than the rest of the storage tank; the reason could be attributed to metallic carbonate or metallic salt. It should also by the same reason for TDS value of water samples in Concrete storage tank been slightly higher than TDS value for water sample in plastic storage tank. The salinity is a confirmation that there are more salt or carbonate in steel than in concrete and more in concrete than in steel. The Total Hardness for plastic and steel is surprisingly higher than that of concrete. No chemical phenomena can prove this to be possible except the hardness is from source of water. The same reason account for calcium and magnesium content.

Iron is detected in water samples from plastic and steel storage tanks only; in concrete storage tank, iron is less than the detection limit. Iron is present in steel because it is made up of iron and corrosion activities could be the cause of the high presence of iron in water samples from steel storage tanks, however, the presence of iron in plastic could be as a result of contamination of the water during storage since there is no presence of iron in HDPE storage tanks. Manganese is also detected in concrete and steel tank but more in concrete storage tanks. This could be attributed to the reason that manganese are trace element in the found during the production of cement. Manganese is present in steel as a result of incomplete purification of iron and hence, can affect the quality of water by its presence.

The biological characteristic is one of the most important quality test of water as this could determine if the water can used for drinking, fishery, house hold uses, and other agricultural purposes.Faecal coliform bacteria were not detected in any of the water samples. This is very important which signifies that the water can be used for fishery, irrigation, household uses (apart from drinking), bathing etc. Total coliform bacteria was not detected in any of the water samples from the storage tank. This signifies that the sanitary condition of a water storage tank is still good.Total heterotrophic bacteria are found in significant quantity in the three storage tank, but more Concrete tank. Concrete materials favour the growth of Total heterotrophic bacteria and for this reason, it is found to be more in concrete storage tank. The water samples from the three storage tank did not meet the WHO standard for drinking water quality.

IV. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

It can be concluded that steel storage facility in conjunction with corrosion protection system installed with it is the best storage facility when storing water for a significant long period of time. The study implies that steel storage tank users should install corrosion protection system in order to avoid harmful metal ion entering into the stored water.

Concrete storage facility users should not allow the water in the storage facility to remain for long period of time as this study reveal that concrete storage facility promotes the presence of heterotrophic bacteria. Likewise for plastic water storage facility users, the water storage time should not be too long and constant maintenance of the storage facility should be implemented.

From the study, it can also be concluded that when storing water for a short period of time, the best storage facility is the plastic storage tank as this has no metal dissociation and no inorganic reaction occurring in the system. The material for construction of plastic tanks does not have a significant effect on stored water except that the promotion of Heterotrophic bacteria is high when water is stored for a long period of time.

4.2 Recommendation

Following the results of this research, the following recommendations;

1. Water storage tank users should not store water in storage facility for too long period as this will promote the Heterotrophic bacterial in the tank thereby making it harmful.
2. Regular maintenance of the water storage facilities is required. If water is stored for long, the bacterial activities can be terminated be carrying out maintenance activities.
3. Further studies showing the daily deterioration level of stored water in the storage facilities should be carried out in order to know when biological activities is at its peak or when they start to gain momentum in the storage facilities.
4. .Other types of storage facilities should be investigated such as ceramics, earthen vessel, glass storage facilities and so on and the result should also be compared so as to draw conclusion on the type of storage facilities that is best used.

REFERENCES

[1] Drews Nelson, A. (2010) Determination of physico-chemical parameters and heavy metals in water samples from Itaogbolu area of Ondo-State, Nigeria, *African Journal of Environmental Science and Technology,* 4(3), pp 145-148.

[2] Dodoo, S. Neden, D., Jones, R., Smith, J., Kirmeyer, G., and Foust, G. (2006). "Comparing Chlorination and Chloramination for Controlling Bacterial Regrowth." *J. Am. Water Works Association,* 73(7), 80-88

[3] Duer G., (2006) Drinking water quality management through correlation studies among various physicochemical parameters: A case study, *International Journal of Environmental Sciences,* 1(2), pp 253-259.

[4] Edwards B., and Dudi, H. (2004) Impact of storage tanks on drinking water quality in Al-Karak province Jordan. *J ApplSci* 5(4):634–638.

[5] + Controlling Bacterial Populations in Potable Waters: Community Water Supply." *J. Am.Water Works Association,* 64(9), 596-602.

[6] Grayman, T., (2004) Chlorination and safe storage of household drinking water in developing countries to reduce waterborne disease. *Water Science andTechnology.* 47:221-228.

[7] Jonathan, E. (2010) Safe water treatment and storage in the home. A practical new strategy to prevent water-borne disease. *J Am Med Assoc* 273:948–953

[8] Kerneis, T. (2009) Water quality assessment of Osun River: studies on inorganic nutrients. Environ Monit Assess 69:17–22

[9] Kerneis J., LeChevallier, M. and McFeters, G. (2005). "Interactions Between Heterotrophic Plate Count Bacteria and Coliform Organisms." *App. Environ. Microbiol.,* 49(5), 1338-1341.

[10] Lagerblad, Q., (2007) California Survey of Solvents Leaching From Cold-Applied Coal Tar Paints Used as Internal Coatings in Potable Water Storage Tanks. In *Proc. Of California-NevadaSection AWWA.* Anaheim, CA

[11] Luck, R. (2008) Waterborne disease outbreaks caused by distribution system deficiencies. *Journal of the American Water Works Association,* Vol 93(9) pp 64–75.

[12] Luck S. Regan, J., Cho, A., Kim, S., Smith, C. (2008). "Monitoring Ammonia-Oxidizing Bacteria in Chloraminated Distribution Systems." *American Water Works Association ResearchFoundation.* Denver, CO.

[13] Meride, F. (2016) Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. *Tropical Medicine and International Health,* Vol 9 (1) pp 106-117.

[14] Nath W., Navneet, Kumar, and D. K. Sinha, (2006), Drinking water quality management through correlation studies among various physicochemical parameters: A case study, *International Journal of Environmental Sciences,* 1(2), pp 253-259.

[15] Rokade, H. and Ganeshwade, E. (2005) Role of chlorine and chloramines in corrosion of leadbearing plumbing materials. *Journal of the American Water Works Association.* Vol 96(10) pp 64-82.

[16] Sawane, C., Donlan, R. M., and W. O. Pipes. (2005) Selected drinking water characteristics and attached microbial population density. *Journal of the American Water WorksAssociation,* Vol 80(11) pp 70–76.

[17] Sobsey, T. (2002) "Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use", *Tropical Medicine and International Health,*vol/issue: 9(1), pp. 106-117.

[18] Sobsey, B., Viraraghavan, T., and Mathavan, G. N. (2003). Effects of low temperature on physicochemical processes in water quality control. *Journal of Cold Regions Engineering* 2(3): 101-110.

[19] Stone D., and Thormforde, B., (2003). Evaluation of the effect of temperature and nutrients on the survival on Campylobacter spp. in water microcosms. *Journal of Applied Microbiology* 86(6): 1024-1032.

[20] Tokajian, T., (2001). Analysis of Water Quality Parameters: A review. *International Journal of Engineering Research.* ISSN:2319-6890. Volume No.6, Issue No.3, pp :145-148.

[21] Tokijian C., and Hashwa, A., (2004) Influence of Temperature on Taste Intensity and Degree of Liking of Drinking Water. *J. American Water Works Association.* 64, 511-515.

[22] Tokajian D. and Hashwa, O. (2003) Physico-chemical and bacteriological quality of drinking water of different sources, Jimma zone, Southwest Ethiopia. BMC Res Notes 8:541

[23] United Nation (2007), Water-related diseases. http://www.who.int/water_sanitation_health/diseases/en/. Accessed January 2018

[24] University of Cambridge, (2005) Advanced the science of water: Awwa RF and distribution system water quality. http://eclass.duth.gr/modules/document/file.php. Accessed January 2018.

[25] Vikal, G., (2009) "Assessing the Effects of Storage Tank Design on Water Quality." *Journal of the American Water WorksAssociation,* 85:7:78.

[26] Viraraghavan E., and Mathavan, S., (1988) "Water Quality Modeling of Distribution Storage Facilities.", *American Water Works Association Research Foundation,* Denver