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Research Article

Assessing Groundwater Quality at CLSU: A WHO Guidelines-Based Evaluation of Health Risks

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Abstract *- Groundwater is a vital resource, especially in rural areas where it serves as the primary source for domestic and agricultural use. However, increasing pollution from human activities necessitates regular quality assessments to prevent waterborne diseases. This study evaluated the physicochemical properties of groundwater from six deep wells at Central Luzon State University (CLSU) to assess its suitability for drinking and recreational use. Parameters analyzed included temperature, pH, total suspended solids (TSS), total dissolved solids (TDS), sulfate (SO_4^{2-}), nitrate (NO_3^-), dissolved oxygen (DO), hardness, and toxic heavy metals. The results were compared with World Health Organization (WHO) guidelines. While most parameters fell within acceptable limits, lead (Pb) and cadmium (Cd) concentrations exceeded WHO thresholds, posing potential health risks and rendering the water unsuitable for consumption.*

Keywords *- Water quality, Dissolved oxygen, Cadmium, lead, Nitrate, Sulfate.*

I. INTRODUCTION

Groundwater is the water that fills the spaces, pores, and cracks in geological formations, originating from precipitation in the atmosphere, either through direct rainfall infiltration or indirectly from rivers, lakes, or canals. The global groundwater supply is estimated to be around 5.0×10^{24} liters, which is over 2,000 times the total volume of water in all the world's rivers and more than 30 times that of all freshwater lakes. Groundwater serves various purposes, including agricultural, industrial, and domestic uses. It provides approximately 50% of the water needed for livestock and irrigation and nearly 40% of overall water supplies. In rural areas, groundwater is the source for 98% of domestic water consumption. It is extracted using methods such as hand-dug wells, hand-pump-operated shallow wells, and submersible pump-operated deep wells or boreholes (Otieno, Olumuyiwa, & Ochieng, 2012).

Water is a vital and abundant component of the ecosystem, essential for the survival and growth of all living beings. However, human population increase, industrialization, use of fertilizers in farming industries and other human activities that have increased pollution levels through the emission of many harmful pollutants. Therefore, it is of importance to store the quality of drinking water regularly since the use of contaminated water may lead to the spread of many waterborne diseases, which negatively impact the health of the population.

In the past, the central Luzon State University (CLSU) used to enjoy the plentiful supply of raw water of high quality, which guaranteed sufficient amounts of this resource. Nevertheless, projections also show that the university might have future problems whereby the low-quality water is to be treated in order to supply to the consumers. The expected change highlights the importance of managing the water quality, and the necessity of specifying the parameters that were traditionally subjective as the university expanded and in other contexts of the general society. To address these challenges, it is essential to test and analyze the quality of water supplied to local residences within Central Luzon State University. Such assessments ensure that the water meets established standards for potability and palatability, safeguarding the health and well-being of its consumers.

II. MATERIALS AND METHODS

A. Sampling Sites

Water samples were collected from 18 selected points in the distribution system, with three sites representing near, middle, and far distances from each of the six deep wells. Currently, there are six operating water pump stations or deep wells across the CLSU campus. Newer buildings and facilities use polyvinyl chloride (PVC) pipes for their water pipelines, while older structures continue to use galvanized iron (GI) pipelines. This approach ensured representative coverage of the distribution network for water quality analysis.

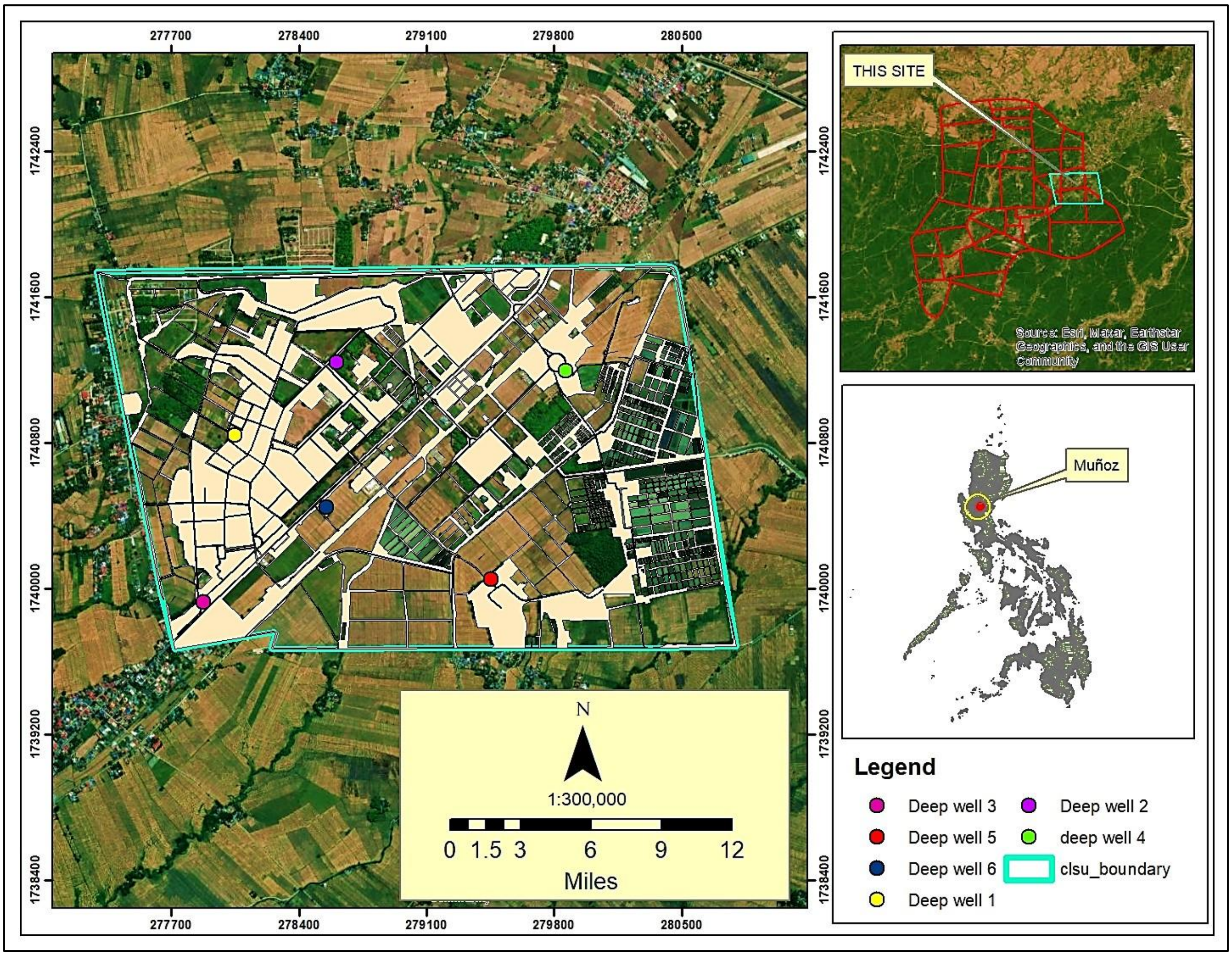


Figure 1. Illustrations of the geographical distribution of six deep wells within Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines. GIS Imagery by For. WC Diguinat, Aurora State College of Technology

a. Deep Well 1

The first deep well is located at Milflor Street and was operating since 1980's. It has an electric submersible pump. It's well size is 12 inches in diameter, suction pipe is 4 inches in diameter, well depth is 480 feet, pump rating power is 30 h.p., delivery rates is 330 g.p.m., pump setting is 140 feet, tank capacity is 53,400 gal per 213 cu.m. (53,400 gal/213 cu.m.), and its tank height is about 80 feet and has a galvanized iron pipeline installed in it. It distribute its water to the residence of Osmeña Avenue, SH. Escudero Street, Inapostol Street, Milagrosa Street, Pirurutong Street, Azucena Street, Executive Street, Milflor Street and to the residence of University Avenue and Kariñosa Street.

b. Deep Well 2

The second deep well is located at Lingap Kalikasan (near CVSM) and was operating since 1980's. It has an electric submersible pump. It's well size is 8 inches in diameter, suction pipe is 4 inches in diameter, well depth is

600 feet, pump rating power is 60 h.p., delivery rates is 600 g.p.m., pump setting is 120 feet, tank capacity is 21,570 gal per 86 cu.m. (20,000 gal/80 cu.m.), and its tank height is about 40 feet and has a galvanized iron pipeline installed in it. It also distributes its water to the residence of University Avenue, SH. Escudero, together with the residence of Lingap Kalikasan, Academic Avenue, College Avenue and Tuerimas Street.

c. Deep Well 3

The third deep well is located at Escudero III Avenue (Research) and was operating since 1980's. It has an electric submersible pump. It's well size is 8 inches in diameter, suction pipe is 3 inches in diameter, well depth is 300 feet, pump rating power is 15 h.p., delivery rates is 280 g.p.m., pump setting is 150 feet, tank capacity is 20,000 gal per 80 cu.m. (20,000 gal/80 cu.m.), and its tank height is about 40 feet and has a galvanized iron pipeline installed in it. It distributes its water to the residence of Research Avenue, Magkumpol Street, Wag-wag Street, Elon-Elon Street, Raminad Street, UNDP street and Intan Street together with SH. Escudero, and University Avenue.

d. Deep Well 4

The fourth deep well is located at Agricultural Science and Technology School (San Juan) and was operating since 1980's. It has an electric submersible pump. It's well size is 8 inches in diameter, suction pipe is 3 inches in diameter, well depth is 300 feet, pump rating power is 15 h.p., delivery rates is 100 g.p.m., pump setting is 140 feet, tank capacity is 10,182 gal per 40 cu.m. (10,182 gal/40 cu.m.), and its tank height is about 40 feet. It has a PVC water pipeline (due to the construction of Hydrophonics) and GI pipeline installed in it. It distributes its water to the residence of Crop Science Avenue and Supt. Maceda Avenue.

e. Deep Well 5

The fifth deep well is located at Barrio Sawmill and was operating since 1970's. It has an electric submersible pump. It's well size is 8 inches in diameter, suction pipe is 2 inches in diameter, well depth is 400 feet, pump rating power is 5 h.p., delivery rates is 70 g.p.m., pump setting is 140 feet, tank capacity is 11,435 gal per 45 cu.m. (11,435 gal/45 cu.m.), and its tank height is about 60 feet and has a galvanized iron pipeline installed to it. It distributes its water to the entire area of Sawmill.

f. Deep Well 6

The sixth deep well is located at University Avenue Street in front of Ladies Dorm 5 Main and was operating since 1990's. It is diesel engine driven. It's well size is 10 inches in diameter, suction pipe is 8 inches in diameter, well depth is 450 feet, pump type is turtine, power source is 100 h.p./diesel engine, delivery rates is 100 g.p.m., and its pump setting is 170 feet. It distributes its water to the residence of Marketing, Academic Avenue and University Avenue.

B. Collection and Preparation of Samples

Water samples were collected either in the morning or afternoon to avoid exposure to high temperatures and intense sunlight. Samples were taken after allowing water to flow for five minutes to ensure representative sampling. One liter of water was collected at each sampling site and placed in clean, properly labeled high-density polyethylene (HDPE) containers. The samples were immediately stored at approximately 4°C to maintain their quality during transit to the laboratory. Samples were collected in acid-washed high-density polyethylene (HDPE) bottles, which were pre-rinsed three times with the sample water before final collection. The bottles used for heavy metal analysis were acidified in the field with concentrated nitric acid (HNO_3) to adjust the pH below 2, preventing metal adsorption onto container walls. Samples for metal determination were not filtered, as groundwater is typically free from significant suspended particulate matter. All samples were immediately stored in insulated ice boxes and maintained at approximately 4 °C during transport to the laboratory to preserve integrity.

C. In-situ Measurements and Instrument Calibration

Dissolved oxygen (DO) measurements were conducted in situ using a multiparameter water quality meter equipped with a DO probe. Since the probe was a calibration probe, it was calibrated on a daily basis as specified by the manufacturer using the air-saturation method. Temperature, pH, and total dissolved solids (TDS) were also established using the same instrument at each site immediately after collection in order to reduce the loss caused by exposure.

D. Physicochemical and Heavy Metal Analyses

The determination of total suspended solids (TSS), total hardness, sulfate (SO_4^{2-}), and nitrate (NO_3^-) followed the standard analytical protocols described by Estefan, Sommer, and Ryan (2013). Acid digestion was followed by the analysis of heavy metal concentrations of cadmium (Cd) and lead (Pb) by Microwave Plasma-Atomic Emission Spectroscopy (MP-AES). In the case of digestion, 10 mL of each sample was reacted with 0.5 mL concentrated HCl and 0.2 mL concentrated HNO_3 and heated in a sand bath at 90-100 °C until the volume had decreased to 10 mL. An MP-AES was then applied to the resulting digest.

E. Total Suspended Solids (TSS)

A filter disc was placed in a filter holder connected to a suction flask apparatus, linked to a vacuum source. The filter was then pre-washed using three aliquots 20-mL of deionized water and vacuumed over 2-3 min. This filter and a crucible were left in an oven at a temperature of 105°C, at least one hour and then cooled in a dry desiccator and then weighed on an analytical balance. This drying and weighing process continued until a weight difference between two consecutive weighing was below 0.5 mg. To analyze the sample, the filter was reconstituted in the device and moistened with deionized water. The filter funnel was filled with a 100-mL vigorously stirred preceded by pouring the sample into the funnel. The filter was removed after filtration, dried at 105°C at least 1 hour, cooled, and weighed. This was continued until the difference in weight became less than 0.5 mg and with this, accuracy in the TSS was measurement.

Calculation:

$$\text{Total Suspended Solids TSS (mg/L)} = Wt_{f+c+s} – Wt_{f+c}(1000)/V$$

Where:

Wt_{f+c+s} = Weight of filter and crucible plus solids (mg)
Wt_{f+c} = Weight of filter and crucible before use (mg)
V = Volume of water sample used for measurement (mL)
1000 = Conversion from mL to liter

F. Total Hardness

A 50 mL aliquot of distilled water was accurately measured and transferred into a beaker. To this, 1.179 g of EDTA, 16.9 g of ammonium chloride, and 780 mg of magnesium sulfate were added, ensuring complete dissolution. Thereafter 143 mL of ammonium hydroxide was measured and added to the mixture. The final volume was also raised to 250 mL by adding some distilled water to the beaker contents in a 250 mL standard flask. The 0.5 g of Eriochrome Black T (EBT) was taken and 100 mL of distilled water was put in a volumetric flask and dissolved. Another preparation involved the dissolution of 3.723 g of EDTA sodium salt in 1000 mL of distilled water to make the EDTA titrant. In titration, 20 mL of water was pipetted into a 250 mL conical flask which was sterilized.

In order to keep a pH between 9-10, 2 mL of the ammonia buffer solution was added followed by a few drops of EBT indicator to give a wine-red colour. The burette was washed by adding a few milliliters of EDTA solution followed by the addition of 0.02 M EDTA solution. Titration was done by adding the EDTA solution to the water sample until it turned to blue, which is the indication of the full complexation of the calcium and magnesium ions with EDTA.

Calculation:

$$\text{Total Hardness} = \text{Volume of EDTA}*N*50*1000/\text{Volume of Sample Taken}$$

G. Sulfate

A 50 mL portion of natural water was measured correctly with a 250-mL Erlenmeyer flask by the use of a pipette. Thereafter, 1 mL of HCl with a concentration of 1:1 solution and 2-3 drops of methyl orange indicator were put in the flask. The solution was boiled in a hotplate until it began boiling and 10 mL of 1 N barium chloride dihydrated ($BaCl_2 \cdot 2H_2O$) solution was put in excess amounts to precipitate the sulfate ions into barium sulfate ($BaSO_4$). The mixture was boiled 5-10 minutes and covered with watch glass and left to cool. Ashless filter paper was then used to filter the cooled mixture to get the precipitate of $BaSO_4$ and then it was washed thoroughly with warm deionized water to eliminate any chloride ions that were left behind. This was established by the addition of silver nitrate ($AgNO_3$) solution to show the absence of chloride ions in the filtrate.

The filter paper with the precipitate of BaSO4 was washed, and then transferred to a dried porcelain crucible (Wt_1). which was pre-weighed. The crucible was heated up in an oven at 105°C in one hour and then subjected to muffle furnace at 550°C in 2-3 hours to dry up ash. After the drying process was done the crucible was taken out of the furnace and allowed to cool inside a desiccator. At last, an analytical balance was used to weigh the crucible and the weight (Wt_2) was recorded.

Calculation:

$$SO_4 - S\ (meq/L) = (Wt_2 - Wt_1)(1000)/V*0.1165$$

Where:
Wt_2 = Weight of crucible + $BaSO_4$ precipitate (g)
Wt_2 = Weight of empty crucible (g)
Note: 0.1165g $BaSO_4$ equal to 1 milli-equivalent of SO_4

H. Nitrate

Potassium nitrate (KNO_3) was dried in an oven at 105°C for 24 hours. A stock solution was prepared by dissolving 0.7218 g of the dried compound and diluting it to a final volume of 1000 mL, yielding a concentration where 1 mL corresponds to 100 μg of NO_3^-–N. A 100 mL aliquot of this stock solution was further diluted further to 1000 mL using distilled water to produce a final concentration of 10 mg of NO_3^-–N per mL. To maintain such solutions, 2 mL of chloroform ($CHCl_3$) was put in per liter. These ready-to-wear solutions last as long as half a year. To analyze it, 1 mL of a hydrochloric acid solution was poured in a 50 mL clear water sample and stirred a mixture. The nitrate ions (NO_3^-) calibration standards were prepared within the concentration range of 0 to 7mg through the dilution of the respective volumes (0, 1, 2, 4, 7 ... 35 mL) of the intermediate nitrate solution to 50 mL. These samples were handled in the same way as the samples.

Measurement of abscondance was carried out with redistilled water as the blank (abscondance= 0). The wavelength of 220 nm was employed to determine the possible interference by dissolved organic matter. In both samples and standards the absorbance at 275 nm (indicative of organic matter) was subtracted twice (to isolate the nitrate-related absorbance) then the absorbance at 220 nm was used. The results were plotted to create a standard curve on the basis of the corrected absorbance values versus the NO_3^-–N concentrations of the standards. The corrected absorbance readings of the samples were then used to determine their nitrate concentrations directly from the standard curve.

I. Heavy Metals

Microwave Plasma Atomic Emission Spectroscopy (MP-AES) was employed for the quantification of heavy metals. Metal analysis of the samples was done by acid digestion using the following methodology: 10 mL aliquots of the samples in 16 x 125 mm polypropylene tubes were acid digested by adding 0.5 mL of concentrated hydrochloric acid and 0.2 mL of concentrated nitric acid, and the mixture was digested at 90 to 100 °C in a sand bath using a hotplate till the resultant volume of the digestion reached 10 mL. Metals that were studied in this paper are cadmium and lead. The obtained results of MP-AES were compared to the allowable range of the World Health Organization (2017).

J. Statistical Analysis

A Completely random Design (CRD) was utilized. Each analysis was conducted thrice and data presented in mean values. One-way Analysis of variance (ANOVA) was used to determine whether there are significant differences among wells, and Duncan Multiple range test (DMRT) was used at 5% level of significance ($p < 0.05$). The Statistical Tool of Agricultural Research (STAR) software was used to undertake statistical processing.

III. RESULTS AND DISCUSSIONS

This study investigates 10 parameters concerning the quality of the water distribution system of Central Luzon State University. The average concentrations were compared with the existing permissible level set by the world health organization for drinking water. The characteristics of the water samples collected from six different deep wells are presented in Table 1.

Table 1. Average concentration of the groundwater samples from different deep wells in CLSU

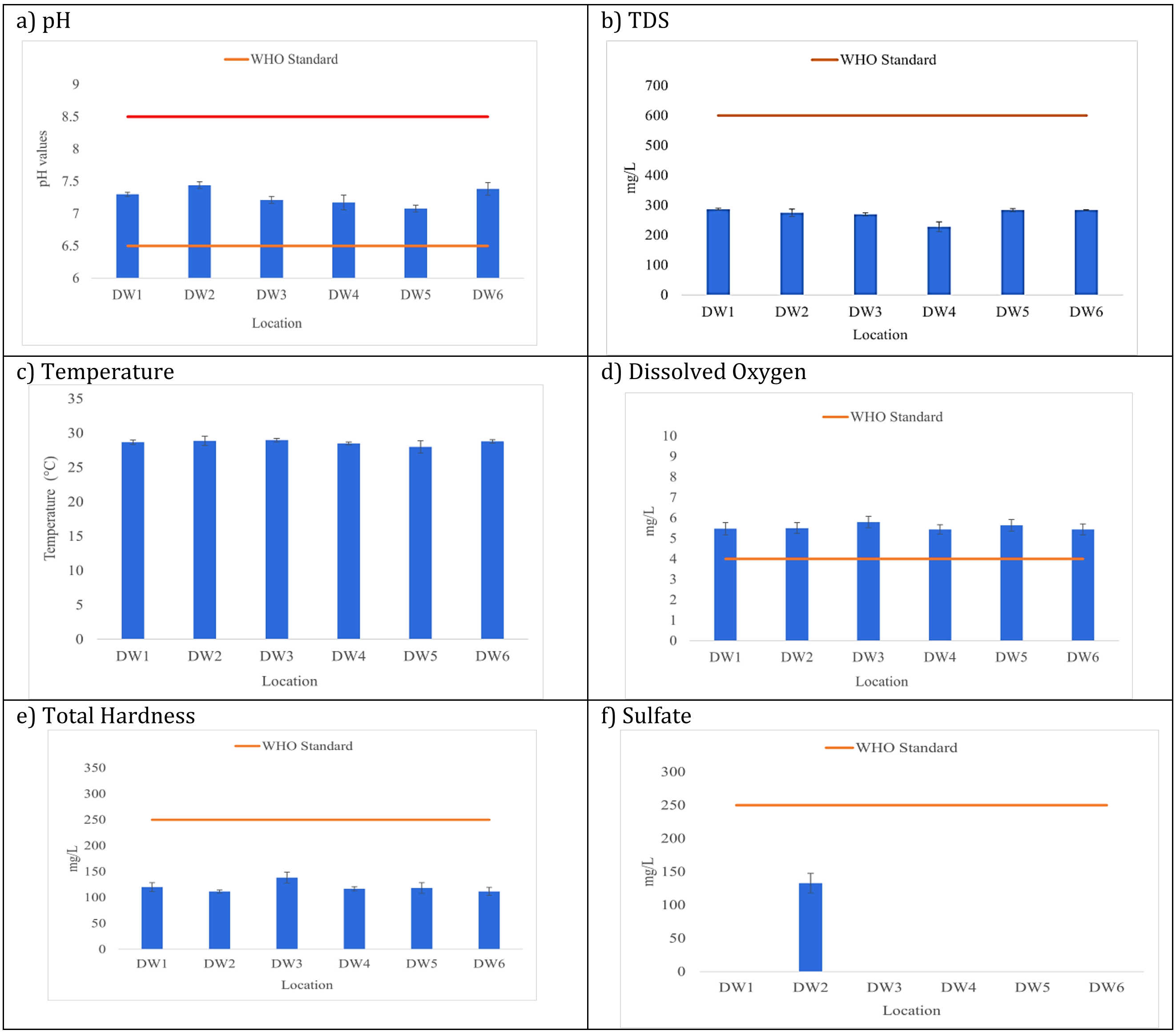
Parameter	WHO Standard	Deep Well					
		1	2	3	4	5	6
pH	6.5-8.5	7.30±0.03^{bc}	7.44±0.05^{a}	7.21±0.05^{c}	7.17±0.12^{cd}	7.08±0.05^{d}	7.38±0.10^{ab}
TDS	<600ppm	286±2.64^{a}	274±12.4^{a}	269±4.89^{a}	227±16.3^{b}	283±4.90^{a}	283±1.90^{a}
Temperature	---	28.7±0.32^{a}	28.8±0.66^{a}	28.9±0.25^{a}	28.5±0.21^{a}	28.0±0.90^{a}	28.8±0.25^{a}
DO	>4 ppm	5.47±0.23^{a}	5.50±0.26^{a}	5.80±0.30^{a}	5.43±0.12^{a}	5.63±0.25^{a}	5.43±0.15^{a}
Hardness	250 ppm	120±8.66^{b}	111±2.89^{b}	138±10.4^{a}	116±4.16^{b}	118±10.4^{b}	111±7.64^{b}
SO_4	250 ppm	0.00±0.00^{b}	132±14.6^{a}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}
Pb	0.01 ppm	0.102±0.0^{a}	0.098±0.0^{a}	0.098±0.0^{a}	0.097±0.0^{a}	0.098±0.0^{a}	0.103±0.0^{a}
Cd	0.003ppm	0.011±0.0^{a}	0.012±0.0^{a}	0.012±0.0^{a}	0.011±0.0^{a}	0.011±0.0^{a}	0.010±0.0^{a}
TSS	500 ppm	6.33±4.9^{d}	36.67±3.5^{b}	24.00±4.6^{c}	25.00±3.0^{c}	35.00±3.0^{b}	44.67±5.0^{a}
NO_3	50 ppm	0.37±0.02^{c}	2.89±1.2^{ab}	0.70±0.25^{c}	1.87±0.62^{b}	3.19±0.48^{a}	1.91±0.34^{b}

In each column, means with the same letter superscript are not significantly different from each other at 95% level of significance using Duncan's multiple range test (DMRT).

The water samples under analysis had a slightly alkaline pH, and the pH of 7.08-7.44. The presence of hydrogen carbonate (HCO_3^-), carbonate (CO_3^{2-}) ions (Ayele, 2015), agricultural soil amendments such as lime [$Ca(OH)_2$], superphosphate [$Ca(H_2PO_4)_2$ and $CaSO_4$], and soaps and detergents are associated with this detergents (Estefan et al., 2013). The Multiple Range Test (DMRT) carried out by Duncan showed that the difference in pH in deep wells 2 and 6 was statistically significant as compared to the other wells. The slight alkalinity has been probably caused by the rainwater penetration in the soil matrix which introduces HCO_3^- ion into ground water aquifer (Singh et al., 2015). World Health Organization (WHO) suggests that potable water should have a pH of 6.5-8.5. The pH parameters of the water samples examined are within these ranges, which means that the water is of good quality in accordance with the majority of drains in the world (Oyem & Ezeweali, 2014). The samples of the ground water contained 227 to 286 ppm total dissolved solids (TDS). It was shown in the DMRT analysis that there was statistically significant difference in TDS in deep well 4 and the other wells with a 95% significance level. Such low TDS indicates that there is less solute dissolution, a quick ion exchange between soil and water, or low soluble geologic materials (Oyem & Ezeweali, 2014). The WHO sets the limit of 600mg per Liter of TDS as acceptable drinking water, and also deems a TDS of over 1,000 mg/L of water unpleasant to consume. The average TDS concentrations were considerably below the allowable levels. Such values are inherent to the hilly recharge areas and reveal freshwater that can be used in consumption and irrigation as they do not have a negative impact on the osmotic pressure of the soil solutions (Oyem & Ezeweali, 2014).

Temperature measurements ranged from 28.0 to 28.9°C, with no statistically significant differences observed among the wells (DMRT). The slight increase in temperature in the dry season can be explained by the presence of solar energy, different depths of boreholes (300-600 feet), the effect of topography, and the status of microorganisms (Ngang and Agbazue, 2016). Although the WHO does not set a particular guideline on the temperature, the average of 28.6°C is regarded as ambient and acceptable to consumers who like colder water (Oyem & Ezeweali, 2014). The rate of dissolved oxygen (DO) was between 5.43 and 5.80 mg/L, without any major differences of the wells (DMRT). DO is mainly produced by atmospheric interactions in groundwater (Rose and Long, 2012), but the average in aquifers and thermal springs is 2-8mg/L (Winograd and Robertson, 2013). The WHO indicates that drinking water should have a DO level exceeding 4 mg/L, and all of the obtained results did not go beyond the permissible range. Total hardness, was a result of cations like calcium and magnesium and was between 111 and 138 mg/L, which means that the water is moderately hard. There was a statistically significant difference in deep well 3 as indicated by DMRT. Limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$), are the usual sources of hardness which dissolve calcium and magnesium into the water (Sengupta, 2013). WHO indicates a taste threshold of hardness at around 250mg /L and all the results were well within the range. The levels of sulfate were usually low, though the concentration of this element was significant in deep well 2 132mg/L. This can be attributed to the dissolution of the soil minerals or agricultural and atmospheric sources (Li et al., 2008; Bashir, 2012). The sulfate level was lower than the WHO taste threshold of 250mg/L.

The level of lead was between 0.097 and 0.103 mg/L, which is higher than the WHO recommendation of 0.01 mg/L, indicating that lead contamination could be as a result of old galvanized steel pipes, which have small traces of lead, zinc, and other heavy metals (Clark et al., 2015). These pipes can be corroded and lead to lead in the water distribution system that is dangerous to human health as it can cause renal and endocrine dysfunction, cognitive impairment, and developmental problems (Assi et al., 2016; Eteng et al., 2015). Cadmium was between 0.010 and 0.012 mg/L and was also over the WHO guideline of 0.003mg/L. Cadmium contamination may be due to corrosion of galvanized pipes and impurities of trace elements in zinc finishes (Pieper et al., 2017). The pH range of 7.0-7.55 also ensures slight dissolution of cadmium, which leads to high concentration in water supply (Burke et al., 2016). A high concentration of total suspended solids (TSS) in drinkable water caused by silts, decomposing organic material, industrial effluents, and sewage may negatively affect the water quality by raising the temperatures of water and lowering the levels of DO (Bharadwaj et al., 2016).



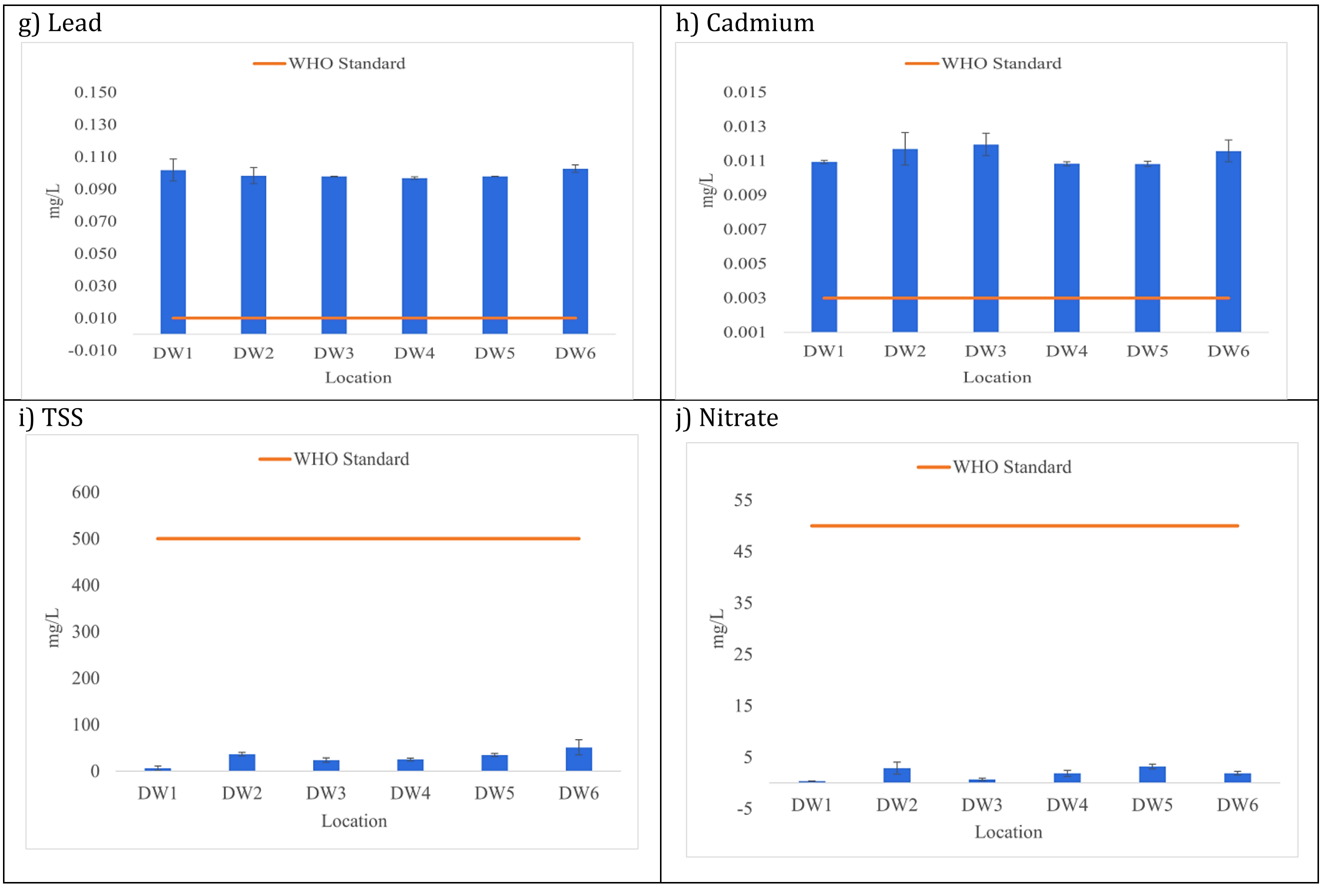


Figure 2. Average concentrations of CLSU groundwater samples in comparison with the WHO permissible level (red line). Data are presented in Mean ± SD

The Duncan Multiple Range Test (DMRT) revealed that there were some statistically significant differences of deep well 1 and deep well 6 at a confidence level of 95. The average TSS level of the water samples in the different deep wells was 6.33 to 44.67mg/L, which is not beyond the acceptable level set by the world health organization (500 mg/L). The nitrates were measured in all the deep wells and the concentrations of the water samples ranged between 0.37 and 3.19 mg/L. The DMRT analysis showed that deep well 1 and deep well 3 significantly differed at 95% level of significance. It is also known that fertilizers represent one of the main contributory factors in agricultural settings; however, the role of nitrogen in anthropogenic waste seems to be a crucial source in the urban setting with the poor centralized water and sanitation infrastructure (Khademikia et al., 2013). Soils Nitrates are naturally present in the ground water in aerobic environments, which is normally several milligrams per liter and is greatly affected by the soil composition and geological setting, with the lowest nitrates occurring in deep groundwater, where the aquifer is compacted or where the water is aged, hence indicating historically low rates of nitrogen use (Burow, Nolan, Rupert, and Dubrovsky, 2010). The value of health based guideline is 50 mg/L as per the world health organization and it was observed that all the water samples of the deep wells fell within this allowable limit. This observation implies that the deep wells at Central Luzon State University (CLSU) are constructed in a manner that is effective, and the use of chemical fertilizers in the surrounding agricultural zones is being adequately regulated.

IV. CONCLUSION

This research investigated the physicochemical characteristics of groundwater at Central Luzon State University (CLSU). The analysis showed that the concentrations of pH, total dissolved solids (TDS), dissolved oxygen (DO), total hardness, sulfate, total suspended solids (TSS), and nitrate met the acceptable levels as required by the World Health Organization (WHO). Although there is no certain standard of temperature, observed values were characteristic of suitability of drinking water. Nonetheless, all deep wells contained high levels of cadmium and lead, which was attributed to corrosion and rusting of the pipes as well as leakages of iron toxic metals through galvanized iron. Such results make the groundwater inappropriate to drink and use at home. The findings of this research can be helpful to understand the quality of groundwater at CLSU and make professionals create proper water purification and treatment measures.

Recommendations

1. **Implementation of Water Treatment Systems**. Considering the high levels of lead (Pb) and cadmium (Cd) in the groundwater, water treatment facilities are advised to be installed in the groundwater to eliminate the heavy metals prior to using the water to consume or perform household duties. Activated carbon filtration, reverse osmosis, or ion exchange are some of the technologies that would not fail in lowering the presence of the said toxic metals and the water qualifies under the safety standards of the World Health Organization (WHO).
2. **Regular Monitoring of Water Quality**. In order to guarantee the long-term safety of the water supply, it should be monitored continuously to ensure the quality of groundwater. Parameters, that should be regularly measured, are the pH, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), and levels of heavy metals (including lead and cadmium). This will enable quick identification of any possible contaminants or alterations in the quality of water that will be promptly addressed.
3. **Upgrading of Water Distribution Infrastructure**. Corrosion of galvanized iron pipes that is a probable cause of lead and cadmium contaminations should be handled by substituting the aged pipes with pipes that resist corrosion. Also, the installation of lead-free pipes and fittings will serve the purpose of reducing future risks of additional contamination of the water supply with heavy metals.
4. **Public Awareness Campaigns on Water Safety**. It is important to educate the CLSU community about the possible health risks of the contaminated water and in this regard, the risks of lead and cadmium exposure. There must be the introduction of public awareness programs that would educate students, faculty, and other staff members on safe water practices, the need to purify water, and the symptoms of heavy metal poisoning.
5. **Exploring Alternative Water Sources**. Where groundwater is still showing signs of contamination to unacceptable levels, there should be other water sources that should be considered. This may include creation of rainwater harvesting systems or sourcing of water in the municipal supplies of high quality water requirements.
6. **Adherence to WHO Guidelines**. Every subsequent water quality analysis must also be done with the consideration of the drinking water quality guidelines as given by WHO. By harmonizing local water management activities to the international standards, CLSU will be in a position to assure that the groundwater is not contaminated to be harmful to human health and also address the global health and safety expectations.

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