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Analyzing Water Quality and Consumer Perceptions at Refill Stations in Guyana: Mixed-Methods Analysis

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Authors' contributions

This work was carried out in collaboration among all authors. Author CB designed the study and wrote the first draft of the manuscript. Author RK performed the statistical analysis and wrote the protocol. Author DB managed the general analysis of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Water refill stations continue to be a means of providing safe and affordable drinking water. However, due to the growing number of water refill stations, there have been concerns regarding the water quality and voluntary compliance with the local standard. Therefore, this study sought to comparatively assess the quality of potable water from selected water refill stations in an urban and rural community and to understand purchaser's attitudes and practices towards water refill stations.
Methodology: The study included six (6) water refill stations and 612 randomly selected purchasers and was conducted from January to May 2022. The water samples were collected at various times and on different days of the week. Data was collected using a pretested interview schedule, observational checklist, and purchaser questionnaire. A p-value of ≤0.05 was used to determine statistical significance.
Results: The results showed that only 50% of the refill stations avail themselves of any form of water quality testing. Moreover, water refill stations within the urban community showed more voluntary compliance with the local standard. A significant association of water quality parameters

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was seen in pH (0.00), turbidity (0.04), iron (0.01), and aluminum (0.000). There were also notable differences within the means of total dissolved solids (Urban (44.1)-Rural (50.7) and total coliform Urban (18.6) Rural (2.1). There were generally good attitudes and practices among purchasers with sex (0.05), education (0.00), and ethnicity (0.03) showing significant association.

Conclusion: In conclusion, while the framework exists, though voluntary, for water refill stations to operate, there are concerns surrounding the quality of refill water. Several water quality parameters were out of range which justifies quality concerns. Nevertheless, water refill stations within the urban community had fewer violations as compared to those in the rural community. Purchasers were noted as having good attitudes and practices towards refill water and water refill stations.

Keywords: Water refill stations; potable water; water quality; consumer's perception.

1. INTRODUCTION

Water refill outlets present a sustainable business model for the supply of potable water to consumers. Globally, this growing enterprise has evolved out of the necessity of people to access safe potable water due to its relatively low cost [1,2]. Bartram and Richard suggested that water quality is largely in part due to its intended use which would suggest that there should be different standards that target the specific use of water [3]. Water that is designated for human consumption is held to a higher standard since the principal reason for water consumption is the maintenance of good health. The World Health Organization (WHO) would have therefore established guidelines that we now know as "safe" limits. These limits are set bearing in mind the limitations that exist in countries across the world and as such, they are used to provide that cushion in which people can consume water without any risk to their wellbeing [4]. While WHO would have provided these guidelines as a baseline for countries across the world to follow, it is not mandatory since countries have the autonomy to develop their standards which take into consideration the local environment, customs, and norms of a particular people [5]. Due to the increasing demand for "safe" potable water for human consumption, several private entities have been established in Guyana to meet this need by providing water refill services. Since this is a relatively new enterprise in Guyana and in some regards unregulated, this project broadly looks to assess whether these entities are following local and international water quality standards and if not, to extrapolate any negative consequences due to long-term consumption of substandard drinking water. Additionally, this project shed light on purchaser's attitudes and practices towards water refill stations.

In 2019, WHO would have stated that around 2 billion people were consuming water from sources that were not operated in a safe way [6]. The United Nations General Assembly in 2010 would have acknowledged the human right to sufficient, continuous, safe, acceptable, physically accessible, and affordable water which aligns with the sustainable development goal target 6.1 [5]. Worth noting, that millions lack basic access to improved water sources and many more consume contaminated water from sources deemed to be safe [5,7]. The WHO estimated that in 2017 some 2.2 billion people used unsafe water and recognizes the predisposition this places on those persons to transmit diseases such as cholera, dysentery, typhoid, polio, hepatitis A, and diarrhea. Therefore, it is safe to state that unregulated and unmonitored water refill services pose a new and direct threat to human health and well-being. A staggering number of around 829,000 persons inclusive of 297,000 children die yearly from diarrhea, a preventable disease, due to unsafe drinking water, sanitation, and hand hygiene [6]. In 2017 alone more than 220 million persons were treated for schistosomiasis- a disease acquired through exposure to infested water [6].

The ability to provide safe potable water has become a necessity, especially in the era of climate change and the potential public health crisis that can arise because of inaction. All of which aligns with Sustainable Development Goal (SDG) 6 – and by extension, in the promotion of health and well-being – SDG 3 [6]. Therefore this study would determine the suitability of potable water from water refill stations for human consumption in a rural community and an urban community in Guyana.

2. MATERIALS AND METHODS

The study was a cross-sectional study. This study comprised selected water refill stations in two communities, one rural and one urban. Water refill stations were included only after giving prior informed consent and having satisfied the inclusion criteria of being operational for no less than one (1) year.

2.1 Sampling Method

Water refill stations were selected through purposive sampling due to the small sample size within each community. Random sampling was used to identify purchasers for the study. This was done by placing numbers one (1) through ten (10) into a brown paper bag and the researcher retrieving a single number. This process was repeated at each of the refill stations within the study. The number identified represented the purchaser that would be asked to participate in the study. For example,

2.2 Rural Community

Water refill Station A – number 5 was pulled which meant every 5th purchaser
Water refill Station B – number 3 was pulled which meant every 3rd purchaser
Water refill Station C – number 5 was pulled which meant every 5th purchaser

2.3 Urban Community

Water refill Station D – number 7 was pulled which meant every 7th purchaser
Water refill Station E – number 4 was pulled which meant every 4th purchaser
Water refill Station F – number 2 was pulled which meant every 2nd purchaser

2.4 Sample Size

A total of six (6) water refill stations, three (3) in each community were selected to participate in the study after giving prior informed consent. Each water refill station suggested a monthly average of approximately five hundred (500) persons purchasing refill water. As such, the sample size for each community, rural and urban, was calculated based on an average total population of 1500 each. Using the single proportion sample size formula, with a precision of 5%, and a confidence interval of 95%.

2.5 Data Collection Instrument

This study utilized three (3) data collection instruments, namely, an Interview Schedule, an observational checklist, and a questionnaire and consent form. All of these were generated based on the GYS 516:2017: Requirements for water re-filling premises (Guyana National Bureau of Standards (GNBS); 2017) [8]. A standard developed by the Guyana Bureau of Standards in response to the growing number of privately owned and controlled water refill stations. This standard is intended to regulate and ensure the quality of water being produced by those entities. The standard covers areas such as location, design and layout of facilities, specifications for re-filling areas, labeling, records, recall, personnel, and testing. The questionnaire was divided into 3 questions in the preliminary data section, 13 questions in the attitudes and practice section, 6 questions in the differential reinforcement section, and 9 questions in the differential association. Before being operational the questionnaire was piloted, and Cronbach alpha analysis was performed to ensure that there is good internal consistency and that the instrument is measuring what it is intended to measure. The Cronbach alpha test revealed a score of 0.80.

Trace metals analysis was done by atomic absorption spectroscopy. After testing, water quality and trace metals data were compiled into an Excel sheet before being analyzed in SPSS version 21.

2.6 Data Analysis

The data was analyzed using SPSS version 21. Descriptive statistics were used to analyze the mean, median, standard deviation, maximum and minimum values, and frequency distribution of each parameter. Inferential statistics were done using t-test, ANOVA, and regression analysis. A p-value of ≤ 0.05 was considered statistically significant.

The questionnaire had Likert scale questions with a scale ranging from 1-7 and “yes and no” questions with a scale range of 0-1. Answers under each section were added and a mean score under each section and a standard deviation was calculated. The minimum and maximum participant's score was also calculated under each section.

3. RESULTS AND DISCUSSION

Among the six (6) water refill stations in this study, the operation period was between 4 years to 10 years with a mean (year)±SD 6.8 ± 2.1. All refill stations had collected their raw water from the GWI standard distribution pipe system. The study identified the following purification techniques at each refill station:

Refill Station A: Single filtration process and chlorination technique
Refill Station B: Three-tiered filtration process and chlorination technique.
Refill Station C: Single filtration process.
Refill Station D: Two-tiered filtration process, reverse osmosis and chlorination technique.
Refill Station F: Two-tiered filtration process.
Refill Station E: Two-tiered filtration process, reverse osmosis and chlorination technique.

3.1 Observational Checklist of Standard Requirements Based on the GYS 516:2017: Requirements for Water Re-filling Premises

The observational checklist which was used to assess the refill station's compliance with the national standard would have revealed the deficiencies that existed at each refill station. The disaggregated data showed that refill stations A, B, and C located in the rural community performed fair and satisfactorily when measured against the compliance checklist. Conversely, locations D, E, and F performed well and satisfactorily when measured against the same checklist [Fig. 1]. The checklist for compliance with water refill stations was checked for location compliance, design compliance, and layout compliance. The overall compliance score was recorded as 99. Overall comparisons of the two communities indicated that the rural community performed fair, and the urban community performed satisfactorily [Fig. 2] with an overall p-value of 0.0001 when assessing the physical infrastructure.

3.2 Water Quality Analysis

Water quality analysis of the treated water showed a statistical significance among pH, turbidity, iron, and aluminum between the means for the two communities. Further comparison of the water quality parameters showed that samples from rural settings were acidic with 4.8 pH compared to the urban setting (6.0 pH). High aluminum concentration and iron were recorded in the rural setting with 2.1 and 0.3 respectively. Total coliform was recorded as high with 18.6 in urban settings [Table 1].

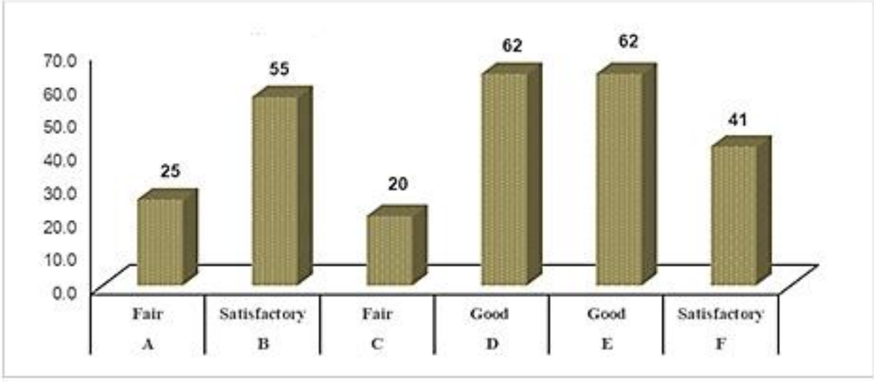

Fig. 1. Cumulative comparison of the observational checklist between communities

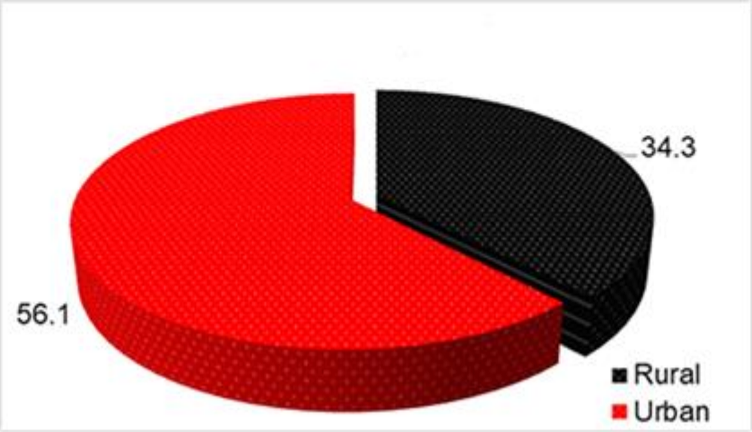

Fig. 2. Percentage from checklist score of water refill stations from rural and urban settings

Table 1. Water quality analysis of the treated water within the two communities

Variable	Site	Mean ± SD	SE mean	Min-Max	t-test/ Chi-Square	p-value
pH (6.5-8.5)	Urban	6.0 ± 0.7	0.2	5.0-6.8		
	Rural	4.8 ± 0.5	0.1	4.3-5.7		
	Total	5.4 ± 0.8	0.1	4.2-6.8	5.6	0.00*
Turbidity (<5.0)	Urban	0.3 ± 0.1	0.3	0.1-0.6		
	Rural	0.5 ± 0.4	0.1	0.1-1.3		
	Total	0.4 ± 0.3	0.1	0.1-1.3	-2.3	0.04*
Iron (<0.3)	Urban	0.01 ± 0.03	0.01	0.02-0.1		
	Rural	0.3 ± 0.3	0.1	0.07-0.9		
	Total	0.2 ± 0.2	0.04	0.02-0.9	2.9	0.01*
Apparent colour (Clear <100)	Urban	10.7 ± 11.2	3.5	1.0-36.0		
	Rural	16.7 ± 15.4	4.0	1.0-48.0		
	Total	13.7 ± 13.6	2.5	1.0-48.0	-1.2	0.2
Aluminium (0.1)	Urban	0.3 ± 0.3	0.10	0.00-0.8		
	Rural	2.1 ± 1.3	0.3	0.3-4.0		
	Total	1.2 ± 1.3	0.2	0.00-4.0	5.40	0.000*
Conductivity	Urban	94.2 ± 55.6	14.3	7.4-154.3		
	Rural	105.5 ± 27.6	8.0	55.1-150.6		
	Total	99.2 ± 44.9	8.6	7.4-154.3	-0.7	0.8
Salinity	Urban	0.05 ± 0.03	0.01	0.00-0.1		
	Rural	0.06 ± 0.04	0.01	0.02-0.2		
	Total	0.06 ± 0.04	0.007	0.00-0.20	-0.7	0.8
Total dissolved solids	Urban	44.1 ± 26.1	6.7	3.6-72.9		
	Rural	50.7 ± 12.7	3.8	28.1-72.1		
	Total	47.1 ± 21.4	4.2	3.6-72.9	-0.8	0.8
Total coliform	Urban	18.6 ± 43.6	12.6	0.0-150.0		
	Rural	2.1 ± 7.0	1.8	0.0-27.0		
	Total	9.4 ± 30.0	5.8	0.0-150.0	1.3	0.1

Table 2. Mean score of attitudes, practices, and differential association among rural and urban purchasers

Scores	Mean ± SD	Min-Max
Attitudes and Practices		
Rural	45.8 ± 0.8	41-48
Urban	44.9 ± 2.1	38-49
Differential Association		
Rural	16.3 ± 2.3	0-21
Urban	15.9 ± 2.7	0-23
Differential Reinforcement		
Rural	6.0 ± 0.3	4-7
Urban	6.0 ± 0.3	4-7

The mean score was calculated among study purchasers for attitude and practices, differential associations, and differential reinforcement. Purchasers from rural settings scored a higher mean score of 45.8 compared to urban purchasers. Similarly, the mean score was higher among rural purchasers for differential association (16.3). Although, the mean score for differential reinforcement was the same among rural and urban purchasers [Table 2].

A study conducted by Onyango et al would have noted that the sum of the refill water quality is a direct reflection of how all the integral parts are functioning together [9]. Therefore, personnel must be adequately trained and prepared to handle the specifics of water treatment or any job task.

It should be understood that water refilling areas are relatively high-touch areas and as such would have the propensity to be a reservoir for infectious agents thereby creating the environment for a potential public health emergency. High-touch areas would then require a more intense recurrent cleaning schedule to alleviate this [10]. Animal model studies have suggested that the pH of drinking water can have an overall effect on gastrointestinal (GI) health affecting such things as gut microbiota and glucose regulations among others [11]. Over the years GI diseases have been increasing in numbers and severity so much that they are now considered the third leading cause of death globally [12–14]. As such, several approaches have been adopted to combat the growing phenomena of GI diseases. One such approach is the use of alkaline-reduced water (ARW) to fight against the effects of an acidic diet. This has been studied in numerous territories under a variation of names. ARW is produced through electrolysis of water and includes properties such as an alkaline pH, micro-clustered water molecules, rich dissolved hydrogen molecule content, active hydrogen, extremely negative oxidation-reduction potential (ORP), and Reactive Oxygen Species (ROS)-scavenging properties [15–17]. All of which have been reported to affect gut microbiota and metabolism [18,19]. Further, a study conducted on newborn mice noted that the occurrence of diabetes was amplified with the use of neutral water as compared to acidic water [18].

Turbidity is a measure of the light refractiveness of water and can be used to determine water quality as increased turbidity is often linked to microbiological contamination [20]. Several studies have reported that increased turbidity in drinking water is linked to problems with the GI tract [21–26]. Schwarts et al would have suggested an association between drinking water turbidity and endemic GI illness in Philadelphia [27]. However, the Environmental Protection Agency (EPA) would have discredited that study claiming technical flaws in turbidity measurement and analysis techniques [28]. Nevertheless, other studies conducted would have confirmed an association [24,27,29–32]. A high concentration of aluminum in drinking water can be a direct result of improper water treatment processes and overconsumption over extended periods has been linked to Alzheimer's disease [33]. As such aluminum salts used as part of flocculation for drinking water have been disparaged [33]. It should be noted that none of the water refill stations would have applied this step in their purification process. However, GWI uses aluminum salts as flocculants in its water purification process. Although this study did not find high concern about iron, it is still significant. Studies have concluded that adverse health impacts can occur due to overuse of drinking water with high iron content thereby leading to potential ailments such as cardiovascular disease, diabetes mellitus, kidney, and liver disease among others [34–36].

WHO would have stated that regardless of a person's social and economic standing they have a right to access safe potable water [37]. This is well aligned with Sustainable Development Goals six and three (3) which speak to health and well-being (6). Two possible explanations for this can be compromised quality control and quality assurance measures during the collection, handling, and/or storage in households [38].

Water is made unpleasant by elements like color, taste, and odor, while substances like PTEs pose serious health risks to those who drink it [39]. PTEs such as lead (Pb), mercury (Hg), cadmium (Cd), and arsenic (As) are associated with increased risks of cancer, renal impairment, and cardiovascular diseases [40]. Not only does it affect humans but also aquatic animals it causes disturbances in the immunological system, oxidative stress, and neurotoxic consequences [41]: also in aquatic animals.

Information regarding refilled water is disseminated through different means; however, consumer's ability to understand the information is what will guide their perception of refilled water. This is a direct association with the level of education attained by the consumer [42]. A previous study done in Guyana showed that water and biofilm samples from The Guyana Water Inc (GWI) sites and residential sites exhibited inadequate quality in terms of physicochemical and biological parameters (43).
Within this study, education played a significant association with the purchase of refilled water. Therefore, overall, participants in this study can be said to have good knowledge and practices towards refilling water all of which are linked to educational level.

4. CONCLUSION

In conclusion, it can be noted that while the local standard provides the framework under which water refill stations should be bound to operate there are also considerable gaps that exist within the standard and issues regarding enforcement.

Purchasers were noted as having generally good attitudes and practices towards refill water and water refill stations. Furthermore, sex, education, and ethnicity had a significant association in regards to purchaser's attitudes and practices. It was also noted that only two (2) of the water refill stations were currently licensed to operate. Based on the observational checklist refill stations within the urban community scored higher as compared to those within the rural community. Furthermore, regarding water quality, it noted that pH, turbidity, iron, and aluminum had significant associations when comparing refill stations and communities. When the raw water was compared to the treated water it showed statistical significance with turbidity and apparent colour. If infrastructure, training, and continuing resource allocation are sufficient, test findings may, however, serve as motivation for supply-level managers to adopt hazard mitigation strategies. Our findings have ramifications for both rural development programs and the dissemination of environmental risks in underdeveloped areas. Additionally, though not significant it was observed that treated water recorded some level of contamination with total coliform as opposed to zero (0) total coliform in raw water. Therefore, the need exists for strengthening the current framework that addresses water refill stations to protect society from a major public health crisis.

ETHICAL APPROVAL AND CONSENT

The study was approved by the ethics committee of, the University of West Indies. An informed consent form was also obtained from the proprietors of water refill stations and their purchasers, before participating in the study.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Keman S. Quality of refilled drinking water in Surabaya City. Folia Medica Indones. 2005;41(1):29–35.
2. Widiyanti NLP, Ristiati NP. Qualitative analysis of coliform bacteria at some shops refilled drinking water in Singaraja Bali. J Ekol Kesehat. 2004;3(1):64–73.
3. Bartram J, Ballance R, Organization WH, Programme UNE. Water quality monitoring: A practical guide to the design and implementation of freshwater quality studies and monitoring programs / edited by Jamie Bartram and Richard Ballance. E \& FN Spon; Published on behalf of United Nations Environment Programme and the World Health Organization; 1996.
4. World Health Organization. Guidelines for Drinking-water Quality. Geneva, Switzerland; 2017.
5. WHO, UNICEF. DRINKING-WATERProgress on sanitation and drinking-water - 2013 update. Geneva; 2013.
6. WHO. Sustainable development goal 6: ensure availability and sustainable management of water and sanitation for all; 2019. Available:https://www.un.org/sustainabledevelopment/water-and-sanitation/
7. Sobsey M. Managing water in the home: Accelerated health gains from improved water supply; 2004 Jan 1.
8. Guyana National Bureau of Standards. Requirements for water re-filling premises. Georgetown; 2017.
9. Onyango LA, Quinn C, Tng KH, Wood JG, Leslie G. A study of failure events in drinking water systems as a basis for comparison and evaluation of the efficacy of potable reuse schemes. Environ Health Insights. 2015;9(Suppl 3):11–8.
10. Casini B, Righi A, De Feo N, Totaro M, Giorgi S, Zezza L et al. Improving cleaning and disinfection of high-touch surfaces in intensive care during carbapenem-resistant acinetobacter baumannii endemo-epidemic situations. International Journal of Environmental Research and Public Health. 2018;15.
11. Hansen TH, Thomassen MT, Madsen ML, Kern T, Bak EG, Kashani A et al. The effect of drinking water pH on the human gut microbiota and glucose regulation: Results of a randomized controlled cross-over intervention. Sci Rep. 2018, Nov;8(1): 16626.
12. Hellier MD, Williams JG. The burden of gastrointestinal disease: Implications for the provision of care in the UK. Gut. 2007, Feb;56(2):165–6.
13. Oshima T, Miwa H. Epidemiology of Functional gastrointestinal disorders in Japan and in the World. J Neurogastroenterol Motil. 2015, Jul;21(3): 320–9.
14. Drossman DA. Functional gastrointestinal disorders: History, pathophysiology, clinical features, and rome IV. Gastroenterology. 2016;150(6):1262-1279.e2. Available:https://www.sciencedirect.com/science/article/pii/S0016508516002237
15. Shirahata S, Li Y, Hamasaki T, Gadek Z, Teruya K, Kabayama S et al. Redox

regulation by reduced waters as active hydrogen donors and intracellular ROS scavengers for prevention of type 2 diabetes BT - Cell technology for cell products. In: Smith R, editor. Dordrecht: Springer Netherlands. 2007;99–101.

16. Ignacio RMC, Joo K, Lee K. Clinical effect and mechanism of alkaline reduced water. 2012;20(1).
17. Shirahata S, Hamasaki T, Teruya K. Advanced research on the health benefit of reduced water. Trends Food Sci Technol. 2012;23(2):124–31.
Available:https://www.sciencedirect.com/science/article/pii/S0924224411002408
18. Wolf KJ, Daft JG, Tanner SM, Hartmann R, Khafipour E, Lorenz RG. Consumption of acidic water alters the gut microbiome and decreases the risk of diabetes in NOD mice. J Histochem Cytochem Off J Histochem Soc. 2014, Apr;62(4):237–50.
19. Sofi MH, Gudi R, Karumuthil-Melethil S, Perez N, Johnson BM, Vasu C. pH of drinking water influences the composition of gut microbiome and type 1 diabetes incidence. Diabetes. 2014, Feb;63(2):632–44.
20. Mann AG, Tam CC, Higgins CD, Rodrigues LC. The association between drinking water turbidity and gastrointestinal illness: A systematic review. BMC Public Health. 2007;7(1):256.
Available:https://doi.org/10.1186/1471-2458-7-256
21. Kent GP, Greenspan JR, Herndon JL, Mofenson LM, Harris JA, Eng TR et al. Epidemic giardiasis caused by a contaminated public water supply. Am J Public Health. 1988, Feb;78(2):139–43.
22. Levy DA, Bens MS, Craun GF, Calderon RL, Herwaldt BL. Surveillance for waterborne-disease outbreaks--United States, 1995-1996. MMWR CDC Surveill Summ Morb Mortal Wkly report CDC Surveill Summ. 1998, Dec;47(5):1–34.
23. MacKenzie WR, Schell WL, Blair KA, Addiss DG, Peterson DE, Hoxie NJ et al. Massive outbreak of waterborne cryptosporidium infection in Milwaukee, Wisconsin: Recurrence of illness and risk of secondary transmission. Clin Infect Dis an Off Publ Infect Dis Soc Am. 1995, Jul; 21(1):57–62.
24. Morris RD, Naumova EN, Levin R, Munasinghe RL. Temporal variation in drinking water turbidity and diagnosed gastroenteritis in Milwaukee. Am J Public Health. 1996, Feb;86(2):237–9.
25. Fox KR, Lytle DA. Milwaukee's crypto outbreak: Investigation and recommendations.Journal-American Water Work Assoc. 1996;88(9):87–94.
26. Schuster CJ, Ellis AG, Robertson WJ, Charron DF, Aramini JJ, Marshall BJ et al. Infectious disease outbreaks related to drinking water in Canada, 1974-2001. Can J Public Health. 2005;96(4):254–8.
27. Schwartz J, Levin R, Goldstein R. Drinking water turbidity and gastrointestinal illness in the elderly of Philadelphia. J Epidemiol Community Health. 2000, Jan;54(1):45–51.
28. Sinclair MI, Fairley CK. Drinking water and endemic gastrointestinal illness. J Epidemiol Community Health. 2000, Oct; 54(10):728.
29. Morris RD, Naumova EN, Griffiths JK. Did Milwaukee experience waterborne cryptosporidiosis before the large documented outbreak in 1993? Epidemiology. 1998, May;9(3):264–70.
30. Beauchamp T, Childress J. Principles of biomedical ethics: marking its fortieth anniversary. The American Journal of Bioethics. Taylor & Francis. 2019;19: 9–12.
31. Aramini J, McLean M, Wilson J, Holt J, Copes R, Allen B et al. Drinking water quality and health-care utilization for gastrointestinal illness in greater Vancouver. Can Commun Dis Rep. 2000, Dec;26(24):211–4.
32. Gilbert M-L, Levallois P, Rodriguez MJ. Use of a health information telephone line, Info-sante CLSC, for the surveillance of waterborne gastroenteritis. J Water Health. 2006;4(2):225–32.
33. Chao H-J, Zhang X, Wang W, Li D, Ren Y, Kang J et al. Evaluation of carboxymethylpullulan-AlCl (3) as a coagulant for water treatment: A case study with kaolin. Water Environ Res a Res Publ Water Environ Fed. 2020, Feb; 92(2):302–9.
34. Powers KM, Smith-Weller T, Franklin GM, Longstreth WTJ, Swanson PD, Checkoway H. Parkinson's disease risks associated with dietary iron, manganese, and other nutrient intakes. Neurology. 2003, Jun; 60(11):1761–6.
35. Wasserman GA, Liu X, Parvez F, Ahsan H, Levy D, Factor-Litvak P et al. Water manganese exposure and children's intellectual function in Araihazar,

Bangladesh. Environ Health Perspect. 2006, Jan;114(1):124–9.

36. Farina M, Avila DS, da Rocha JBT, Aschner M. Metals, oxidative stress and neurodegeneration: A focus on iron, manganese and mercury. Neurochem Int. 2013, Apr;62(5):575–94.
37. Biglari H, Chavoshani A, Javan N, Mahvi A. Geochemical study of groundwater conditions with special emphasis on fluoride concentration, Iran. Desalin Water Treat. 2016, Mar 31;57:1–8.
38. Ercumen A, Naser AM, Unicomb L, Arnold BF, Colford JMJ, Luby SP. Effects of source-versus household contamination of tubewell water on child diarrhea in rural Bangladesh: A randomized controlled trial. PLoS One. 2015;10(3):e0121907.
39. WHO. Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum World Health Organization, Geneva. 2017:155e200 Available:https://www.who.int/water_sanitation_health/publications/drinkingwater-quality-guidelines-4-including-1st-addendum/en/
40. Yao X, Xu SX, Yang Y, Zhu Z, Zhu Z, Tao F, Yuan M. Stratification of population in NHANES 2009–2014 based on exposure pattern of lead, cadmium, mercury, and arsenic and their association with cardiovascular, renal and respiratory outcomes. Environ Int. 2021; 149:106410.
41. Ihunwo OC, Dibofori-Orji AN, Olowo C, Ibezim-Ezeani MU. Distribution and risk assessment of some heavy metals in surface water, sediment and grey mullet (*Mugil cephalus*) from contaminated creek in Woji, southern Nigeria. Mar Pollut Bull. 2020;154:111042
42. Tilahun M, Beshaw M. Customer's perception and preference towards packaged drinking water. Pasquinelli G, editor. Sci World J. 2020;2020:6353928. Available:https://doi.org/10.1155/2020/6353928.
43. Kurup R, Persaud R, Caesar J, Raja VR. Microbiological and physiochemical analysis of drinking water in Georgetown, Guyana; 2010. Available:https://www.sciencepub.net/nature/ns0808/31_3526ns0808_261_265.pdf

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