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Evaluation of Chemical Properties in Wells in Ghana (A Case Study in Ho Municipality)

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ABSTRACT: The most important inorganic contaminant is nitrate ion, NO_3^-.Excess nitrate ion in drinking water is a potential health hazard: risk of methemoglobinemia (or "blue-baby" syndrome). Sources of nitrate in groundwater: nitrogen fertilizers, atmospheric deposition, human sewage deposited in septic systems. The results of the study show that the values of parameters of the water samples such as, alkalinity, phosphate and nitrate etc are higher than WHO standards. None of the samples had nil value of nitrates and nitrites. The levels of nitrogen ammonium were less than WHO limits of 1.5 mg/L. All the samples had the phosphate concentration higher than 0.01 mg/L (WHO) Guideline value. The mean values also exceeded the limits. It was recommended that, the focus of any programme designed to deliver safe drinking water should therefore be the effective management and operation of water sources, treatment plants and distribution systems whether piped or manual. This will demand action by water suppliers, environmental protection agencies and health bodies. © JASEM
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Wellhead completion is also important in preventing direct chemical contamination, but often does not provide the same degree of protection. The sub-surface leaching and transport of mobile and persistent chemical contaminants means that land-use controls will be required to limit risks. This is illustrated, for instance, by studies in a small town in Uganda that showed little contamination by microbiological contaminants, but significant increases in nitrate derived from faecal sources (Barrett *et al.*, 2000). Ensuring that chemicals of health concern do not occur at significant concentrations in groundwater implies understanding sources of pollution, aquifer vulnerability and specific attenuation processes as well as recognizing the importance of naturally occurring chemicals of health concern.

It is important to bear in mind that there may be a number of factors that may lead to the contamination of groundwater. There are a range of factors that may compromise quality close to the wellhead. These can be broadly categorised into hazards, pathways and contributing factors (Howard, 2002). These are described further below:

Hazard factors: These are sources of faecal material located so that they represent a risk to the groundwater. An example is a pit latrine overlying an aquifer and close to an abstraction point.

Pathway factors: These are potential routes by which contamination may enter into the water supply. Pathway factors include cracks in the lining of boreholes, improperly sealed apron surrounding the headwall of a dug well or borehole, eroded backfilled area of a protected spring, abandoned dug wells and borrow pits. Pathway risk factors often result from poor operation and maintenance.

Indirect factors: These are factors that represent a lack of a control measure to prevent contamination and therefore increase the likelihood of a hazard or pathway developing, but do not themselves represent either a hazard or a pathway.

Literature *Review*

The risk to health from chemicals is typically lower than that from pathogens. The health effects of most, but not all, chemical hazards arise after prolonged exposure, and tend to be limited to specific geographical areas or particular water source types. Much remains to be understood about the epidemiology of diseases related to chemical hazards in water and the scale of disease burden remains uncertain. However, some data do exist. Craun *et al.* (2004) report that 11 per cent of waterborne outbreaks in the USA between 1971 and 2000 were associated with acute effects following ingestion of a chemical.

Ensuring that chemicals of health concern do not occur at significant concentrations in groundwaters implies understanding sources of pollution, aquifer vulnerability and specific attenuation processes as well as recognizing the importance of naturally occurring chemicals of health concern. In groundwater, however, there are two contaminants in particular that represent particular hazards of concern: fluoride and arsenic.

Fluoride affects bone development and in excess leads to dental or, in extreme form, skeletal fluorosis.

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The latter is a painful debilitating disease that causes physical impairment. However, too little fluoride has also been associated with dental caries and other dental ill-health (WHO, 2004b). Drinking water is the principal route of exposure to fluoride in most settings, although burning of high fluoride coal is a significant route of exposure in parts of China (Gu *et al.*, 1990).

Other chemical contaminants of concern in groundwater may also lead to health problems. These include nitrate, uranium and selenium. Of these, nitrate is of concern as it is associated with an acute health effect called methaemoglobinaemia or infantile cyanosis. The scale of the health burden derived from nitrate remains uncertain although it has been suggested to cause significant health problems in some low-income countries where levels in groundwater reach extremely high values (Melian *et al.*, 1999). Nitrate is also of concern given that it is stable once in groundwater with reasonably high oxygen content, where it will not degrade. Thus it may accumulate to a long-term water resource problem that is expensive and difficult to remediate and whose effect may not be noticed until concentrations become critical.

Methodology

In this research, water samples from the hand-dug wells were collected for six months; three in the dry season and three in the wet season. At each sampling site, water samples were collected from wells, which served as the main source of drinking water for the people.

Analyses were carried out at two different laboratories. Chemical analyses were carried out in Ecological Laboratory which is located at the Department of Geography and Resource Development, University of Ghana.

RESULTS AND DISCUSSION

Dissolved Oxygen (DO): Figure 1 shows graphical illustration of mean dissolved oxygen of the water samples for the various sites. The values for the individual sites for the seasons are presented in Table 1. The amount of oxygen dissolved in water is a good indicator of water quality. Dissolved oxygen content is not only important with respect to the species of aquatic life which can survive in water but also as a measure of its ability to oxidize organic impurities in the water. The mean DO values recorded for the dry season ranged from 2.50 mg/L to 6.97 mg/L. The wet season varied from 2.70 mg/L to 7.60 mg/L. The relatively low dissolved oxygen recorded over the period may be indication of pollution from nearby pit latrine. Microbial decomposition is an oxygen-requiring process. Groundwater is in less contact with atmospheric oxygen and this also explains why DO is relatively low in the wells. The solubility of oxygen in water also depends to a large extent on the water temperature and partial pressure of oxygen in the atmosphere as well as the depth and turbulence of the well water. Solubility of oxygen in water decreases with an increase in temperature.

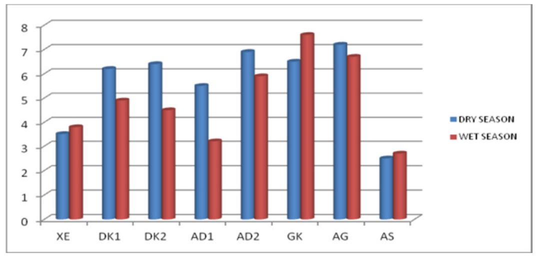


Fig 1: Mean Seasonal Variations in dissolved oxygen

Biochemical Oxygen Demand (BOD): Figure 2 shows graphical illustration of mean biological oxygen demand of the water samples for the various sites. The dry season ranged from a minimum of 2.42 mg/L at DK1 to a maximum of 18.6 mg/L at AS. The wet season varied from a minimum of 2.33 mg/L at DK1 to a maximum of 10.77 mg/L at AS. The values for the individual sites for the seasons are presented in Table 2. The mean variation for the dry season fluctuated between 2.2 at GK & AD1 and 8.8 at AS whilst the wet season fluctuated between 2.1 mg/L at DK1 and 12.3 mg/L at AS. BOD measures the amount of biodegradable organic content in water. Natural waters with BOD values of 4mg/l are considered to be highly polluted with organic matter but safe for drinking (Fianko, 2003)

The dry season ranged from 2.42 mg/L to 18.6 mg/L. The wet season varied from 2.33 mg/L to 10.77 mg/L. High values were recorded in Aflao-Soviefe (AS). This is suggestive of high organic matter contamination in the water sample. Domestic sewage may be the contributing factor to the rise in organic matter of the well water.

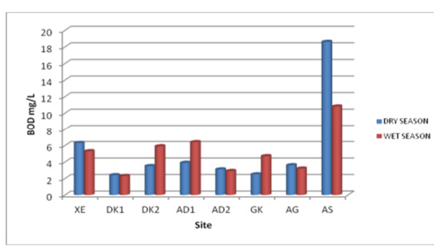


Fig 2: Mean Seasonal Variations biological oxygen demand

Nitrogen- Nitrate (NO_3^- -N): Nitrogen-nitrate level did not show any seasonal variation. Analysis of variance of mean seasonal values indicate no statistically significant difference between the dry and wet seasons (P>0.05). Values obtained for the dry season ranged from 0 mg/L to 11.2 mg/L whilst values obtained for wet season varied from 0 mg/L to 14.8 mg/L. The level of nitrogen- nitrate showed spatial variations with site AS recorded the highest mean seasonal value (Figure 3). Mean values recorded for the entire study period are presented in Table 3. Generally the nitrogen nitrate and nitrogen nitrite levels concentrations in the eight boreholes were found to be low in accordance with WHO (1996) of 10mg/l and 3mg/L respectively. None of the samples had nil value of nitrates and nitrites. Presence of these nutrients in the water samples is an indicator of recent or remote faecal pollution. Nitrate is harmful when it is above this concentration as it causes methemoglobinemia in infants less than six months. Other ailments associated with high nitrate concentration are diarrhea and respiratory diseases (Ward *et al.,* 2005). In an unpolluted river nitrate is usually less than 1.0 mg/l (Meybeck, 1982). The observed high nitrate from this study might have resulted from lawn fertilizer run-off, leaking septic tanks and cesspools, manure from farm livestock, animal wastes and discharges from car exhausts (USEPA, 1986; Knepp and Arkin, 1973). The levels of nitrogen ammonium were less than WHO limits of 1.5 mg/L

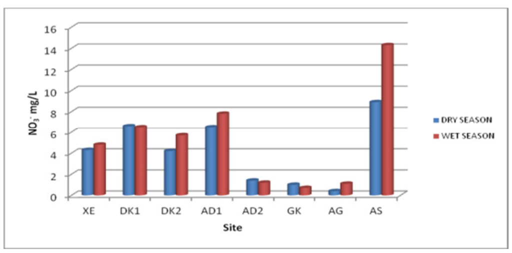


Fig 3 Mean Seasonal Variations in nitrogen nitrate

Nitrogen- Nitrite (NO_2^- -N): Figure 4 shows graphical illustration of mean nitrogen nitrite values of the water samples for the various sites. The dry season ranged from a minimum of 0.002 mg/L to a maximum of 4.288 mg/L. The wet season varied from a minimum of 0.002l to a maximum of 5.220 mg/L.

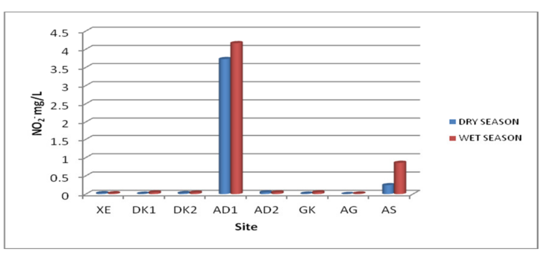


Fig 4: Mean Seasonal Variations in nitrogen nitrite

Nitrogen Ammonia (NH_3 -N): The range of ammonia (in the form of ammonium nitrate) in this study was 0.00-0.59 mg/l. With the exception of well number 4, the concentration of ammonia was less than 0.50 mg/l. However, over half of the well sampled had zero value of ammonia. WHO standard for ammonia for drinking water is 0.5 mg/l (WHO, 1993). In uncontaminated surface or groundwater, the value of ammonia is usually less than 0.1 mg/l (Wilcock *et al.*, 1995). About 20 % of the sampled wells in this study have ammonia values greater than this value (0.1 mg/l). Ammonia is toxic to aquatic organisms (Richardson, 1997). The toxicity however depends mainly on pH and temperature (Wilcock *et al.,* 1995).

The nitrogen ammonia levels were relatively high in dry season and showed a statistically significant differences (P>0.05) for all the sampling points. The mean seasonal values varied from 0.25 mg/L to 0.45 mg/L in dry season and from 0.06 mg/L to 0.36 mg/L in wet season. The dry season values ranged from 0.10 mg/L to 0.75 mg/L with the highest value recorded at AD1 and the lowest value recorded at GK and DK2. The wet season values ranged from a minimum of 0.02 mg/L at GK to a maximum of 0.55 mg/L at AD2.

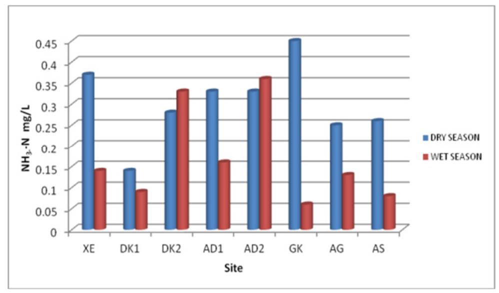


Fig 5: Mean Seasonal Variations in nitrogen ammonia

Phosphate-phosphorus (PO_4^{3-}): Phosphate-phosphorus concentrations for the wet season was relatively high than the dry season but did not indicate statistically significant differences (P>0.05). The mean seasonal values fluctuated between 0.20 mg/L and 3.44 mg/L in dry season and 0.43 mg/L and 4.56 mg/L in wet season. The dry season values ranged from 0.01 mg/L to 4.28 mg/L with the highest value recorded at AD1 and the lowest value recorded at GK. The wet season values ranged from a minimum of 0.26 mg/L at DK2 & AG to a maximum of 5.31 mg/L at AS.

All the samples had the phosphate concentration higher than 0.01 mg/L (WHO) Guideline value. The mean values also exceeded the limits. Presence of phosphates in water may be indicative of the original presence of organic matter, but when found, they merely confirm the more definite indicators given by nitrates and chlorides which are quantitatively greater and no more difficult to determine. (Thresh *et al*, 1958).

Phosphate are found in underground water in minute traces and the amounts vary according to the original pollution of the water and strata through which it has percolated and protect them from removal by water treatment (WNAS, 1997). Water having phosphate may support a large population of algae, both planktonic and attached, especially in opens storage reservoirs. Phosphate also appear to be vital to microbial persistence and adaption to the harsh environment of minimal nutrient concentration, toxicities of disinfectants residuals, the adversities of a shearing action of flowing water (AWWA, 1990). As a result, these findings may have possible public health implications.

There was no clear trend in the seasonal variation. The phosphate range of the well water samples during the study period was 0.01-5.31 mg/L. Almost all the well samples had their phosphate values higher than Ministry of the Environment and Energy, Canada (1994) permissible limit of 0.3 mg/l normally found in natural water. The major concern of phosphate in water is eutrophication (Environmental Manual for Poultry Practice, 2003). Phosphate is toxic to animals and humans at extremely high levels and could cause digestive problems (D'Amelio, 2007).

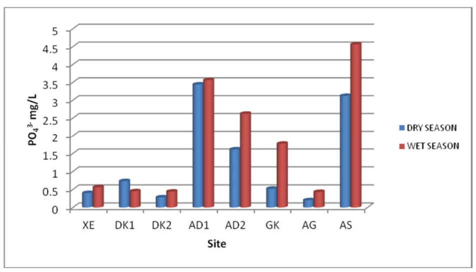
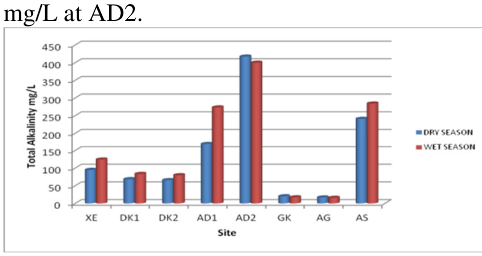


Fig 6 Mean Seasonal Variations in phosphate

Total Alkalinity: The total alkalinity did not show any statistically significant seasonal variation at ($P>0.05$) for all the sampling points. The mean seasonal values varied from 17.0 mg/L to 417.3 mg/L in dry season and from 16.0 mg/L to 400.0 mg/L in wet season. The values for the individual sites for the seasons are presented in Table 7. The dry season values ranged from 12.0 mg/L to 658.0 mg/L with the highest value recorded at AD2 and the lowest value recorded at AG. The wet season values ranged from a minimum of 15.0 mg/L at AG to a maximum of 664.0 mg/L at AD2.



Conclusion and Recommendation: The delivery of safe drinking water requires actions to be taken throughout the water cycle from the catchment to the point of consumption. The focus of any programme designed to deliver safe drinking water should therefore be the effective management and operation of water sources, treatment plants and distribution systems whether piped or manual. This will demand action by water suppliers, environmental protection agencies and health bodies. WHO (2004b) outlines that the delivery of safe drinking water is most effectively achieved through a risk management framework that is the "Framework for Safe Drinking-water" that encompasses five key steps:

Establishing health based targets for drinking-water based on evaluation of health concerns

An assessment of the water supply system to determine whether the water supply chain (from source through treatment to the point of consumption) as a whole can deliver water that meets the health based targets
Identification and operational monitoring of the control measures in the drinking water supply that are of particular importance in securing drinking water safety;

Preparation of management plans documenting the system assessment and monitoring plans and describing actions to be taken in normal operating and incident conditions, including upgrading documentation and communication;

A system of independent surveillance that verifies that the above are operating properly.

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