International Research Journal of Social Sciences ISSN 2319–3565
Vol. **6(11),** 1-10, November **(2017)** *Int. Res. J. Social Sci.*

Evaluation of the effectiveness of purifier of water as used in household water treatment on different raw water sources

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Available online at: www.isca.in, www.isca.me
Received 30th September 2016, revised 30th September 2017, accepted 25th October 2017

Abstract

Household water treatment is important to improve quality of water from different sources that are likely to have contaminants. The Purifier of water (PUR) has been proven to remove the vast majority of bacteria, viruses, and protozoa, even in highly turbid water. The use of PUR at household level poses two main technical limitations: i. it does not take into account variations in raw water ii. Pre-chlorination is associated with the Disinfectant-By-Products (DBPs) formation. The study devised to assess the effectiveness of PUR use in household water treatment on different raw water sources. Thus, it wanted to know how PUR treatment may be effective to the users of identified raw water sources in Juru Sector. The study design adopted an objective philosophy and used an experimental and survey strategies. It has exploited the subjective and interpretive character to have more understanding of how people do to purify water they use. The study has been mainly exploratory and explanatory. It adopted a deductive research approach. The study took 3 years to be completed. The study was cross-sectional. As results, PUR reduced 100% of fecal coliforms, 100% of all tested water samples presented turbidity less than 5NTU (norms in drinking water is <5NTU) and 100% of all water samples presented residual Chlorine which is in the standard range of World Health Organization (0.2-0.5mg/l). Total coliform colonies less than 12 were observed in 19% of tested samples of water treated using PUR ready to drink (norms <100 colonies in 100ml). DBPs were likely to be formed. Compared to the accepted norms, the PUR treatment has been effective. The study suggested employing coal-based carbons and retention to protect public health by limiting exposure to disinfectant by-products. Conduct a mapping study in the District to identify and locate the sources of water recommended for disinfection in general and those mostly recommended for other specific household water treatment like the use of PUR. Based on the results from the study where the researcher observed the occurrence of DBPs when using PUR, he proposed guiding theories using coal-based carbons and retention to eliminate or reduce DBPs formation.

Keywords: Purifier of water(PUR), Disinfectant-By-Products(DBPs), Water treatment.

Introduction

PUR is a powdered mixture that removes pathogenic microorganisms and suspended matter, rendering previously contaminated water safe to drink. It was developed by Procter & Gamble (P & G) in collaboration with the United States Centers for Disease Control and Prevention. It uses the same ingredients used in municipal water treatment as it contains a chlorine disinfectant (calcium hypochlorite) for killing bacteria and an iron salt coagulant (ferric sulfate) for removing suspended matter, protozoa, and viruses. It also contains a buffer, clay and polymer to provide good coagulation and flocculation. The difference is that PUR provides these ingredients at the household level rather in a centralized treatment facility. It is safe for a long-term use by the entire family, including infants, and is considered an effective technology by the World Health Organization[1].

PUR turns contaminated drinking water into purified water. It uses the same ingredients used in municipal water treatment as it contains a chlorine disinfectant (calcium hypochlorite) for killing bacteria and an iron salt coagulant ferric sulfate) for removing suspended matter, protozoa, and viruses. It also contains a buffer, clay and polymer to provide good coagulation and flocculation. The difference is that it provides these ingredients at the household level rather than in a centralized treatment facility[2].

Water treatment varies according to a number of factors, including the nature of the raw water (ground water or surface water, presence of natural organic matter and inorganic solutes and other components, such as turbidity). Understanding variations in raw quality is important, as will influence the requirements for treatment, treatment efficiency and the resulting health risks associated with the finished drinking-water. For example, turbidity can have negative effects on chlorine disinfection because particles can shield microorganisms from chlorine[3].

Additional studies have shown that "point of use" water quality interventions significantly reduce diarrheal diseases stemming from pathogens in the household water supply[4].

A preliminary study on disinfection (chlorination) of water by using bleaching powder solution (PUR) at household level has shown significant reduction in Thermo-tolerant Coliform Bacteria count (TTC) in a few villages in Bangladesh[1]. But lack of availability of bleaching powder and/or affordability to buy bleaching powder discouraged the use of point-of-use method after the project. Therefore, there is an urgent need for locating and field testing and/or developing appropriate point-of-use water treatment technologies (PUR) in Bangladesh[5].

Procter and Gamble (P&G) have developed a safe water intervention for PUR for household treatment of contaminated drinking water, particularly in less developed countries. PUR has been demonstrated in a variety of emergency situations and shown to effectively treat water and reduce diarrheal disease. It got 2005 Stockholm Industry Water Award. The study in Bangladesh presents findings during ‘Assessment of PUR Water Treatment for Flood Mitigation (RFP)2/006-029’ commissioned by UNICEF-DPHE. We have tested Aquatab with PUR[5].

PUR-Purifier of Water manufactured by Procter and Gamble and Aqua tabs Medentech Ltd, Wexford, Ireland. PUR is a relatively new product and has been tested in other countries, such as Pakistan, Afghanistan and other countries and found efficient and acceptable. Aqua tabs are often distributed during floods in Bangladesh. The study was implemented during September 2006 to February 2007. It followed cross-sectional observation method of evaluation. It was done by Environment and Population Research Center (EPRC), a non-government and non-profit research and training organization, in response to a DPHE-UNICEF’s call for assessment of PUR in flood/disaster mitigation based on an outline provided by UNICEF[5].

The PURs were distributed with food and other relief packages by Oxfam International through its relief partner NGOs; Bachteshekha and Uttaran (partner NGOs of Oxfam). It was distributed among selected priority water logged poor families in three sub-districts Abhoynagar, Keshabpur and Monirampur of Jessore district, Bangladesh. Oxfam selected those families based on impacts of water related problems and poor economic status. The NGOs distributed food among approximately 15000 families. Out of those 15000 families PUR & Aquatabs were included in the relief packages of 4800 families (beneficiaries) in 67 villages. The NGO partners of Oxfam distributed PUR (20 sachets of PUR and 20 Aquatabs), food, two buckets of 20-liter capacity, one plastic water container (jug) of 3-liter capacity and other items in the relief packages. One sachet of PUR can provide 10 liters of clean drinking water and cost US $ 0.035. One Aquatab can provide 4-5 liters of clean water. The process involves mixing an Aquatab in 4-5 liters of water for a few minutes, letting the mixed water stand for 30 minutes and safe storage in a suitable container[5].

The partner NGOs were trained on importance of drinking and promotion of safe water in disasters, ways of water treatment, treatment by the PUR (demonstration), distribution plan, education method about how to use the PURs by the beneficiaries, and other issues by EPRC. The training plan and materials were developed based on consultations with the field staff of the relief NGOs and instruction on use of PURs as provided by UNICEF.

Out of the 4800 beneficiary households 200 households which had treated water during our visit were systematically randomly selected from 17 villages by EPRC. Two hundred water samples were collected and tested for Thermo-tolerant Coliform bacteria (TTC in colony forming unit, cfu/100 ml), pH, turbidity and residual chlorine (RCL in mg/l) from the households, which had treated water during the sample collection visits. The evaluation techniques included testing of the specified water quality parameters by the kit instruments provided by UNICEF, interviewing of the caretaker of water in the household on the use and views about the PUR, and treatment demonstrated by 35% of the 200 households on request by EPRC staff. The pH, turbidity and RCL were tested at the household level after water collection. About 300 ml of the same water was collected in sterilized glass bottles and transported in sample collection boxes (which maintained temperature below 4 degree C with ice packs) to EPRC field Laboratory. The water samples were tested for TTC by Wegtech Potatest FC Count Instruments within approximately 5 hours of its sampling from the households[5].

The relief NGOs demonstrated the use of the PUR among all the beneficiaries in the 17 villages during the distribution with assistance from EPRC members. Out of the 17 sampled villages, 14 received follow-up education by EPRC community educators. As a results, all the tested stored 200 drinking water samples were found with ‘nil’ TTC cfu/100 ml of TTC. Presence of RCL was observed in all water samples. The mean and median values of RCL in water treated by PUR were respectively 0.28 mg/l and 0.19 mg/l and those by Aquatabs were 1.45 mg/l and 1.08 mg/l. The values of pH varied over 6.3 – 8.6 for PUR and 6.5 - 8.8 for Aquatabs. The results of turbidity varied over 0 -18 NTU for PUR and 0-18 NTU for Aquatab treated samples. The threshold concentration of residual chlorine is usually recommended 0.3 – 0.5 mg/l. The median RCL in Aquatab treated water was significantly higher than the threshold concentration[5].

In Rwanda, PUR water purifier product is being used by the community where there is insufficient safe water. The community of Bugesera located around Akagera River and lakes have been using PUR product in household water treatment. In Karongi district, the use of PUR water purifier product started in July 2011. World Vision Gashora Area of Development Program (ADP) has trained all Community health workers, coordinators of Juru, Gashora and Rilima health centers and all social affairs of Juru, Gashora and Rilima sectors on the use of PUR. Nowadays PUR is being used in different sectors of Bugesera especially Juru due to insufficient safe water supply in the sector leading the population to using water from sources like swamps or marsh and Akagera rivers (World Vision Gashora ADP, 2013). A study is required to evaluate or determine if PUR remain constantly effective to various raw water sources of Juru sector, the possibility of DBPs formation resulting from the use of PUR in household water treatment and propose how these DBPs can be eliminated.

Research methods

The study adopted an objective and positive philosophy. The study used an experiment and survey strategies. The study used a mixed method; qualitative and experiment method. Qualitative questions served to have a good understanding of the level of knowledge and skill of using PUR according to the nature of water. Hence, the sampling was non-probability sampling, and adopted a purposive technique. Data collection has exploited mixed methods. Qualitative data has been collected using an interview guide and direct observation, while experimental data was collected using laboratory equipment. Data have been analyzed through analytic and synthetic methods.

The sampling was non-probability sampling, and adopted a purposive technique to select the study participants (Community Health Workers). CHWs are subdivided into three categories according to their attributions: 2 binomes, in charge of social affairs (in charge of environmental health and chronic diseases) and the in charge of maternal-child health. The researcher concluded to use CHWs in charge of social affairs because the topic is related to their attributions. The sampling frame consisted of 21 CHWs who have been trained and always receive PUR from World Vision Gashora ADP for use and distribution in the community. World Vision is an NGO responsible for the supply and the follow up of the use of PUR in Juru sector. The CHW in charge of environmental health and chronic diseases is one in each village and the total villages to be researched on are 21 villages. Those villages are located around identified risky water points (swamps or marshes of Akagera river) and they are far away of tape water and water from springs. A purposive sampling technique was used to select the study participants. The researcher decided to take all the study population which is 21CHWs because the study population is small (lower than 50). Working with a representative of community Health Workers, researcher reached physically identified CHWs from each selected village with his/her help.

Data collection has exploited mixed methods; qualitative and experiment. Qualitative data has been collected using an interview guide and direct observation, while experimental data was collected using laboratory equipment. Water samples were collected in sterilized glass bottles and transported in sample collection boxes (which maintained temperature below 4 degree C with ice packs) to the Laboratory of water analysis of the University of Rwanda (UR). The water samples were tested for TTC by Wegtech Potatest FC Count Instruments within approximately 5 hours of its sampling from the households.

Before taking sample hand was first sterilized using sterilizing oil in form of alcohol.

Data for water analysis was obtained from samples strategically taken from 5 points (stages) based on the process of water treatment with PUR. The strategic points are: i. Water before treatment (raw water), ii. Immediately after stirring, iii. before filtration (5minutes after stirring), iv. Immediately after filtration and v. 20 minutes after filtration.

Parameters that are considered from each individual sample are: i. For physico-chemical parameters: The measure of pH, turbidity, ammonia, and residual chlorine is undertaken. ii. For bacteriological analysis, researcher measured total coliforms and fecal coliforms as they have sanitary significance in treated water and likely to be found in all samples (untreated water).

All the specified physico-chemical water quality parameters have been tested on the field. Samples for total coliforms and fecal coliforms testing was collected in sterilized sample bottles (rubber) and transported to the Laboratory for testing. Procedure for bacteriological and physico-chemical analysis.

Data on filter cloth was collected by observation during treatment process (filtration) where the researcher observed whether the filter cloth used is cotton and washed after using it or if it is inappropriately (not cotton) washed or unwashed. Selected water point for data collection fulfilled the criteria of being in marshes/swamps of Akagera river and is highly colored/turbid seeing by naked eye and is among water draw points used by most people from the village of assessed CHW. A selected Community Health Worker were asked to went with the researcher to show him where the community from his/her village frequently draw water to be treated using PUR. Then the researcher chose the water point which matches the set criteria. A CHW draw water from that point and return back home to treat it. Also the researcher took sample for initial test (raw water). Arriving back at home of a CHW, a Community Health Worker starts water treatment process using PUR. The research observes the process and asks some questions in order to better fill the observational questionnaire. Meanwhile, at a design step for taking sample, the researcher took it and keeps it in thermos with ice packs keeping the temperature less than 4^{0C}. The researcher visited 1 CHWs per day. The researcher followed the designed standards to take sample.

Data presentation and analysis: Variation of pH in PUR water treatment process: As it is shown on the Figure-1, important changes in pH values occurred in the first 3 stages of water treatment in all samples (i.e from raw water until filtration). In all stages of treatment, pH values changed slightly and 100% of values were in the standard intervals of 6.5-8.5 in both raw water and treated water. At pH less than 7.5 the bactericide power of PUR are strong whereas at pH greater than 7.5 the bactericide power of PUR are weak.

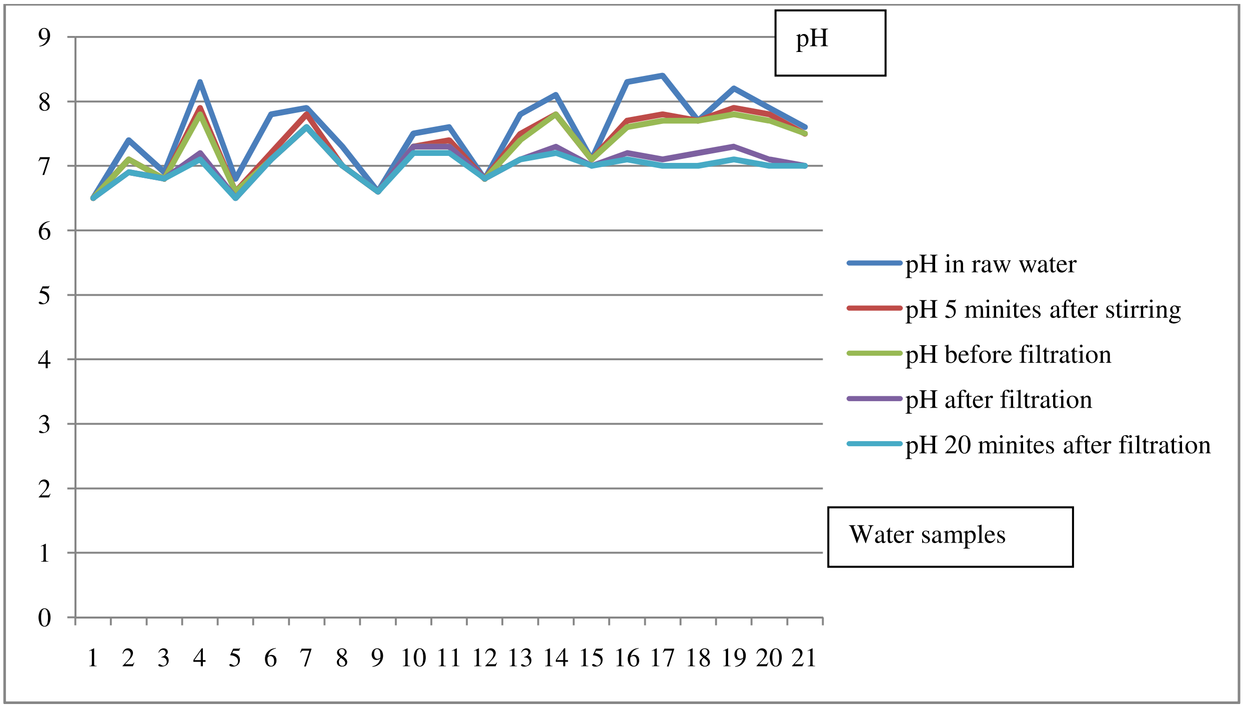

Figure-1: The variation of pH in PUR water treatment process.

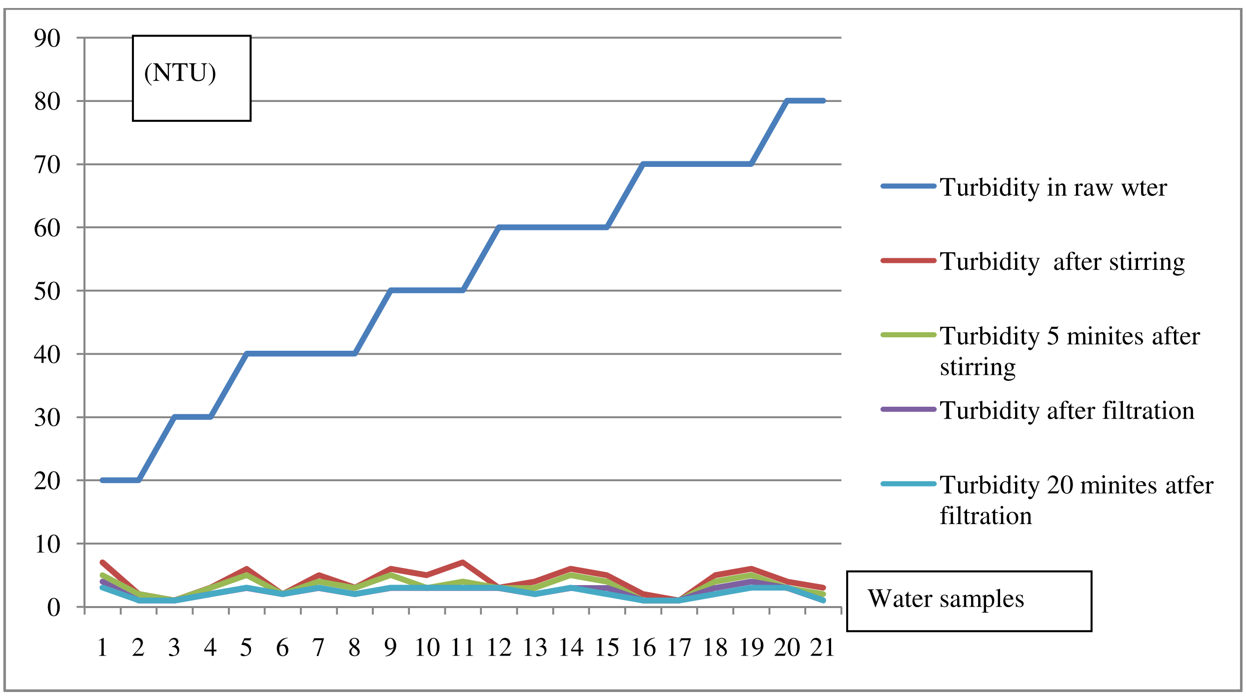

Figure-2: The variation of turbidity in PUR water treatment process.

As it is shown on the Figure-2, important changes in turbidity values occur in the first stage of water treatment and this especially occur in highly turbid water.

In the last three stages of treatment, turbidity levels changed slightly and patterns in the lines show that for all samples, 100% have turbidity less than 5 NTU at the last stage.

At the beginning of the treatment, 100% of samples (raw water) had turbidity above the standard 5NTU. After filtration there was almost no change on turbidity and 20 minutes after filtration 100% of all filtered water samples were in the standard.

As it is shown on the Figure-3, tremendous changes in ammonia content in water occur in the first stage of water treatment. This is shown by lines representing other stages which have now merged apparently in one line for most of samples. 71.5% of samples before treatment were above 0.5mg/l and decreased around 0.2mg/l.

As it is shown on the Figure-4, there are no regular changes in residual chlorine values in the second stage of water treatment (stirring) as the patterns and trends in lines representing values picture. In low turbid water samples, values before filtration (5 minutes later after stirring) and after filtration (20 minutes later) tended to coincide. In the last two stages of treatment, residual chlorine concentration levels changed constantly and some patterns in lines are displayed in merged patterns. This observation means that turbidity was a key factor influencing values of residual chlorine during the treatment.

When you look in the next stages, trends also tend to incriminate turbidity as a key factor influencing concentrations of residual chlorine. There was a constant and regular change in residual chlorine concentration levels in the last two stages of treatment. This trend is describe like "reducing turbidity makes residual chlorine change uniformly in all sample as if they were all similar".

It is important to note that, as the lines patterns, each stage of treatment goes with a consumed quantity of residual chlorine. Before filtration the residual chlorine levels in 38% of samples were above the standard of the recommended doses (0.2-0.5mg/l). After filtration residual chlorine of 100% water samples were between 0.2-0.5mg/l meaning that 100% of filtered water samples meet the guidelines requirements of WHO regarding the quality of potable water (Values between 0.2-0.5mg/l). The observed residual Chlorine was ranged in 0.3-0.5mg/l in water ready to drink when before ready it was 0.3-0.9mg/l. This change means that there is a quantity removed in residues meanwhile other quantity is inactivating pathogens. For some samples, changes continue until 20 minutes after filtration.

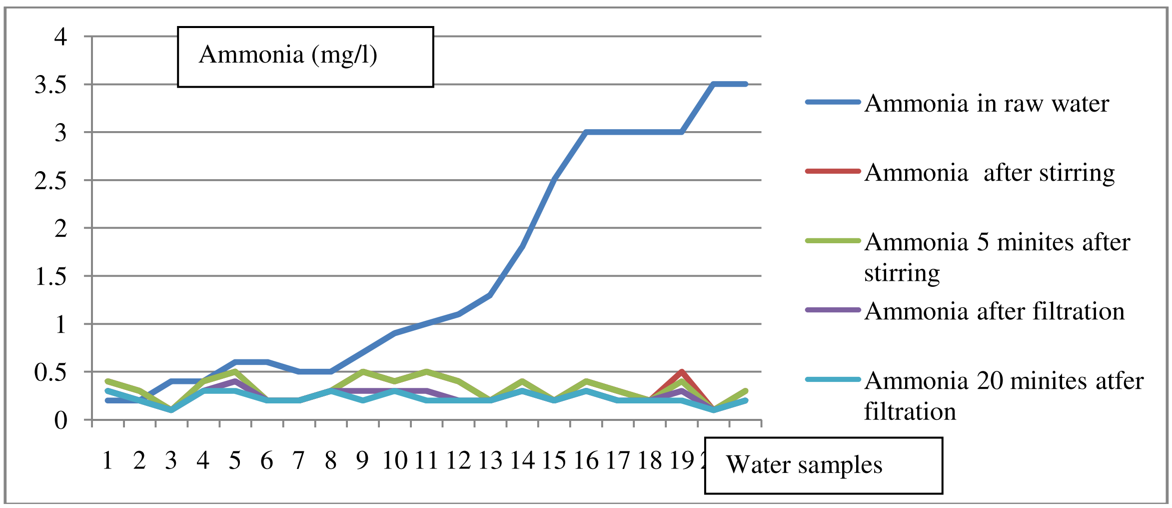

Figure-3: The variation of Ammonia (mg/l) in PUR water treatment process.

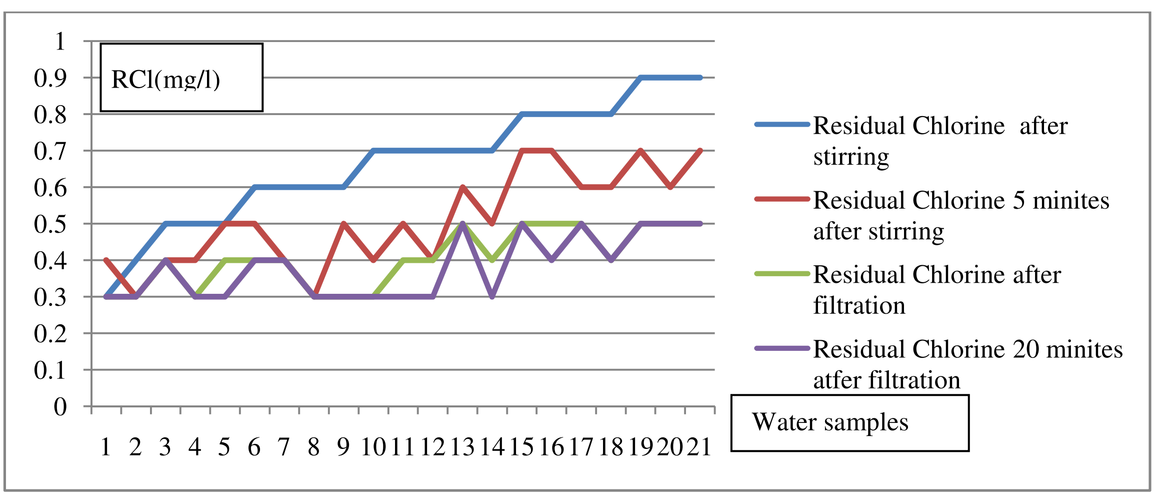

Figure-4: The variation of residual chlorine (mg/l) in PUR water treatment process.

As it is shown in Figure-5, before treatment all water samples tested were positive having colonies of total coliforms all with more than 300 colonies i.e. Total Coliforms, cfu/100ml in raw water (>300x10^0). At the end of treatment with samples taken 20minutes after filtration, samples having total colonies were 19%. All those 19% of samples had total colonies less than 12.

Normally, total coliforms are not harmful when they are less than 100 colonies in 100ml of sample (Total Coliforms, cfu/100ml <100x10^0). Those colonies fly in air from plants flowers and they can enter sample in air during sample taking process and during filtration.

As indicated by the Figure-6, there is a significant change during stirring, coliforms reduced until <300x10^0cfu/100ml but there were constant changes in 5 minutes later. Other great changes are observed during filtration, coliforms reduced to <100x10^0cfu/100ml. Likewise for 20 minutes after filtration, there is a continuous reduction until coliforms <1.0x10^0cfu/100ml. The change during filtration is explained by the effect of filter clothes and the remaining pathogens were inactivated as time goes on until they become totally eliminated in 20 minutes later.

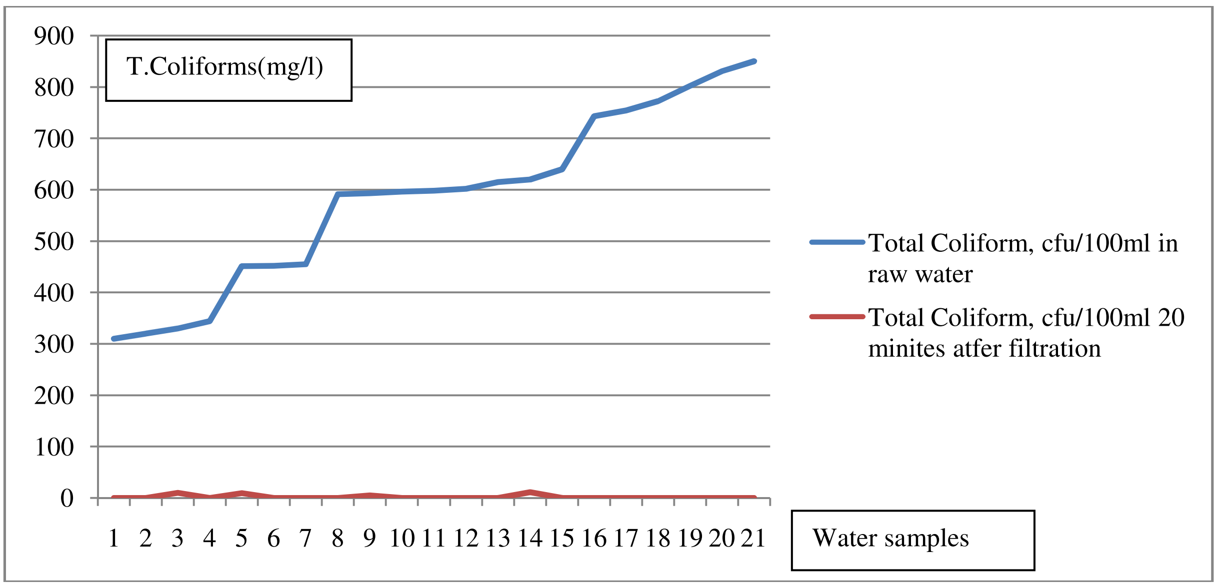

Figure-5: The removal of total coliforms in PUR filtered water.

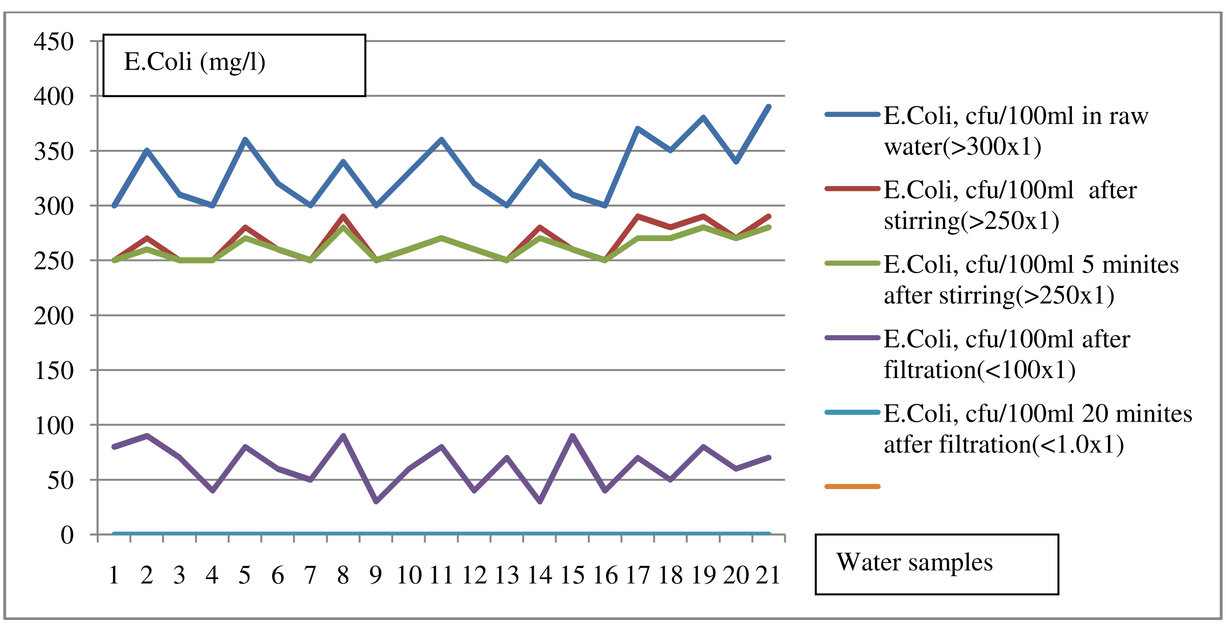

Figure-6: The removal of fecal coliforms in PUR filtered water.

Table-1: Type of cloth used in filtration.

Types of cloth	Number of respondents	% of respondents
Cotton	18	85.7%
Inappropriate (not cotton)	3	14.3%
Total	21	100%

The Table-1 shows that 85.7% of respondents used cloth in cotton for filtration of water against 14.3 % used inappropriate cloth (not cotton cloth).

Table-2: The status of filter cloth before reusing it for filtration.

Status of filter cloth	Number of respondents	% of respondents
Washed	20	95.2%
Not washed	1	4.8%
Total	21	100%

The Table-2 shows 95.2% of respondents had washed filter cloth before reusing it for filtration against and 4.8% who had not washed it.

Results and discussion

Efficacy of purifier of water on varied raw water samples: Two major parameters, pH and turbidity affect both the quality of water and chemical treatment of water by chlorination, which is the case with PUR. The study found that important changes in pH values occur in the first stage of water treatment and in all samples. As changes in the last three stages of treatment pH values changed slightly where 100% of values were ranged in guidelines recommended by WHO (6.5-8.5). These results suggest that pH stabilized in early stage of treatment when using PUR in household water treatment.

It is important to note that after the treatment, all values of pH ranged between 6.5 and 8.5. This is another important feature to highlight in the findings as it favors the action of chlorine as a disinfectant. Chlorine efficiency increases as pH decreases as at pH values below 7.5, HOCl is the dominant species[5]. As a disinfectant, HOCl is more effective than OCl^-, by controlling the pH, we can ensure that the more effective bactericide, HOCl remains the dominant species in solution[5]. Further research showed that HOCl is 70 to 80 times more effective than OCl^- for inactivating bacteria[3].

In the same line of pH values favoring action of chlorine, virus inactivation studies have shown that 50% more contact time is required at pH 7.0 than at pH 6.0 to achieve comparable inactivation, and that raising the pH from 7.0 to 9.0 requires a six-fold increase in contact time for comparable viral inactivation. Though some viruses has been shown to be more sensitive to chlorine at high pH rather than low pH[3].

In a study done in rural Bangladesh on the effectiveness of PUR on varied water sources, similar observations were done where all tested stored 200 drinking water samples, the values of pH varied on intervals of 6.3–8.6 for PUR filtered water[1].

Regarding turbidity**,** the study found important changes in values occurred in the first stage of water treatment and this especially occurs in highly turbid water. High turbid sample decreased more noticeably than low turbid water samples. Changes were so important after filtration where all samples had values below 5NTU.

Like pH, such changes of turbidity values favor action of chlorine. The findings were similar to the results of the study conducted in western Kenya demonstrates that for source water over a range of turbidities, PUR product effectively reduces turbidity to < 5 NTU[7].

Residual chlorine in PUR water treatment process: The study found that there were no regular changes in residual chlorine (RCL) values in the second stage of water treatment (stirring). This was mainly observed in low turbid water samples, values after stirring and before filtration (5 minutes later) tended to coincide. This observation means that turbidity was a key factor influencing values of residual chlorine during the treatment.

When you look in the next stages, trends also tend to incriminate turbidity as a key factor influencing concentrations of residual chlorine. There was a constant and regular change in residual chlorine concentration levels in the last two stages of treatment. This trend is describe like "reducing turbidity makes residual chlorine change uniformly in all sample as if they were all similar".

Presence of Residual Chlorine (RCL) was observed in all water samples. As when chlorine is added to a water source, it purifies the water by damaging the cell structure of bacterial pollutants, by destroying them and oxidizing other impurities. This means that the chlorine demand in samples was met. Also, it important to realize that the chlorine demand of water source will vary as the quality of the water varies[5].

This was proven to be true in their samples where the same amount of chlorine was applied to the same quantity of water and end to be in interval between 0.3-0.5mg/l. The standard of World Health Organization for residual chlorine in drinking water is 0.2-0.5mg/l.

Total coliforms in PUR water treatment process: As it is shown in the above figure, before treatment all water samples tested were positive having colonies of total coliforms some with more than 100 colonies. At the end of treatment with samples taken 20 minutes after filtration, total coliform colonies less than 12 were observed in 19% of tested samples.

The sample size did not allow them to explore these findings to investigate more objectively on the reasons why the positive colonies were found in some sample. However, I retrieved the samples presenting positive colonies in my data base and surprisingly I found that the same samples had residual chlorine concentrations of 0.3 mg/l and samples were filtered by using inappropriate filter cloth (not cotton cloth).

Though they could not be statistically attributed to the level of residual chlorine. The researcher suggests that they are attributed to the status of cloth used in filtration and the colonies circulated in wind because total colonies can be developed on flowers and circulate in wind. It is worth to note that it is one of the important finding of the study which need to be explored a bit further:

Concerning the positive colonies of their study seems to be against field testing carried out on drinking-water source samples (spring, lake, river, well, rain and tap water) collected and treated in three developing countries (Kenya, Guatemala, Bangladesh) where 320 drinking water samples that initially contained *E. coli* were devoid of measurable *E. coli* and coliforms post-treatment, suggesting that PUR treatment was effective and possible under a wide variety of conditions[5].

The total coliforms generally live on plant surfaces and in the environment, and are not indicators of fecal contamination; these include Enterobacter, Klebsiella, Citrobacter. No risk water contain less than 100 total colonies per 100ml[6].

Fecal coliforms in PUR water treatment process: The researcher observed a significant change during stirring, coliforms reduced until <$300x10^0$cfu/100ml but there were constant changes in 5 minutes later. Other great changes are observed during filtration, coliforms reduced to <$100x10^0$cfu/100ml. Likewise for 20 minutes after filtration, there is a continuous reduction until coliforms <$1.0x10^0$cfu/100ml. The change during filtration is explained by the effect of filter clothes and the remaining pathogens were inactivated as time goes on until they become totally eliminated in 20 minutes later. The researcher tested the presence of E.coli in samples. The presence of E.coli in samples helped the researcher to conclude whether samples contain fecal coliforms or not.

The presence of E. coli indicates a potential public health hazard from fecal coliforms or contamination; they include Salmonela, Vibrio-Cholerae and *Shigella* bacteria dysentery etc. The total coliforms generally live on plant surfaces and in the environment, and are not indicators of fecal contamination; these include Enterobacter, Klebsiella, Citrobacter. No risk water contain less than 100 total colonies per 100ml. Safe water contain 0cfu/100ml for fecal coliforms or E.coli[6].

Possibility of disinfection by product formation in PUR filtered water: The use of low dosage of chlorine may lead to inefficient disinfection and the use of high dosage of chlorine may results in high concentration of Disinfectant-by-Products (DBPs) and that the formation of DBPs known as HANs is observed; when in chlorinated water nitrogen containing organic material is present. Another important fact is that in post-chlorinated water, the concentration of formed trihalomethanes (THMs) and haloacetic acids (HAAs) is much lower than in pre-chlorinated water.

Free chlorine readily reacts with Ammonia and other ammoniated compounds to form what are known as chlorines. These chloramines are known as monochloramine, dichloramine, and trichloramines. Chloramines are also referred to, in the industry, as combined chlorine. When chlorine is added to water containing ammonia (NH_3), chlorine will replace one hydrogen ion on the ammonia molecule with a chloride ion, resulting in the formation of monochloramine.

If ammonia is present, and the demand has been satisfied, some of the free chlorine will react with the ammonia to form chloramines or combined chlorine residual. As more chlorine is added, it will convert the chloramines that have been formed from monochloramine to trichloramine. To explore the possibility of DBPs formation in samples, three clues were considered: i. The level of ammonia where in raw water, 71.4% of samples before treatment were above 0.5mg/l. Ammonia is known as the precursors of DBPs in chlorinated water and Water containing ammonia less than 0.5mg/l before chlorination is not a major source of exposure to DBPs[8]. ii. The results of this study showed that the pH values varied between 6.5 and 8.5, the range in which DBPs are favored to form in chlorinated water. In that range chlorine is dissociated in HOCl and OCl- where HOCl is dominant in the solution and it reacts with organic matter to produce DBPs[5]. iii. Measurement of the association between ammonia and residual chlorine. The clues allowed the researcher to conclude that there was possibility of DBPs formation in the samples of water he took. Studies suggest that human exposure to unusually large amounts of some DBPs could experience liver damage and decreased nervous system activity. Many studies showed increased bladder cancer, stillbirths, miscarriages and serious birth defects[9].

Filter cloth: The results showed that 4.8% of respondents did not wash their filter cloth before reusing it. Among PUR filtered water samples tested, 19% of them presenting total coliforms and any presented *E. coli* or fecal coliforms. As discussed under “Total coliforms in PUR water treatment process”, they could not attribute statistically the occurrence of positive colonies to the status of cloth used in filtration. Even though the size of the sample did not allow them to establish a relationship between the positive colonies occurrence and the status of the cloth used in filtration, reasons given under the same point “total coliforms in PUR water treatment process” tend to attribute the occurrence to the environmental factors like wind transporting them from plants”. Also, the same results showed that 14.3% of the respondents used inappropriate cloth.

They did not establish impacts of inappropriate cloth on the quality of finished treated water but a study found that, coliform bacteria associated with the <7-µm fraction were inactivated more rapidly than the >7-µm fraction when exposed to 0.5mg/l free chlorine at pH 7.0 [3].

Conclusion

After viewing that PUR is efficacy for all types of raw water and that raw water containing organic matter has a high possibility of developing DBPs, the researcher developed and recommended the community to use the following model applicable generated in this study.

The research defined three major approaches water suppliers use to protect public from potential health effects posed by DBPs: i. Remove DBPs precursors, ii. Reduce the amount of disinfectant and / or change the point of application, iii. Switch from chlorine to alternative primary and / or secondary disinfectant. Water plant operators are able to reduce potential of DBPs by reducing the color of treated water. Color being an organic molecular, an operator can use color measurements as an indicator of organic removal. The organic material in water is the main cause of color. All chemical disinfectants produce inorganic and / or organic DBPs that may be of concern. The basic strategies that can be adopted for reducing the concentration of DBPs in finished treated water include:

Retention: It allows suspended material to settle, which makes subsequent disinfectants more effective and reduce the formation of DBPs. Disinfectant by-products (DBPs) form when organic and minerals present in water react with chemical addition used for disinfecting water. DBPs are present in most drinking water supplies that have been subjected to chlorination, chloramination or ozonation. When the organic load is higher in water to be chlorinated, DBPs concentrations will be higher because of chlorine reaction with natural organic matter to form DBPs. Once the water looks clear, and the floc, or precipitated material, is at the bottom of the bucket, filter the water through a clean cloth into a clean storage container. The filter must be a clean, 100% cotton cloth, without holes, that prevents floc from passing through. Rinse and wash the cloth thoroughly before reusing.

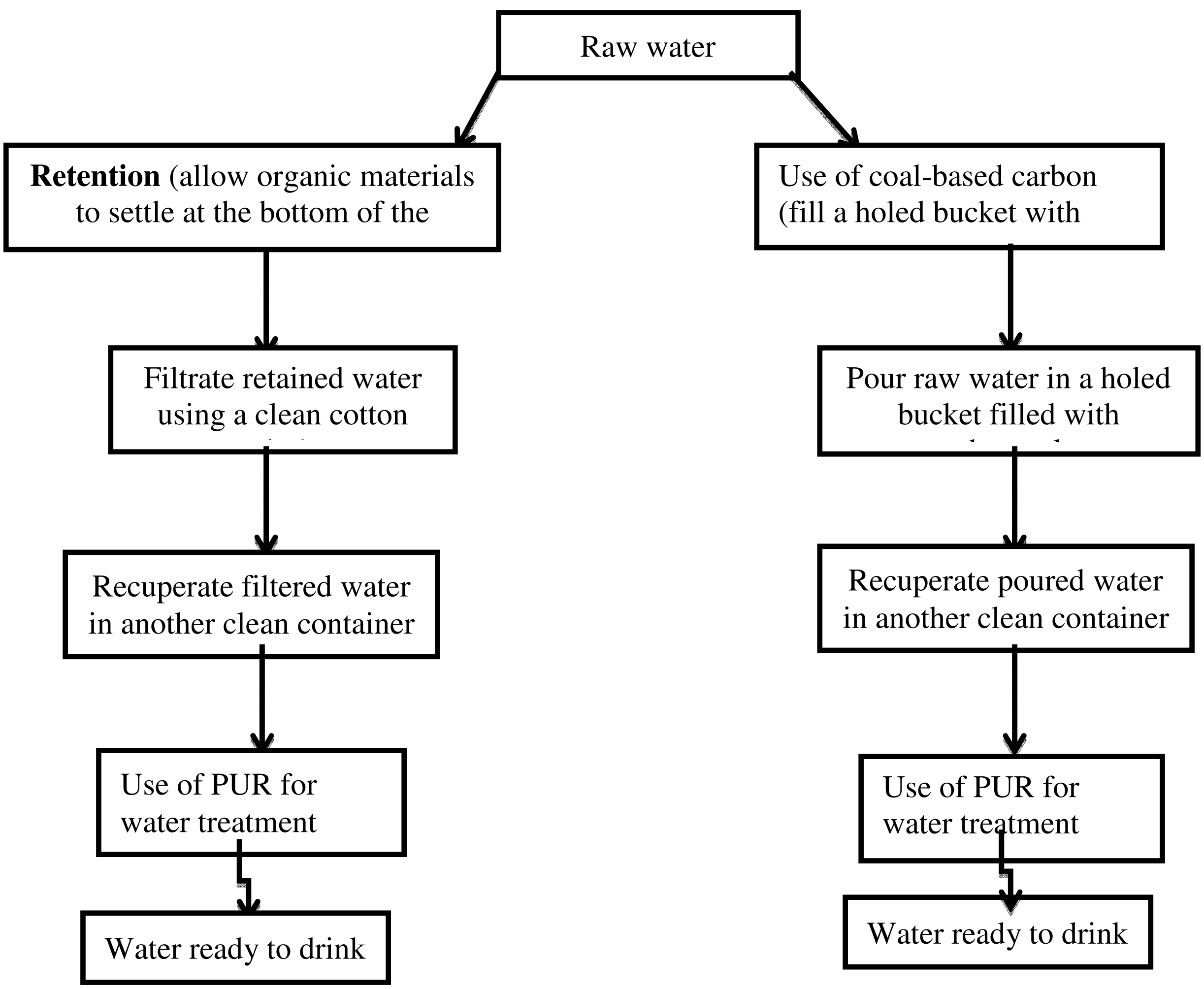

Figure-7: The flow diagram showing the steps of the model generated by this research for water treatment using PUR.

Coal-based carbons: It is a cost-effective treatment option for disinfection by-products removal. For decades, municipalities have utilized chlorine as a primary disinfectant for surface water sources, to inactive microbial pathogens such as Giardia. While the benefits of chlorination are well documented, a side effect of chlorination is that residual chlorine can react with naturally occurring organics in water to form disinfection by-products (DBPs) such as trihalomethanes (THMs) or five haloacetic acids (HAAs). These by-products may lead to increased health risks if present at high levels. To address the issue of DBPs formation, the research finalized rules to protect public health by limiting exposure to these disinfectant by-products.

The rule builds upon early regulations by requiring households to employ retention and coal-based carbons to remove organics precursors of DBPs, or adsorb the DBPs themselves. Coal-based carbons have been the traditional products choice.

Acknowledgement

I appreciate particularly the Executive secretary of Jury sector and all Staffs of Jury sector for their untiring contribution in my study. I strongly give my thanks also to the Community Health Workers of Jury sector for their willing to welcome me and their support towards the completion of this study. I can't pose off my acknowledgement without thanking all Staffs of World Vision Rwanda working in Gashora ADP for their warm facilitation during my study. I will strive for the global excellence.

References

1. Hoque B.A. and Khanam S. (2007). Efficiency and Effectiveness of Point-of Use Technologies in Emergency Drinking Water: An Evaluation of PUR and Aquatab in Rural Bangladesh. *Environment & Population Research Centre, Dhaka, Bangladesh*.

2. Laurent P. (2005). Household drinking water systems and their impact on people with weakened immunity. MSF-Holland, Public Health Department.

3. Pickard Brian C. (2006). Chlorine Disinfection in the Use of Individual Water Purification Devices. Technical Information Paper 31-002-0306.

4. Quick R. (1999). Diarrhoea prevention in Bolivia through point-of-use disinfection and safe storage: a promising new strategy. Available at: http://www/edc.gov/safewater/publ/pub/quick-r-2.htm (accessed Jully7, 2015).

5. UNICEF Bangladesh final Report by EPRC (2008). Efficiency and Effectiveness of Point-of UseTechnologies in Emergency Drinking Water: An Evaluation of PUR and Aquatab in Rural Bangladesh.

6. WHO (2005). Guidelines for Drinking Water Quality. 2^{nd} Edition.

7. Crump J.A., Okoth G.O., Slutsker L., Ogaja D.O., Keswick B.H. and Luby S.P. (2004). Effect of point-of-use disinfection, flocculation and combined flocculation–disinfection on drinking water quality in western Kenya. *Journal of Applied Microbiology*, 97(1), 225-231.

8. Valentine R.L., Choi J., Chen Z., Barrett S.E., Hwang C., Guo Y., Wehner M., Fitzsimmons S., Andrews S.A., Werker A.G., Brubacher C. and Kohut K. (2006). Factors Affecting the Formation of NDMA in Water and Occurrence. Denver, Colo.: Awwa Research Foundation.

9. Kelly Reynolds A. (2010). Novel Study Improves Toxicity Analysis of Disinfection By products in Drinking Water.