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The pH of Drinking Water and Its Human Health Implications: A Case of Surrounding Communities in the Dormaa Central Municipality of Ghana

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Abstract:** Of all the things to consider about safe water, the pH of drinking water probably has been overlooked. Most spoken about, however, is alkaline water which has a host of supposed health benefits? For instance, it is known to help the body to clear toxins thereby improving metabolism. Meanwhile, research has shown that most diseases, illnesses, and bad bacteria thrive in an over-acidic environment. Additionally, the acidic water indirectly may impact on budget as this would contribute to the metallic or sour taste of drinking water, and stained laundry and provide blue-green staining of sinks and other household fixtures. Acidic water having low pH often are known to contain high amounts of heavy metals. Also, research has found that solutions with low pH are more likely to have heavy metals from the environment. Other researchers have identified that acidic water can be high in Pb, As, Cu, Ni, Cb, Cr, and Zn. All these elements fall under heavy metals and exposure to them can be dangerous, and could lead to heavy metal poisoning and toxicity. This is concerning as water is said to be life and the population within Dormaa Central Municipality is most likely to have symptoms such as diarrhoea, nausea and vomiting, abnormal pains, weakness, shortness of breath, suppression of the immune system, organ damage, and enamel wear-out leading to dental cavities. Water samples and their corresponding spatial locations were collected from (how many?) communities within the Dormaa Central Municipality. The potential for hydrogen (pH) readings of the respective water samples was measured using a pH meter. The results obtained range from 0.2 mmHg to 6.5 mmHg.

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Keywords: Acidic Environment, Potential For Hydrogen (Ph), Drinking Water, Heavy Metal Poisoning, Health Effects.

1. INTRODUCTION

Water with a very low or high pH can be a sign of chemical or heavy metal pollution. Safe drinking water must fall within a certain pH range. This pH range is 6.5 to 8.5 and is found to be safe to drink because it is neither acidic nor alkaline enough to be dangerous to the human body [19]. Water with a pH of less than 6 can be corrosive and filled with toxic metals. However, water that doesn't fall in 6.5 to 8.5 particularly if it's alkaline, is not necessarily unsafe but will be unsafe if it is < 6.5. Meanwhile drinking alkaline water may lead to digestion problems. Alkaline water can seriously disrupt nutrient absorption, leading to indigestion and malnutrition [15]. People over 60 years of age are at the highest risk and should not drink alkaline water [4]. Doctors refer to digestion problems resulting from the over-consumption of alkaline water as a milk-alkali syndrome [1]. Likewise, drinking acidic water is not recommended, as it may lead to heavy metal poisoning and toxicity with repeated exposure. Heavy metals can include iron, copper, manganese, and zinc [10]. The human mouth is already filled with many natural acids that break down food and bacteria. Trying to clean it with more acid via acidic water will only have a counterproductive effect [3]. Particularly, among children, elevated levels of metal contaminants found in acidic water can cause plenty of health issues that could prove fatal or debilitating [20]. Vomiting, diarrhoea, kidney disease, liver disease, stomach cramps, and nausea are among the leading health issues caused by the consumption of acidic water [16]. Drinking acidic water also leads to low calcium retention which results in more rapid bone loss over long periods of time. It further causes gastrointestinal sicknesses. The leaching of metals from acidic water leads to gastrointestinal upset [7].

There are benefits and banes in drinking clean water and it is an important commodity in the lives of humans and other living creatures. We need water in our day-to-day lives for growth and to stay healthy [6]. According to Lorenzo [14], the human body is about 60% water, the brain is about 75% water, the muscles are about 75% water, the human blood is approximately 82% water and the bones are approximately 25% water. Drinking water for human consumption generally must not be clean only but it should be safe as indicated in sustainable Development goal number 6 (SDG 6) [8]. In Ghana and most developing countries, all transparent water free from suspended impurities is considered potable and serves as drinking water [12]. However, there are other characteristics that make clean water safe for human development. Though, the eight (8) key important characteristics of good quality water not conspicuous to the consumers of water are temperature, clarity, conductivity, pH, chlorine, hardness, and dissolved oxygen [18]. This article is picking on the pH of drinking water in twenty-two (22) communities in Dormaa Central Municipality. This feature that determines the acidity and alkalinity of water has health benefits and banes to humans. It is unclear if this important parameter pH of the boreholes drilled in and around the municipality was measured. This article, therefore, seeks to measure the pH levels of water of all boreholes drilled in the study area to ascertain those that fall within and outside the safe levels. It also intends to

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highlight the possible health effects of the pH of drinking water within the Dormaa Municipality so that the necessary possible public Health interventions could be introduced.

Case Study Area

Location, Geomorphology, Climate, and Geology

The study area is located at Dormaa Central Municipal Assembly, whose Capital Dormaa Ahenkro is approximately 206 km northwest of Sunyani to Kumasi (Fig. 1). The research was carried out in rural communities surrounding Dormaa Ahenkro the district capital (Fig. 1). The landscapes of the study areas consist of undulating terrains with low hills and isolated hills separated by relatively wide and narrow valleys. The terrain is fairly flat with broad hills and gentle slopes with elevations ranging from 270 to 360 meters above mean sea level. The climate of the area is tropical with distinct wet and dry seasons. Dry seasons are from late November to February and briefly in August. Two maxima rainfall occurs in a year and these are March to July and September and early November. Annual rainfall ranges from 700mm to 2,100 mm. Vegetation is rainforest-type with several canopies of trees and undergrowth. However, the indiscriminate logging of the upper and middle layers of trees and farming had led to the primary forest turning into a secondary forest and shrubs. Rocks of the Sunyani sedimentary basin characterize the area and are bounded to the southeast by the Paleoproterozoic Sefwi gold Belt and to the northwest by the Bui Belt [22]. The underlying geology is made up of thick sediments of north-east trending Birimian metasedimentary rocks intruded at places by biotite-rich - granites [11, 13, 5] comprising argillites, and wacke - facies. There are also occurrences of minor chert and few volcanoclasitic rock units [9]. These rocks may contain some heavy minerals that may leach into the water bodies to influence the pH levels.

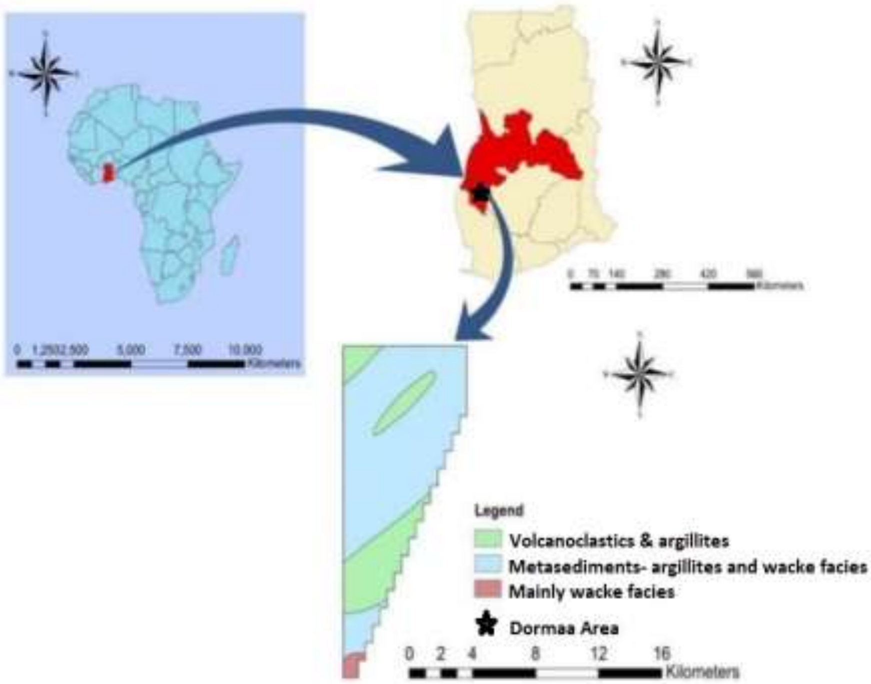

Fig. 1 Location and Geology of the Study Area [2].

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2. MATERIALS AND METHODS

There are two types of water sampling strategies. These are grab samples and composite samples. The Grab sample is a single sample collected in an individual container at a time frame contrary to Composite samples which consist of smaller samples collected at a predetermined time or predetermined flow and mixed in a container [17]. Grab sampling is the method used in this study and the samples collected were representative of the chemistry only at the time and place at which the sample was taken. The flow rate was challenging to control but the time period was possible and the water collection time was fixed generally between 10 to 15 minutes. A total of 90 borehole water fitted with pumps was sampled in thirty-two (32) in the study area. This exercise was carried out in the morning with the objective to obtain temperatures not above room temperature of 27ºC. During the sampling, hand gloves were worn while the sample water bottles were rinsed three times with the water from the borehole to sample with a cap on. The rinsed water bottles were filled to within one to two inches from the top. The filled bottles were then screwed tightly to prevent leakage. Precautionary measures were taken into consideration during the sample collection, preservation, and transport to prevent cross-contamination. The water samples were then transported to an in-house laboratory at the University of Energy and Natural Resources at Dormaa for pH level measurements. In measuring the pH of the sampled water, deionizing water was used to rinse a glass beaker meant for the measurement. The sampled water was then poured into the rinsed glass beakers. The electrodes for pH and temperature measurements connected to the digital pH meter were inserted into the sample and stirred gently. The pH readings were then recorded alongside the temperature readings for the study.

3. RESULTS

Water with a pH level between 6 and 8.5 is safe to drink according to the World Health Organization and Ghana Standards Authority (http://www.fdaghana.gov.gh). The reason for setting this range as a safe pH level is that such water is neither acidic nor alkaline enough to be dangerous to the human body. They further indicated water with a pH of less than 6 can be corrosive and may be filled with toxic metals that leach trace elements which are known as potentially harmful elements from the environment. The environment could be the surrounding rocks and/or metals used in developing the boreholes. The results of the 88 water samples whose pH levels were measured are shown in, Table 1 and Fig. 2.

Table 1 Summary statistics of pH levels from boreholes in Dormaa Traditional Area

No of Boreholes (N)	Minimum (pH) level	Maximum(pH) level	Mean (pH) value	Standard Deviation (pH)
90	2.03	7.15	4.63	1.08

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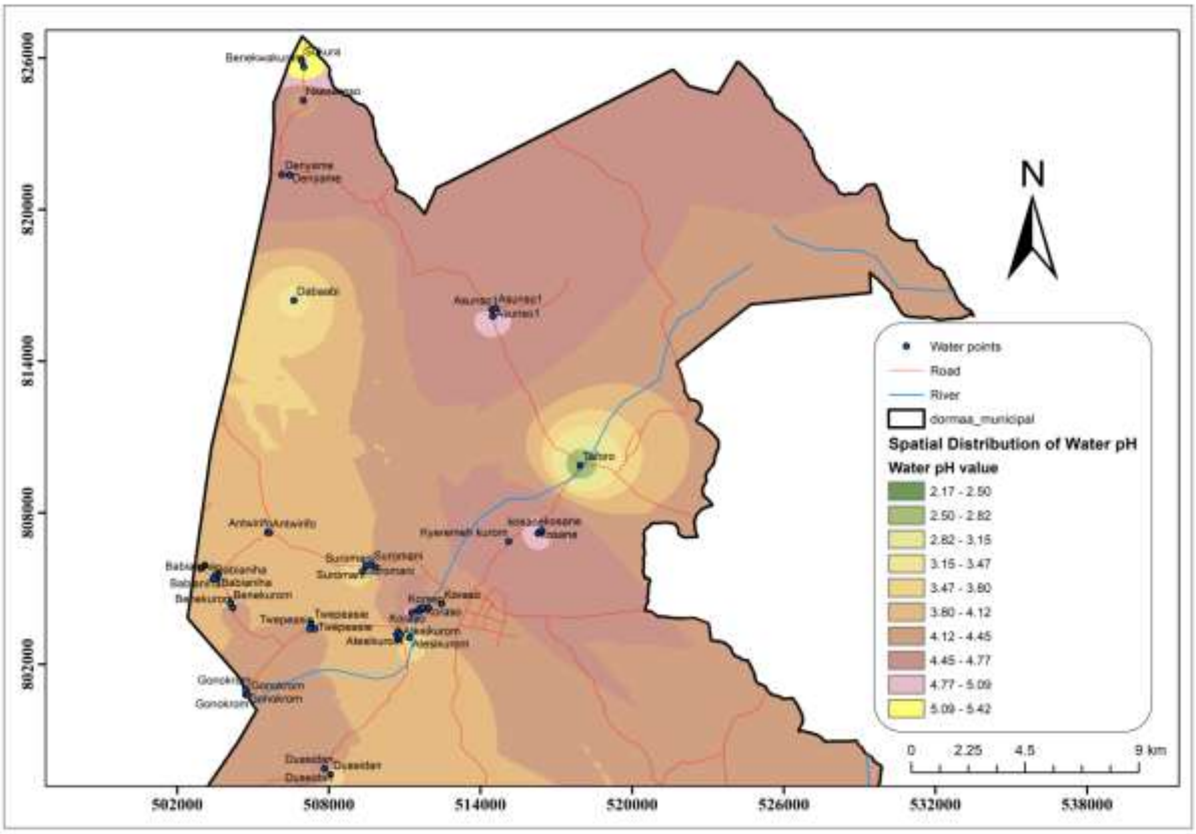

Fig. 2 Spatial distribution of water points sampled and the nearby communities

Also, the geo-spatial distribution of the water points and the corresponding pH levels showing limits of safe and unsafe limits obtained in communities with respect to time of sampling and in space is shown in Fig. 3 and Fig. 4

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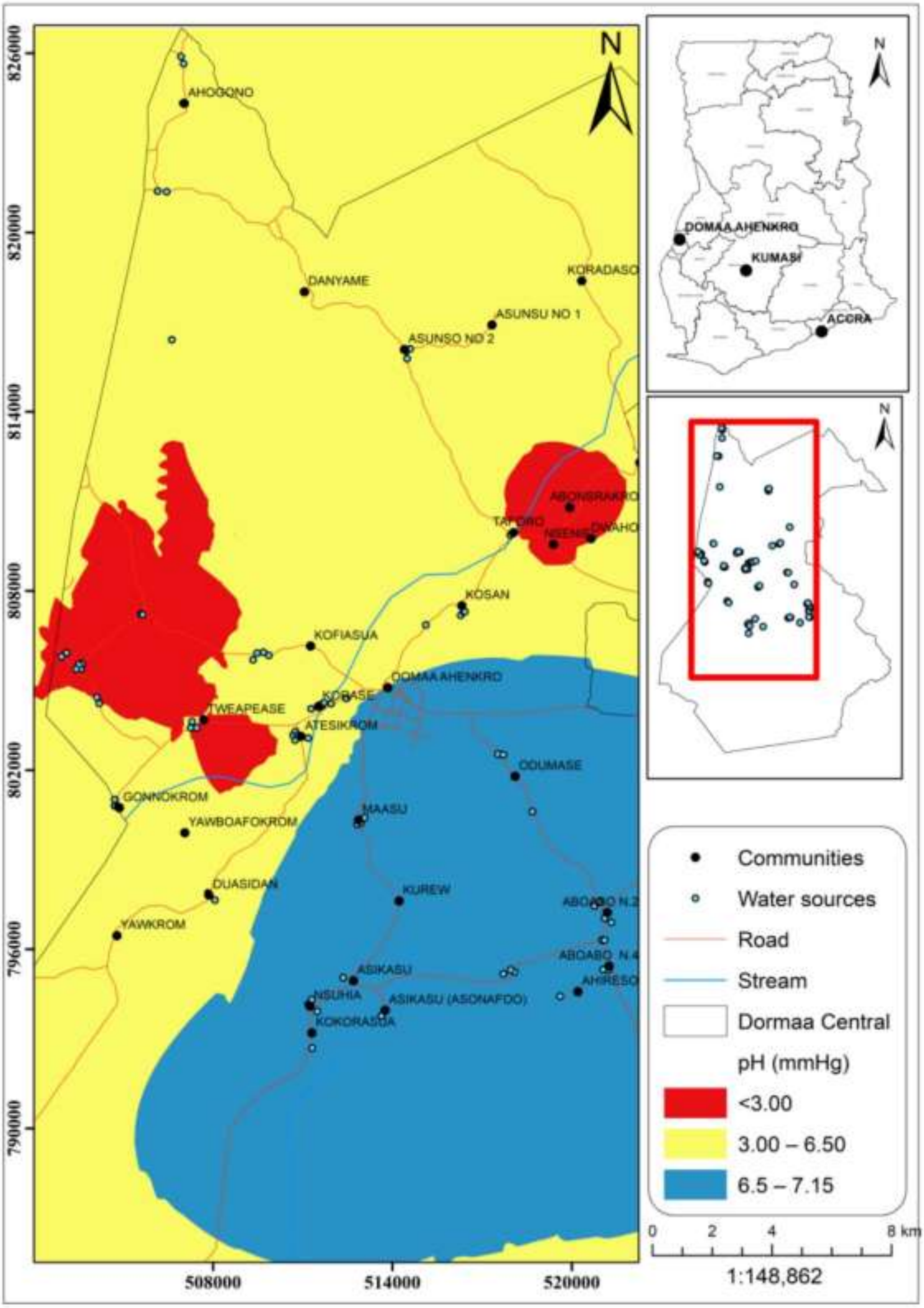

Fig. 3 The geo-spatial distributions and concentrations of pH levels in the study area

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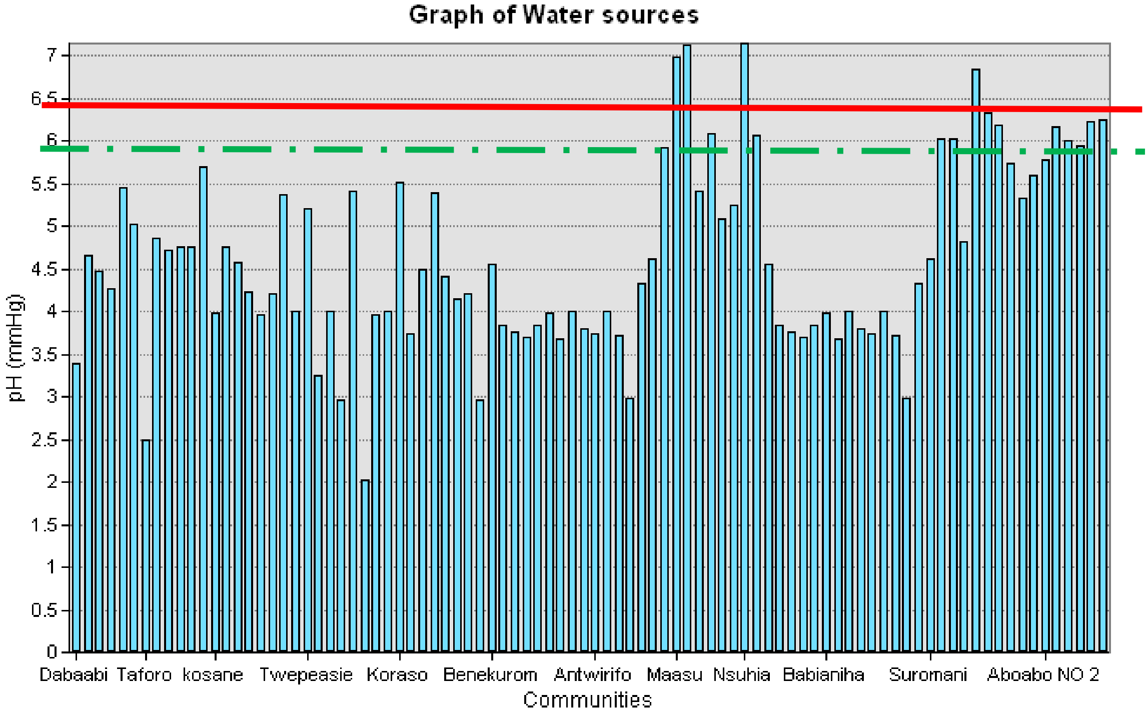

Fig. 4 pH levels measurement of drinking water in boreholes at Dormaa Central Municipality

Table 2 and **Figs**. (**5 and 6**) represent the number of boreholes and the corresponding pH ranges and descriptions of the potential implications on human health.

Table 2 pH range, pH condition, and Health Status descriptions

pH Range	No of Boreholes	Percentages	pH levels	pH Condition	Health Status
2.03 -2.98	6	**6.82**	<3	Very Acidic	Dangerous
3.25 - 3.99	24	**27.27**	<4	Acidic	Unsafe
4.00 - 4.87	27	**30.68**	<5	Acidic	Unsafe
5.03 - 5.94	17	**19.32**	<6	Acidic	Unsafe
6.00 - 6.98	12	**13.64**	<7	Weakly Acidic	Safe
7.13 - 7.15	2	**2.27**	>7	Near neutral	Very Safe

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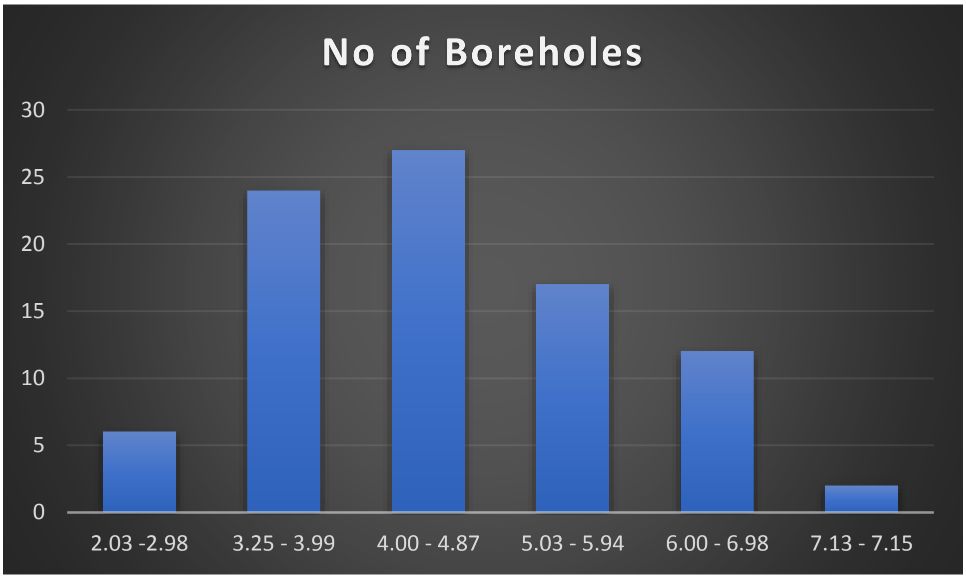

Fig. 5 pH ranges and number of boreholes falling in that pH range levels

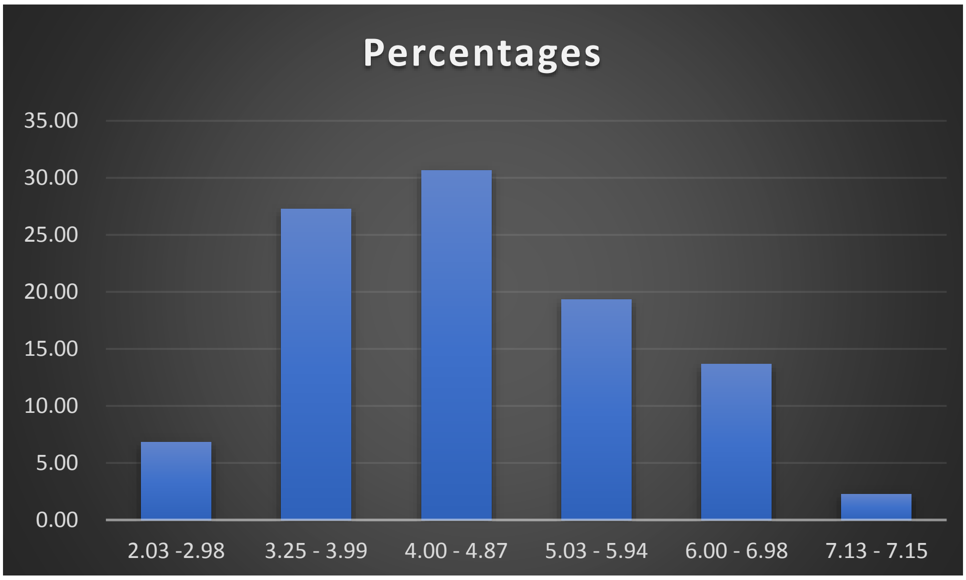

Fig. 6 pH ranges and the corresponding percentages falling in that pH range levels

4. DISCUSSIONS

From UN Sustainable Development Goal 6 (SDG 6); drinking water must be clean. However, clean water necessarily might not be safe drinking water in light of new scientific information (as has been observed by science). To safely drink clean water without human health issues, the quality of the water must be assessed on the basis of water quality assessment properties. These are classed into physical (pH, EC, and Turbidity), chemical (fluoride, nitrate/nitrite, arsenic, heavy metals), and bacteriological (E-coli, etc.) properties. However, from Ban-ki Moon, the former UN Secretary-General’s statement, all people must have the right to safe

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drinking water. Lack of safe drinking water is considered a human rights abuse as it may impact the health of the population in the affected communities. From Table 1, the minimum and maximum pH levels measured from borehole water used as drinking water in the study area were 2.02 mmHg and 7,15 mmHg respectively. The pH measurements revealed a low standard deviation of 1.08 mmHg meaning the pH level data are clustered around the mean (4.63 mmHg). This, by implication generally suggests most people of Dormaa Central Municipality drink acidic water. This generally may come with several health issues that require some attention. Dormaa Central Municipality has seventeen (17) health institutions with only one hospital. From the 2021 population census, the population of the study area was 112,702 and the land space hosting the populace is 1,229 km^2 translating to 91.73 people/km^2. Therefore, appraising it literally means that 6630 people will be using a health institution ranging from a CHP compound to a clinic and only one hospital. The numbers suggest great pressures will be exerted on these seventeen health institutions of which only one can be considered as a standard hospital based on Ghana Health Services. Conversely, quoting a pre-Socratic Greek philosopher Thales (Miletus, 624 – 546 BC), a sound mind dwells in a sound body, making the achievement of the vision of the municipal assembly and SDGs 1 and 3 a mileage. The first part of the municipality vision is "to improve upon the living standards and quality of life of its people" and SDGs 1 and 3 are to eliminate poverty whilst SDG 1 calls for an end to poverty in all its manifestations by 2030. SDG 3 also seeks to provide good health and well-being but in Ghana, the intent is to reduce by one-third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being by 2030. In providing good quality of life for people in the municipality and attaining the UN global sustainable goal of good health and well-being the pH levels of drinking water has to be safe and should measure between 6.5 - 8.5 mmHg. The relative distributions of safe drinking water as seen in Fig. 3, occur in the south-eastern portion of the municipality. The communities falling within the safe pH drinking water zone include Dormaa Ahenkro, the municipal capital, and ten (10) other communities. All other areas appear to fall within the unsafe pH levels with two geographic areas falling in low pH < 3 mmHg. These areas geospatially are located at the northwest of Tweapease and four other communities on the eastern side Taforo, Dwaho, Abonsrakro, and Nsenie.

The concerns based on the pH levels of the authors are that iron, manganese, arsenic, copper, lead, and zinc are commonly found in acidic water. Zhang et al., (2018) have identified the effect of pH on heavy metal release from polluted surrounded sediments. This, thus suggests that boreholes drilled in a Birimian terrain and known to be rich in gold may have sulphide mineral associations as seen in Birimian terrains where productive gold mining is active. It is therefore likely that sulphide minerals and other trace elements in the manganiferous sediments will leach the heavy metals and some potentially harmful elements in the environment into the ground-waters developed into boreholes for drinking water. However, from Fig.1, the geology of the area forms part of the Birimian terrain in Ghana that has been reported to contain minerals such as arsenopyrite, chalcopyrite, galena, spharirite [11, 5, 9] and are a host of the potentially harmful elements arsenic (As), copper (Cu), lead (Pb) and zinc (Zn). The presence of these heavy metals and PHE's ability to be leached from the surrounding rocks by virtue of the low pH of the drinking water can indirectly affect the health of people. Nonetheless, the severity of the health impacts may depend on several factors including the degree of exposure,

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concentrations of chemicals, dose, and extent of exposure. For example, high levels of lead (Pb) in drinking water are of great concern as it places adults at risk for health problems such as cancer, stroke, kidney disease, memory problems, and high blood pressure. Children are likewise not spared because their rapidly growing bodies absorb the contaminant more quickly. Other elements that are leached from the environment into the clean drinking water due to the low pH comprise nickel (Ni), chromium (Cr), cadmium (Cd), nitrate (NO3), and manganese (Mn) and these elements are also classified as secondary drinking water contaminants. These contaminants are likely to cause hard water and staining problems at home. As displayed in Fig. 3, the areas shown in red and cover a land space of 5331.06 ha (53.31sqkm) have lower pH < 3 mmHg.
These areas are more likely to leach metalloids and heavy metals like As, Cu, Pb, and Zn from the surrounding rocks and soils. Health issues such as abdominal pains, chills, weakness, shortness of breath, suppression of the immune system, and organ damage may be common in areas with low pH in drinking water. However, it is worth noting that the severity of these health conditions depends on several factors consisting including age, sex, individual susceptibility, and the route, dose, and frequency of exposure. Children in these areas who rely on the low pH drinking water are at great risk as it has been reported that children who drink low-pH water have more severe side effects from heavy metal exposure including an increased risk of developmental delays, respiratory issues, behavioral disorders, certain types of cancers and heart diseases [21]. Other health threats that the low pH levels < 6 mmHg of drinking water could cause and may become public health concerns are nausea, vomiting, diarrhoea, stomach cramps, kidney disease, liver disease, and nervous system problems.
Meanwhile, the analysis of safe and unsafe drinking water based on pH level measurements from the 88-borehole water sampled (Figs. 5 and 6) showed only 16% of the total boreholes sampled are safe to drink whilst 84% are unsafe. The safe boreholes are fourteen (14) and the unsafe boreholes are 74. The caution is human body wants to stay at a pH level of 7.4 mmHg or in a tight range of 7.35-7.45 mmHg. If the drinking water is acidic as shown in some communities (Fig. 3-6), then the body pH can be thrown off, which could make the exposed person very sick, damage certain tissues or even result in fatality. The minor alterations from this tight range of human pH can have severe implications. It is for this reason that the safe pH levels of drinking water must stay in the 6.5 - 8.5 mmHg safe pH range.

5. CONCLUSION

In conclusion, this study provided valuable insights into the issue of unsafe drinking water in the Dormaa Central Municipality of Ghana, with a particular emphasis on the pH levels of borehole water used for drinking purposes. The results of the study indicated that a vast majority of the boreholes 84% sampled in the area have unsafe pH levels, which could lead to the leaching of trace elements which are potentially harmful elements and heavy metals from surrounding rocks and soils into the drinking water. The presence of heavy metals and some metalloids in drinking water can have severe implications for human health, particularly for children, who are more vulnerable to heavy metal exposure. The study highlighted the importance of water quality assessment properties, including physical, chemical, and bacteriological parameters, to assess the safety of drinking water. It is crucial to monitor and

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maintain safe pH levels of drinking water within the range of 6.5 - 8.5 mmHg to avoid any adverse health effects. Six communities (Babianiha, Benekurom, Twepiesie, Abonsrakro, Dwaho, and Nsenie) within the municipality were identified to have water sources with a pH of less than 3.0 mmHg, highlighting the need for appropriate measures to address the issue of unsafe drinking water in these areas.
The findings of the study have significant implications for policymakers and public health professionals in the Dormaa Central Municipality and other regions facing similar challenges. The study emphasized the need for implementing appropriate measures to promote access to safe drinking water as a basic human right. Above all, the study highlighted the importance of ensuring access to safe and clean drinking water, which is vital for promoting public health and reducing the burden of indirect health issues accounting for emerging noncommunicable diseases (NCDs). Addressing the issue of unsafe drinking water requires a collaborative effort involving all stakeholders, including the government, universities, civil society organizations, and local communities. The findings of this study should serve as a call to action for all stakeholders to work together toward ensuring access to safe and clean drinking water in communities facing similar challenges.

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