Water quality assessment of post-chlorinated wells in San Juan, Molo, Iloilo City following acute gastroenteritis (AGE) outbreak

JANUS NATHANIEL G. CASBADILLO, SOFIA SOLEIL P. HARESCO, and MARIA DEANNA JOLITO

Philippine Science High School Western Visayas Campus - Department of Science and Technology (DOST-PSHS WVC), Brgy. Bito-on, Jaro, Iloilo City 5000, Philippines

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Abstract

Groundwater wells in residential areas like San Juan, Molo, Iloilo City are important water sources for domestic use. However, these wells are susceptible to contamination, leading to waterborne illnesses. Following an outbreak of acute gastroenteritis (AGE) in Iloilo City in August 2022, water sources in affected communities were examined and treated with chlorine. Despite these efforts, the number of AGE cases continues to rise in San Juan, Molo, one of the most affected areas in the city. This study aimed to evaluate the water quality of post-chlorinated wells in San Juan, Molo, Iloilo City, focusing on physicochemical and microbiological properties. The assessment revealed that the analyzed wells exceeded the maximum allowable level (MAL) set by the Philippine National Standards for Drinking Water (PNSDW) of 2017 in terms of turbidity, color, residual chlorine content, and total coliform count. Consequently, the water from these post-chlorinated wells is unsuitable for domestic use. These findings suggest that local disinfection strategies for well systems in San Juan, Molo, Iloilo City are ineffective in eliminating water pathogens and maintaining water quality.

Introduction. - The addition of a substance to water that adversely affects and changes its properties is called water pollution [1]. Water pollution has been a present and imminent threat to the health and livelihoods of many people all over the globe with over 780 million people having no safe and secure water sources and 2.5 billion having no proper water sanitation [2]. There are different categories of pollutants: chemical, physical, physiological, and biological pollutants [1]. Physical pollutants include any effect on color, turbidity, temperature, suspended solids, foam, and radioactivity, while physiological pollutants include any change in taste and odor. Chemical pollutants include inorganic and organic materials that affect the Biological Oxygen Demand (BOD), pH, and toxicity of a particular body of water. Biological pollutants include the presence of bacteria, viruses, protozoa, and helminths.

Pollutants that lead to adverse effects to water supply are considered as contaminants. All contaminants are considered to be pollutants; however, not all pollutants can be considered contaminants. Contamination is the presence of a pollutant, where it should not be, or at abnormal concentrations, making it a contaminant [3]. Instances of waterborne contamination are prevalent and waterborne disease epidemics can still occur even when drinking water is piped but not disinfected [4]. Moreover, within a five-year span, exposure to waterborne biological contaminants, such as parasites, bacteria, protozoan or viruses, was thecause of approximately one third of illnesses in the Philippines, such as acute gastroenteritis (AGE) [5].

Acute gastroenteritis (AGE) is a common and potentially serious infectious illness characterized by diarrhea, vomiting, and abdominal cramps. It is most often caused by a variety of pathogens, including bacteria, viruses, and parasites. AGE is transmitted through the fecal-oral route, meaning that the pathogen is ingested from contaminated food, water, or surfaces, or through direct contact with an infected individual. Symptoms typically develop within 1-3 days of exposure and can range from mild to severe. Severe cases can lead to dehydration, electrolyte imbalances, seizures, coma, and even death [6].

Waterborne outbreaks of enteric disease occur either when public drinking water supplies are not adequately treated after contamination with surface water, or when surface waters that are contaminated with enteric pathogens, have been used for recreational and/or domestic purposes.

Water quality analysis is an important step to identify water contamination of biological contaminants. Studies that focused on analyzing the quality of drinking water in the Philippines have been conducted in different regions of the country, such as the analyzing of the physicochemical and biological properties of water samples from selected barangays in Laoang, Northern Samar, Philippines [7], as there were existing cases of waterborne diseases from the specific barangays they collected water samples from. Another study also examined the drinking water quality of different schools in Tarlac City, Philippines, through its physicochemical and biological properties [8].

Last August 30, 2022, a sudden surge of cholera cases was reported in Iloilo City, causing an outbreak [8] that resulted in over 777 cases of Acute Gastroenteritis (AGE) as of October 4, 2022 [10]. The district in Iloilo City with the highest number of cases was Molo, Iloilo City with 165 cases; and Barangay San Juan, Molo having the most with 30 cases as of October 4, 2022 [10]. The City Health Office had already begun examining and treating different water sources around the city's localities where Acute Gastroenteritis cases were starting to rise in numbers [11]. However, according to the CHO acting officer, the chlorination efforts in Iloilo City remain ineffectual since the cases of AGE keep on rising, which is probably due to recontamination, the proximity of water well systems to canals and septic tanks, ineffectiveness of chlorination protocols, and the water table itself being contaminated [12]. As of October 4, 2022, the district of Molo has reached 30 cases of AGE, the highest in the whole city of Iloilo. More specifically, Barangay San Juan, Molo had the highest number of AGE cases [10] in the district which placed a huge risk towards the health and well-being of citizens residing in the community.

Domestic water is termed as water coming from domestic water supplies that provides water for households for their daily use such as cooking, bathing, washing the dishes and utensils, cleaning the house, and doing laundry [13]. According to the Department of Environment and Natural Resources (DENR) Administrative Order (DENR-AO or DAO) No. 08, series of 2016, different water bodies are classified depending on where it is sourced, how it is used, and on what standards should the water source be compared to [14]. In the Administrative Order, domestic water is classified as Class A and listed as Public Water Supply Class II which is intended as sources of water supply requiring conventional treatment that includes processes such as coagulation, sedimentation, filtration, and disinfection which are all processes that are conducted in wells supplying water in Barangay San Juan, Molo, Iloilo City. Furthermore, Class A water sources are compared with the Philippine National Standards for Drinking Water (PNSDW) of 2017 [15] to determine if they are viable for public use. In this study, the modified PNSDW mandatory parameters are used to assess if the wells comply with the given standard.

The knowledge obtained from this research would assist in providing a comprehensive water quality assessment of post-chlorinated wells using an evidence-based analysis that outlines the physicochemical and microbiological properties [16] which is especially useful to localities that fall short in observing well water monitoring, and will serve as a basis for future well disinfection and recovery protocols that can properly inactivate water pathogens [17]. This study sought to record water quality parameters such as the physical properties consisting of color (apparent) and turbidity; the chemical properties consisting of nitrate, pH, total dissolved solids (TDS) and residual chlorine; and the microbiological properties specifically total coliform count. These parameters are modified from the Philippine National Standards for Drinking Water (PNSDW) of 2017 [15], with the exclusion of the heavy metals consisting of lead, cadmium and arsenic. Heavy metal contamination usually occurs due to human activities such as mining, industrial discharge from steel plants, battery factories and thermal power plants, sites for traffic, municipal and hazardous wastes and lastly, agricultural runoff from the overuse of fertilizers containing heavy metals [18, 19, 20]. San Juan, Molo, Iloilo City is a residential area that lacks any present factory, farmland nor mining areas which makes heavy metal contamination uncommon; hence it was excluded from the study in favor of studying parameters that are more relevant given the conditions and the environment.

The data and results would be most significant to the citizens of Barangay San Juan, Molo, Iloilo City, the Iloilo City Epidemiological Surveillance Unit, the Iloilo City Health Office, and Department of Health Region 6 since it would provide them with the information on the water quality of selected post-chlorinated wells in terms of the physicochemical and microbiological properties. Lastly, it would provide baseline information that would be significant in providing clean water and sanitation to developing communities, which is in accordance with Sustainable Development Goal number 6.

Methods. - This study is categorized as descriptive as it sought to assess the water quality of post-chlorinated wells in San Juan, Molo, Iloilo City (10.6856°, 122.5449°) on January 11, 2023 following the Acute Gastroenteritis outbreak in August 2022. The data gathering procedure of the research consisted of: sampling site selection, water sample collection, transportation of water samples, onsite physicochemical analysis, laboratory microbial analysis, the data analysis and safety precautions and disposal methods. The timespan of the data gathering procedures was two weeks to ensure that a representative sample of water quality data was collected.

Site Selection. The selected sampling site was Zone 3 barangay San Juan, Molo, Iloilo City due to its high incidence of acute gastroenteritis (AGE) cases. Three well samples were selected, with three replicates varying on depth as water quality can vary with depth, due to factors such as temperature, salinity, and the presence of different organisms and chemicals. (top, middle and bottom) were followed, with the well samples being the well attributed to the highest number of AGE cases (10.68844° 122.54146°), the well that has no cases of AGE (10.68882° 122.54298°), and a well that has a moderate number of AGE cases (10.68786° 122.54126°); serving as the median, and distilled water as the control sample.

Materials. The materials used were derived from the guide by the Department of Science and Technology Regional Standard and Testing Laboratory (DOST RSTL) Region VI specifically for collecting water samples from wells. The physicochemical analysis utilized the bucket found in the selected wells for the collection of water. Other materials included a clean, disinfected plastic bucket where collected water was poured in for physicochemical analysis. The following equipment was used for the physicochemical analysis: YSI ProDSS multiparameter water meter, and TDS meter.

The microbiological analysis also followed the aforementioned guide in which an autoclaved 400mL glass bottle with a metal cap was used. Other materials included a 20-meter rope for sample collection, a cooler box for transport, masking tape and a pen for labelling. The total amount of water collected for the physicochemical analysis was not strictly measured as long as the YSI ProDSS's probes were able to be fully submerged. The microbiological analysis used 400mL of water as prescribed by the DOST RSTL Region VI.

Water Sample Collection. An autoclaved and sterilized bottle was prepared for water sample collection by tying a rope around the neck of the bottle and attaching a weight underneath the bottle for it to descend faster. The bottle was then slowly lowered into the well, whilst avoiding hitting the sides, to fill and collect the water sample. After the bottle is almost full, it is pulled back up, making sure to leave an air gap within the bottle before sealing. The bottle was then labeled with the sample number, time collected, and researcher name before being stored in an ice box to preserve its contents.

Physicochemical Analysis. Physicochemical analysis did not follow strict guidelines in the volume of water used as the YSI ProDSS multiparameter water meter only required its probes to be fully submerged. The Physicochemical analysis was done onsite using a YSI ProDSS multiparameter water meter and a TDS meter to measure the physicochemical parameters: pH, turbidity, TDS, residual chlorine content and nitrate content. Each probe for the corresponding parameters was calibrated using distilled water. Color was personally evaluated [14] for any discernible discoloration that affects the opinion of the consumer.

Microbiological Analysis Microbiological analysis utilized 400mL of water per replicate. The research followed a triplicate approach in which 1,200 mL of water was collected from each well. The microbiological analysis involved the Multiple Tube Fermentation Test (MPN) to confirm and specify the microbial presence within the water samples. A presumptive test involving the culture of water sample bacteria in Lactose Broth was done and followed by a confirmatory test involving the same culture in Brilliant Green Lactose Bile (BGLB) broth. The total coliform count of the water samples is determined using the table below.

Table 1. Most Probable Number (MPN) Index in a Five 10-mL Water sample (Standard Method for the Examination of Water and Wastewater, APHA, AQQA, 2012 22nd Ed.)

No. of Tubes with Positive results in 5 tubes with 10 mL Each	MPN Index/100 mL
0	<1.1
1	1.1
2	2.6
3	4.6
4	8.0
5	>8.0

Data Analysis. The means of the parameters (pH, turbidity, TDS, residual chlorine content, nitrate content and total coliform count) were equated and compared with the PNSDW [13].Color was instead evaluated wherein any noticeable discoloration will affect a consumer's opinion, rendering it unable to comply with the standards for drinking water. The results are then tabulated and are highlighted where the wells comply or do not comply with the established standard,

Safety Procedure. To ensure safety, personal protective equipment (PPE) such as gloves, face masks and laboratory coats were worn at all times, especially when handling possibly contaminated water and hot objects. The contaminated water and the culture tubes were autoclaved to get rid of possible recontamination before the water and broth is poured into the drain.

Results and Discussion. - The study focused on the physicochemical and microbiological properties of the selected wells. The results were then compared with the Philippine National Standards for Drinking Water (2017) [15].

Physicochemical Analysis. The physicochemical properties taken from the sampling sites were: pH, color, turbidity, TDS, residual chlorine content and nitrate content. Table 2 below presents the pH, color, turbidity, TDS, residual chlorine content and nitrate content of the selected wells. There is noticeable discoloration of water (yellowish) in all the selected wells.

pH. As observed from Table 2, the pH of the three selected wells are slightly basic, nearing the pH of 8. The allowable limits set by the PNSDW 2017 [15] for pH is 6.5 - 8.5. This makes the three wells compliant with the standards set for pH. The mean pH of the selected wells is under 8.0, which resembles seawater (pH 8.1). This alkaline pH can irritate the skin and eyes, and may also affect the absorption of nutrients. In addition, some microorganisms, such as bacteria and parasites, can thrive in alkaline environments, which could increase the risk of waterborne diseases. [21] The normal range for pH in surface water systems is 6.5-8.5 and 6.0-8.5 for groundwater systems. When pH becomes too high, water becomes caustic and can clog or damage water systems by creating coatings, films and precipitates [22]. Although the results are within the standards for drinking water, the WHO recommends a pH of water to be less than 8.0, stating that basic water inhibits effective chlorination [23].

Turbidity. The mean turbidity of the wells ranges from 7-10 Formazin Nephelometric Units (FNU) which makes them non-compliant with the limit of 5 FNU by the PNSDW 2017 [15]. The turbidity of the wells is observed to increase with depth, attributable to the free-floating particles near the middle and bottom of the well, including the composition of the well bottom which is mostly silt, clay and sand particles. The particles scatter light which contributes to the rise of turbidity.Turbidity and chlorine-demanding solutes also inhibit the disinfection of free chlorine [24]. High turbidity levels, such as the ones recorded in the selected wells, protect microorganisms during decontamination and stimulate their growth, significantly increasing the chlorine demand [24].

Total Dissolved Solids (TDS). Two of the three wells are compliant with the standards set for the total TDS of drinkable water which is 600 ppm [14]. The TDS of the selected wells also increase with depth and are most often contributed to the application of chlorine. However, as observed from Table 2, the mean TDS of the samples are not in correlation with the residual chlorine content. Total dissolved solids (TDS) indicate the presence of inorganic salts (commonly being calcium, magnesium, potassium, sodium, carbonates, nitrates, bicarbonates, chlorides & sulfates) and a small amount of organic material in well water [23]. Humans contribute to the increase of TDS through agricultural (fertilizers) and urban runoffs (industrial wastewater); the latter being the most probable factor in the high amount of TDS recorded from the selected wells [23]. High amounts of TDS are not necessarily a health hazard when ingested, but it can produce hard water, potentially accompanying a health risk [25].

Color. The results indicate that all of the sampled wells show signs of yellowish discoloration which is not compliant with the PNSDW standards for apparent color. Despite the slight discoloration of water found in the selected wells, it is not enough to dissuade some consumers. Consumer perceptions and aesthetic properties of water should always be considered alongside the health-related guidelines whenever developing and administering regulations and standards. The wells were sampled during the rainy season, with flooding in some areas of the research locale, which may have drastically altered the water properties prior to observation and testing. These alterations most notably affect the physical properties including color. [24]

Residual Chlorine Content. The residual chlorine content of the samples notably exceeds the PNSDW limits which is 0.3-1.5 ppm [15]. This can be attributed to the chlorine application process of the well owners as well as the frequency and the date of chlorination wherein the last chlorination occurred on the same day that the well samples were tested. Residual chlorine partially provides a safeguard to low-level bacterial contamination and growth but has limitations against protozoans and viruses [26]. Chlorine can be monitored and controlled with ease as a disinfectant, and frequent monitoring is recommended whenever chlorination is practiced. The lack of monitoring after chlorination, which is observed in the selected wells, increases the risk of waterborne illnesses stemming from very high concentrations of harmful compounds to the presence of water pathogens. Residual chlorine is not only affected by dose but is also heavily dependent on the frequency and date of the last chlorination. The selected wells significantly surpassed the MAL of the PNSDW 2017 which is most probably due to them being chlorinated a week prior to testing. In addition, factors such as high turbidity and alkalinity (pH) influence the effectiveness of chlorination; but as the pH of the selected wells were within the allowable limits, the residual chlorine content and its effects may not have been affected by the water alkalinity [24].

The nitrates content was undetectable and yielded 0.00 ppm for every single well sample. This is understandable as nitrate content in well water is mostly attributed to industrial or agricultural runoff, which is highly unlikely to occur in San Juan, Molo, a residential area. Nitrates are inorganic salts [23] which, as previously mentioned, contribute to an increase of TDS in water. However, the results yielded little to no nitrate content, rendering these effects negligible. the absence of detectable nitrates implies minimal contribution from this specific source to the overall TDS . Table 2. Physicochemical Data of selected wells.

Table 2. Physicochemical Data of selected wells.

Sampling Site	Mean pH	Color (apparent)	Turbidity (FNU)	TDS (ppm)	Residual Chlorine Content (ppm)	Nitrate Content (ppm)
Well A (Well with no attributed AGE cases)	7.99	Light straw	10.12	542.00	207.11	0.00
Well B (Well with most attributed AGE cases)	7.99	Light yellow	7.28	146.30	852.08	0.00
Well C (Well with moderate attributed AGE cases)	7.89	Light yellow	9.33	677.67	291.79	0.00

Microbiological Analysis. Table 3 exhibits the microbiological data of the sampled wells. When compared with the PNSDW 2017 [15] maximum allowable level for total coliform count of 1.1 MPN/100 mL, the data presented on Table 3 shows that the three selected wells are beyond the standard. The number of coliforms in the water samples makes the wells unfit for domestic use. The microbiological analysis used distilled water as its control to indicate water free from coliform bacteria.

Table 3. Microbiological Data Table (Multiple Tube Fermentation Technique)

Sampling Site	Presumptive test	Confirmatory Test	Total Coliform Count
Well A	5	5	>8.0
Well B	5	5	>8.0
Well C	5	5	>8.0
Control	0	0	<1.1

Table 4. Overall Analysis of selected wells compared to the PNSDW

Sampling Site	Parameters						
	Mean pH	Turbidity (FNU)	Color (apparent)	TDS (ppm)	Residual Chlorine Content (ppm)	Nitrate Content (ppm)	Total Coliform Count (MPN/100 mL)
Well A	7.99	10.12	Light straw	542.00	207.11	0.00	>8.00
Well B	7.99	7.28	Light yellow	146.30	852.08	0.00	>8.00
Well C	7.89	9.33	Light yellow	677.67	291.79	0.00	>8.00
PNSDW 2017 Maximum Allowable Level (MAL)	6.50-8.00	5.00	No noticeable discoloration	600	0.30-1.50	50.0	<1.1

Overall Analysis. Table 4 presents a comprehensive comparison of the selected wells against the Maximum Allowable Limits (MAL) set by the Philippine National Standards for Drinking Water (PNSDW), considering both physicochemical and microbiological properties.

Limitations. Water collection sampling and onsite physicochemical testing were done in the rainy season of January, which may directly or indirectly affect the content and properties of the well through rainwater intrusion, possibly introducing foreign objects, sediments and bacteria to the well. There was also a lack of consistency on the well depth as the top, middle and bottom portions of the wells were only estimated instead of using a standard depth. The study is restricted to three wells, making it unable to provide a general well profile of the area.

Conclusion. From the comparison between the data obtained from the selected wells and the PNSDW 2017, it can be concluded that the water from the wells are not fit to be used domestically by the residents. Majority of the wells are highly turbid, with noticeable yellowish tint and an extremely high residual chlorine and coliform presence.

Recommendations. It is recommended for the well owners to follow a robust and technical procedure in the application of chlorine in order to avoid over chlorination of wells. Post-chlorination monitoring should also be implemented in order to confirm the presence or absence of coliforms and other harmful bacteria in the well water before being used for drinking or domestic purposes. Proper shock chlorination methods should be adequately followed such as properly measuring the volume of the well water together with measuring the diameter of well casings. Relying only on the amount of well casings and the well casings filled with water is insufficient in providing an effective amount of chlorine for chlorination. In addition to proper stewardship and by following proper methods in shock chlorination, the physicochemical and microbiological properties of wells can be preserved, promoting the well-being of citizens.

Additionally, future well water assessment studies perform the on-site physicochemical and microbiological testing multiple times over a long period of time to observe the effects of chlorination with respect to time and to determine if weather circumstances or seasons affect well properties. Increasing the sample size is also recommended to create a more general well profile of San Juan, Molo, Iloilo City. Other non-mandatory parameters should also be included such as salinity, BO, Dissolved Oxygen (DO), phosphorus, and total hardness of water.

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