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ORIGINAL ARTICLE

Modification and Evaluation of the Traditional Pottery Water Pot for Avoidance of its Technical Shortcomings and Improvement of Water Quality

Suad Ahmed Mohammed Osman

Environment, Natural Resources & Desertification Research Institute,
National Centre for Research, P.O. Box 6096, Khartoum, Sudan
Corresponding author, E-mail: wuhhab@yahoo.com, Mobile: 0915388727

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Abstract

The widely used pottery water pot for drinking water storage in Sudan and other developing countries is disadvantageous. The water inside the pot is exposed to contamination, algal growth and deterioration of quality due to loss of filtered water. Therefore, a research study to overcome these shortcomings was conducted at the Environment, Natural Resources and Desertification Research Institute, Khartoum, Sudan. The pot was modified into two chambers aligned vertically and pasted with adhesive material. The upper chamber was made of permeable pottery, while the lower one was made of sparingly permeable. The lower chamber opens to the exterior via a tube (pressure regulator) fitted at its upper end, and was connected to a tap at its lower one. The volume ratio of the upper chamber to the lower one was 3:1. Operation took place by filtration and pressure regulation by: turning off the tap, filling the upper chamber with the water in question and opening the pressure regulator to maintain the atmospheric pressure in the lower chamber. Water filtered from the upper chamber was collected in the lower one until water droplets were seen dripping through the pressure regulator which was then closed. The upper chamber was cleaned and refilled with the water in question. Collection of filtered water took place through the tap leaving a vacuum in the lower chamber that accelerated the rate of filtration. In addition, an alternative model for the lower chamber made of aluminum sheet was also designed, but so far, evaluation was only made for the model that both of its chambers were made of pottery. Parameters tested included; efficiency in improving water quality for turbidity, total count of bacteria, total dissolved solids, productivity of filtered water and drop of temperature. Water samples studied were collected from the Blue Nile River and from wells in Khartoum south. Results showed that the removal efficiency of turbidity, bacterial cells and total dissolved solids were ranged between 98.7-99.9%, 97.0-97.6% and 18-21%, respectively. Productivity of filtered water was 24-28% and 29-31% before and after evacuation, respectively, while the drop in water temperature was in the range of 11- 15%. Hence, this improved model is recommended to be used instead of the traditional pottery pot, and more research can be attempted for further improvement.

Keywords: Filtered water, pressure regulator, water turbidity, upper chamber, lower chamber.

Introduction

Investment in human capital through healthcare is the most profitable. This concept is supported by the estimation that, sanitation and drinking water investments have high rates of return: for every $1 invested there is a projected $3-$34 economic development return (UN WWAP, 2009). Accordingly, high care must be devoted to water quality improvement for different levels of citizens.

It has frequently been observed that the microbiological quality of water in vessels at home is lower than that at protected sources, suggesting that contamination is widespread during collection, transport, storage and drawing of water (Van Zijl, 1966, and Lindskog and Lindskog, 1988). Studies proved that covered vessels reduce fecal and total coliform counts in stored water by 50% (Chidavaenzi *et al*., 1998, and Mazengia *et al*., 2002). According to Firth *et al*. (2010), water storage containers which prevent in-home contamination can lead to almost 70% reduction in coliform counts and 31% reduction in diarrhea in children.

It is obvious from the above facts that study of in-home water storage and kind of storage vessels is the key point for improving drinking water quality in the developing world. In the developing countries the commonly used storage vessels are the pottery pots which are mostly made of clay mixed with burnt out material (Fig. 1).

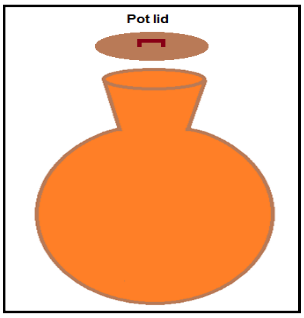


Figure 1. External view of the traditional pottery water pot.

Shortcomings of the traditional water pots

- Water inside the pot is exposed to sun light leading to algal growth. After termination of algae life cycle, bacterial multiplication takes place (Baker, 1961). This condition leads to deterioration of the aesthetic and biological quality of water.
- Upon scooping of water from the pots, contamination may take place by hands and utensils leading to spread of infections to family members and even to neighbors as clan communities in rural areas.
- Re-suspension of impurities takes place upon scooping of water, and this aborts the self purification processes that take place over quite a long time.
- Dripping of relatively good quality water through the permeable wall out of the pot comes at the expense of the quantity and quality of water (i.e., concentrate water impurities inside the pots).

Problem statement

- Almost one billion people collect their waters from distant, unprotected sources (WHO/UNICEF, 2010). They all suffer from the fallout of distant collection of water and in-home storage and contamination.
- In sub Saharan Africa, 35% of population in rural areas practiced open defecation (WHO/UNICEF, 2012). This condition exposes water in open storage vessels to microbial contamination and prevalence of diseases. Under the above facts, the design of the storage vessels used in the developing world shown in figure 1, generally subjects water to contamination and all possible consequences as mentioned above.

Objectives

- Avoidance of scooping of drinking water by utensils for control of point of use contamination.
- Protection of water from exposure to sunlight for control of algal growth.
- Protection of the good quality dripping (filtered) water from contamination.
- Enhancement of the dripping rate, quality and cooling of the filtered water to be used for drinking.

Hypotheses

- Making use of the dripping (filtered) water and control of contamination require modification in the design of the traditional water pot to accommodate two chambers (aligned vertically and pasted together by adhesive material): an upper chamber of permeable pottery walls to filter water in the lower one.
- The lower chamber wall is made of either sparingly permeable pottery or any safe material.
- Maintaining the atmospheric pressure inside the lower chamber for the filtration process to take place will be facilitated by a pressure regulating system as explained in figure 2 and figure 3.
- Protecting the filtered water from sun light to prevent growth of algae necessitates darkness of the lower chamber. This can be attained by directing the pressure regulator downward to make an acute angle with the wall of the lower chamber.
- Control of scooping of water by utensils would be achieved by fitting a tap on the distal end of the lower chamber.
- Pressure regulation can be achieved by electrical power, as shown in the hypothesized models (Fig. 2).

The hypothesized model operates by filtration and pressure regulation as follows:

1. The tap is turned off.
2. The upper chamber is filled (preferably at night) with the water in question.
3. The pressure regulator is left open for maintaining the atmospheric pressure in the lower chamber.
4. Water is left to drip in the lower chamber overnight.
5. Filling of the lower chamber with filtered water is detected by dripping of water droplets from the pressure regulator.
6. The pressure regulator is then stoppered by the cork.
7. The upper chamber is cleaned and re-filled with the water in question.
8. Upon collection of filtered water through the tap, evacuation of the lower chamber leads to acceleration of the filtration rate.
9. Operation can also take place by electric supply of negative pressure as shown in figure 2.

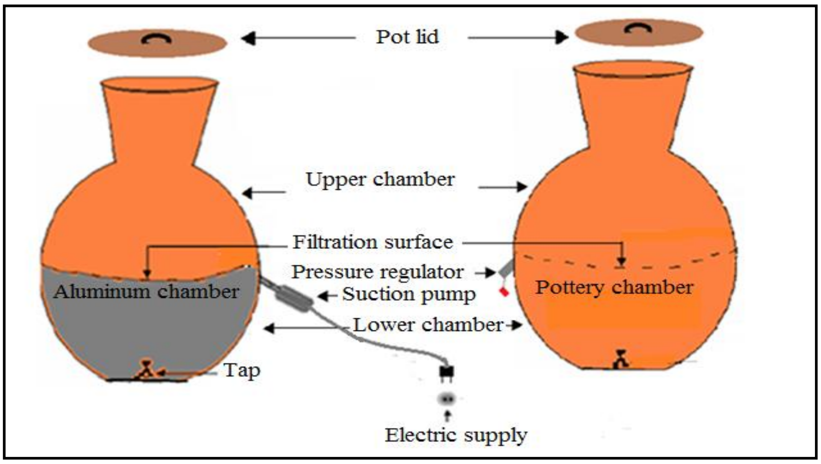


Figure 2. External views of the hypothesized models of the water pot.

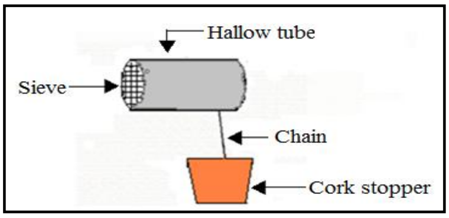


Figure 3. External view of the pressure regulator.

Materials and Methods

Production of the upper chamber

Saw dust of specified grain size and clay were used for production of the upper chamber in a studied ratio for the optimum compromise between productivity of filtered water and its quality. The mixture was transferred to a kneading machine with water for thirty minutes so that a paste was prepared. The paste was shaped using a template, allowed to dry for one week and fired in an electric furnace at 900^0C according to Tite *et al*. (1982). The base of this chamber is slightly concave for facilitation of cleaning.

Production of the lower chamber

The lower chamber was manufactured from pottery of permeability that was adjusted to prevent water dripping, but just to keep a wet surface for cooling. That was done via specified grain size of the saw dust and its ratio to clay. The pressure regulator and the tap were fixed using adhesive material. Another alternative material for manufacturing the lower chamber was aluminum using a template and aluminum forming machine. The pressure regulator and the tap were welded to this chamber by aluminum metal. The volume ratio of the upper chamber to the lower one is 3: 1. The volume of the upper is 48 liter.

Evaluation of the modified pot for fulfillment of the research objectives

For any of the parameters assigned for this study, ten similar pottery models were used. The models were firstly filled with clear soft water and left to drip it completely for washing out the ash left in the pores after burning.

Five parameters were selected for evaluating the efficiency of the modified model that both of its chambers were made of pottery material for fulfillment of the prescribed objectives. These included turbidity, total bacterial count, total dissolved solids, productivity of filtered water and drop of temperature. Water samples were collected from two different sources; the Blue Nile River to resemble surface waters, and Khartoum south boreholes to resemble ground waters.

The Blue Nile sample was collected on the 22nd of August 2011 and characterized for total dissolved solids and major cations and anions as well as pH. These parameters were used for simulation of a dilution solution using distilled water. The Blue Nile water sample was divided into two portions A and B. Portion A was inoculated with bacterial suspension. Dilutions took place by use of the dilution solution for preparation of different total counts. Different turbidity levels of portion B were prepared by dilutions using the same dilution solution. On the other hand, the sample collected from South Khartoum borehole on the 15th of September 2011, was characterized for total dissolved solids. Sodium chloride was used to top the total dissolved solids up to 1520 ppm.

The modified model was evaluated for productivity of filtered water over nine hours during night, as a period of sleeping or dead hours. Variations of water temperature of the upper and lower chambers were detected.

For all of the above investigations the water in the upper chamber was considered as control. All of the quality control techniques used in the study were according to APHA (1989). Statistical analysis was carried out for the correlation coefficient and p value as well as the relation between dependent and independent variables.

Results and Discussion

Considering the water turbidity, figure 4 showed that the modified pot was highly efficient for the removal of turbidity. Highly significant difference (P= 0.0001) was attained regarding turbidity reduction in the lower chamber as compared with that in the upper chamber. The turbidity levels recorded ranged between 1.5-3.3 NTU, which is below the upper limit (5 NTU) recommended by the WHO (2008). From the figure it can be observed that the higher the turbidity level the more efficient is the treatment process. This may be attributed to the increased thickness of the sediments layer, which is proportional to the turbidity level. This sediments layer acts as a filter as well. The more thick the sediments layer, the more it was efficient for meshing off the turbidity causing particles. Reduction in turbidity levels was 86.19% due to the filtration process.

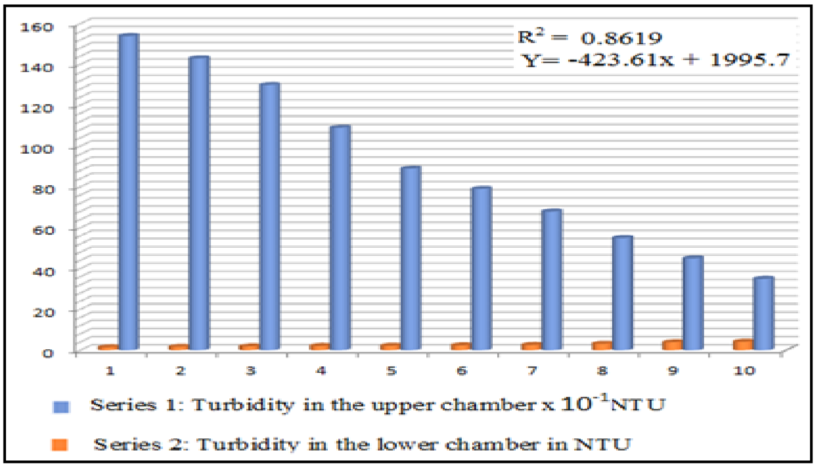
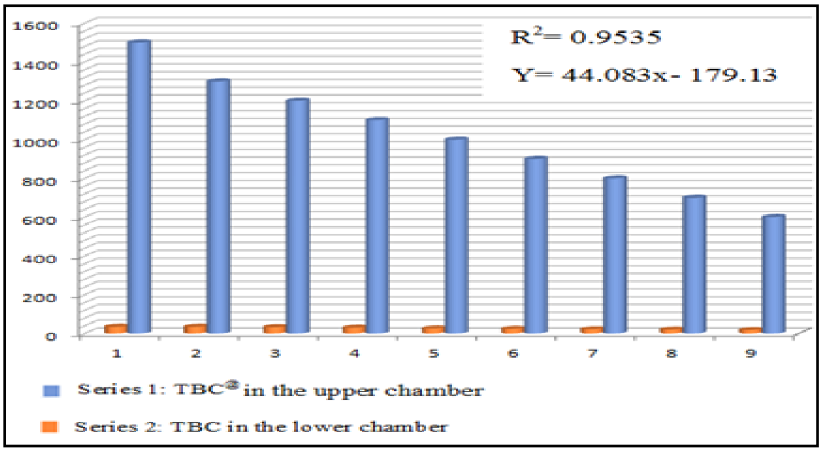


Figure 4. Efficiency of the modified pottery pots for reduction of water turbidity.

Regarding the bacterial count reduction, as shown in figure 5, the pore size of the filtration surface between the two chambers of the modified pot is large enough to pass the bacterial cells to the lower chamber. That an average sized bacterium, is about 2 µm long and 0.5 µm in diameter, with a cell volume of 0.6 - 0.7 μm^3 (*Kubitschek, 1990). In spite of that, they* get reduced substantially in number, with highly significant difference (P= 0.0001), in the filtered water. This may be attributed to the fact that bacterial cells have slight negative charges on their cell walls (Corpe, 1970). This may end in attracting positively charged particles and ions to the bacterial cell forming clusters of impurities which are too large to pass through the filtration surface pores. Decay of bacterial cells due to starvation might take place as the filtered water in the lower chamber represented poor nutritional medium for them. Reduction of the bacterial total count was 95.35% due to the filtration process (Fig. 5).

Total dissolved solids are found in water in form of cations and anions which are small enough to pass through the filtration surface pores. That is because the largest ion is polonium of ionic radius of 2.3 Å (Kenneth, 1995), while the pore area of the filtration surface is ≤ $1 mm^2$. Ground water was found to contain relatively fewer amounts of impurities in form of colloidal matter and/or other impurities than surface water (Degremont, 1991). It seemed that both adsorption on the pot's walls and filtration



@ Total bacterial count

Figure 5. Efficiency of the modified pottery pots for reduction of total bacterial count.

process contributed to reduction of total dissolved solids. This comes in agreement with the findings of Helal *et al*. (2009) that cobalt gets adsorbed on pottery material and to higher extent on potter's clay because it contains organic matter.

Adsorption of ions on organic matter appeared to form clusters which were too large to pass through the pores of the filtration surface, thereby they getting retained on it. Both processes (adsorption of ions on the pottery walls of the pot and on organic matters) point to the need of frequent wash of the upper chamber. The results obtained were definitely not constant due to variation in quality of the water in question, the type of impurities and the pottery material. The removal of the total dissolved solids obtained was 99.96%, with highly significant difference (P= 0.0001), due to adsorption on pottery material and on water impurities (Fig. 6).

From the results of the percentage productivity of filtered water (Fig. 7), it is clear that productivity was higher after evacuation (after collection of filtered water when the pressure regulator was stoppered), though the difference was not significant (P= 0.08). Three factors (gravity, atmospheric pressure and the water pressure) contribute to enhance the filtration process before evacuation, after which they also work, so why productivity increased. The evacuation process had contributed by 8.3% for the increase in productivity.

Drop in temperature was 0.0045% in the lower chamber due to the filtration process, but without significant difference (P= 0.8)

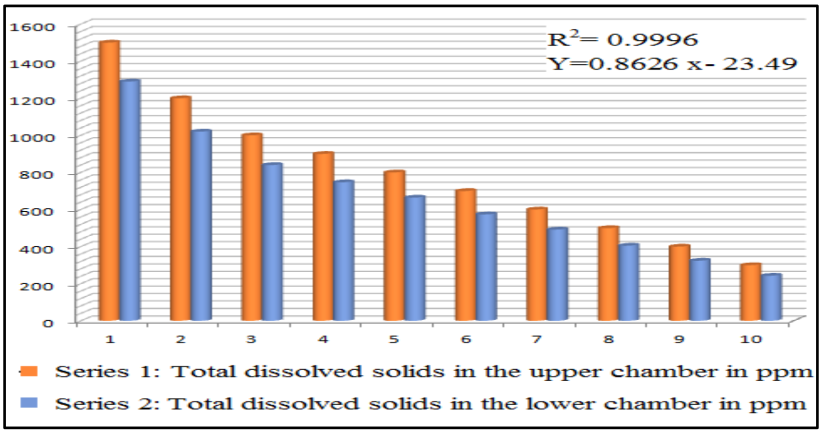


Figure 6. Efficiency of the modified pottery pots for reduction of the total dissolved solids.

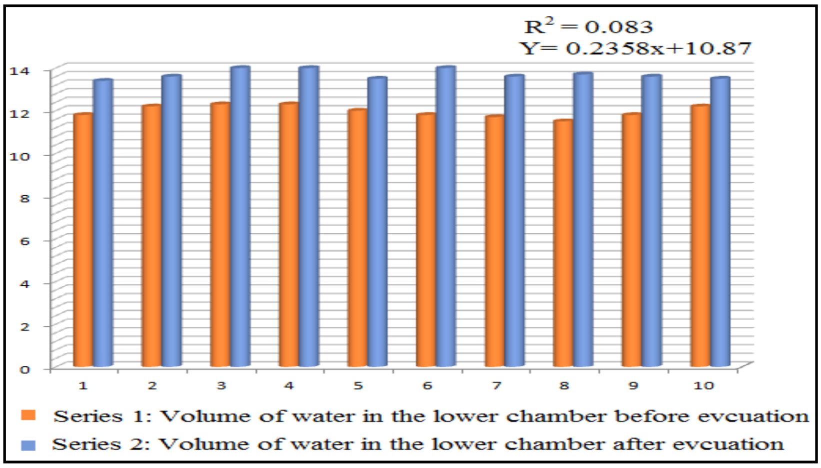


Figure 7. Productivity levels of filtered water attained by the modified model before and after evacuation.

from it in the upper chamber (Fig. 8). This low value of R^2 seems logic, because the filtration process itself has nothing to do with temperature. Decrease in temperature of the water in the lower chamber compared to that in the upper one may be due to the fact that the water in the lower chamber was surrounded by wet surfaces from all sides. Water in the upper chamber was surrounded by wet surfaces from all sides except for the upper one which was either open to get in contact with the atmosphere, and so ambient temperature, or was covered by dry material mostly made of wood.

Costs

Through this work, being in frequent contact with pottery pots producers, it was estimated that the cost of the modified model is twice that of the traditional one.

Conclusion

The modified model of the traditional pottery water pot proved high efficiency for drinking water quality improvement, regarding: turbidity and total count of bacteria included pathogenic species. Reduction of total dissolved solids of saline borehole water was achieved to moderate degree. Thereby, the aesthetic values and the biological quality were improved. Moreover, point of use contamination was controlled to a high degree due collection of water through the tap instead of scooping by utensils that might be contaminated. Equally, algal growth was controlled due to the darkness of the lower chamber. Filtered water was protected from contamination and wastage since being stored in the lower chamber.

Increase of productivity of filtered water after evacuation compared to it before evacuation and drop of temperature were detected, but weakly correlated to the filtration process. According to the productivity level two models are sufficient for the daily drinking of an average family of about eight members.

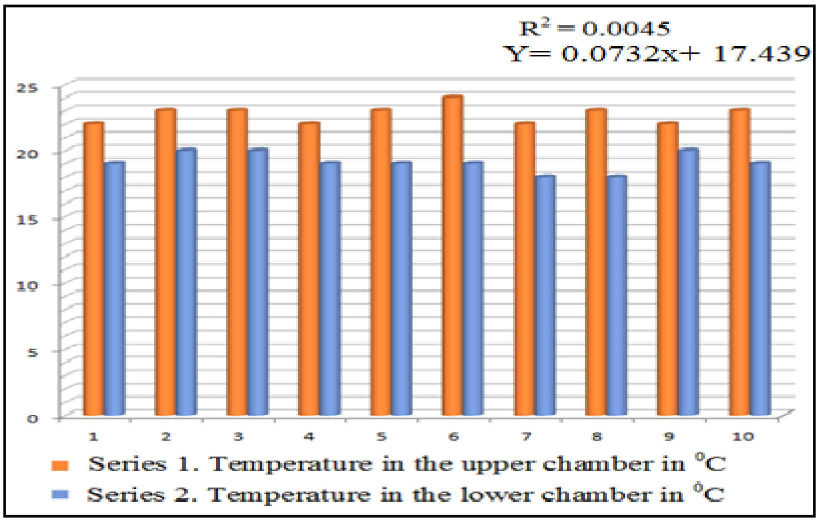


Figure 8. Drop in temperature of water in the lower chamber of the modified pottery pot.

References

Helal, A.A.; Aley, H.F.; Khalifa, S.M., and Ahmad, M.I. (2009). Sorption of radiocobalt on pottery. *Radiochimica Acta*, 93(8): 471- 476.

APHA (American Public Health Association) (1989). *Standard Methods for the Examination of Water and Wastewater*, 17th ed., New York, U.S.A.

Baker, R.A. (1961). Taste and Odor in Water - Critical Review. Final report F-A2333. The Franklin Institute, Philadelphia: 159p.

Chidavaenzi, MT.; Jere, M.; Nhandara, C.; Chingundury, D., and Bradley, M. (1998). An evaluation of water urns to maintain domestic water quality. 24th WEDC Conference, Islamabad, Pakistan. Pickford, J. (ed.); WEDC, Loughborough, pp. 249- 253.

Corpe, WA. (1970). Attachment of marine bacteria to solid surfaces. In: Manly, R.S. (ed.), *Adhesion in Biological Systems*, Academic Press, New York London, pp. 73- 87.

Degremont, G. (1991). *Water Treatment Handbook*, 6th Ed. Lavoisier Publishing, Paris. 1596p.

Firth, J.; Balraj, V.; Muliyil, J.; Roy, S.; Rani, L.M.; Chandresekhar, R., and Kang, G. (2010). Point-of-use interventions to decrease contamination of drinking water: a randomized, controlled pilot study on efficacy, effectiveness, and acceptability of closed containers, *Moringa oleifera*, and in-home chlorination in rural South India. *The American Journal of Tropical Medicine and Hygiene*, 82(5): 759-765.

Kenneth, B. (1995). Periodic Table of Element - Stored by Ionic Radius. EnvironmentalChemistry.com.https://EnvironmentalChemistry.com/yogi/periodic/ionicradius.html

Kubitschek, H.E. (1990). Cell volume increase in *Escherichia coli* after shifts to richer media. *Journal of Bacteriology*, 172(1): 94- 101.

Lindskog, R.U.M., and Lindskog, P.A. (1988). Bacteriological contamination of water in rural areas: an intervention study from Malawi. *Journal of Tropical Medicine and Hygiene*, 91: 1- 7.

Mazengia, M.S.; Chidavaenzi, M.; Bradley, M.; Jere, M.; Nhandara, C.; Chiqunduru, D., and Murahwa, E.C. (2002). Effective and culturally acceptable water storage in Zimbabwe: maintaining the quality of water abstracted from upgraded family wells. *Journal of Environmental Health*, 64: 15- 18.

Tite, M.S.; Freestone, I.C.; Meeks, N.D., and Bimson, M. (1982). *The Use of Scanning Electron Microscopy in the Technological Examination of Ancient Ceramics. In Archaeological Ceramics*, Olin, J.S. and Franklin, A.D. (eds.), pp. 109- 120. Smithsonian Institution Press, Washington, D.C

UN WWAP (2009). United Nations World Water Assessment Programme. The World Water Development Report 3: Water in a Changing World. UNESCO: Paris, France.

Van Zijl, W.J. (1966). Studies on diarrheal diseases in seven countries by the WHO Diarrhoeal Diseases Advisory Team. *Bulletin of the World Health Organization*, 35: 249- 261.

WHO (2008). *Guidelines for Drinking-water Quality*, 3rd ed. Incorporating the First and Second Addenda, 1: Recommendations. World Health Organization, Geneva, Switzerland. 219p.

WHO/UNICEF (2012). Estimates for the Use of Improved Sanitation Facilities. World Health Organization and UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP). World Health Organization; Geneva, Switzerland.

WHO/UNICEF (2010). Progress on Sanitation and Drinking-Water. World Health Organization and UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2010 Update. World Health Organization; Geneva, Switzerland.