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39th WEDC International Conference, Kumasi, Ghana, 2016**ENSURING AVAILABILITY AND SUSTAINABLE MANAGEMENT
OF WATER AND SANITATION FOR ALL****Ground water quality in a low income community:
case study of Kotei, Kumasi***Bernadette Dzifa Agbefu (Ghana), Vivien Chikogu-Ameso & S. Oduro-Kwarteng***REFEREED PAPER 2554**

The quality of groundwater, is low in low income peri-urban communities where onsite sanitation facilities and ground water resources are barely apart. This paper assesses the influence on-site sanitation facilities have on groundwater quality by determining the level and source of contamination and identifying the associated pathways to contamination at various levels of storage. Groundwater samples from randomly selected sources with different storage levels were analysed for physio-chemical parameters, microbial contamination levels and the presence of heavy metals. The risk to contamination of selected sources was conducted using a questionnaire developed by Howard et al. The results indicate that, groundwater quality deteriorates from source to storage with counts of microbes increasing. However, as microbial contamination level increases, risk to contamination levels decreases for primary and secondary storage. This suggests that, contamination at primary and secondary storage levels is not directly from on-site sanitation systems but from other identified factors.

Introduction

Assurance of drinking-water safety is a foundation for the prevention and control of waterborne diseases (WHO, 2010). Initiatives for water safety do not only support public health, but often promote socio-economic development and well-being (WHO, 2012). There are several sources of ground water pollution from leachate and on-site sanitation system is one of the known sources. (ARGOSS 2001). It has been reported that pathogens and nitrate in these leachate are two major public health issues commonly related to onsite systems (Lewis.et.al 1980). In low income communities for where there is rapid urbanization for instance, on-site sanitation is preferred to off-site sanitation (Dzwaairoa et al, 2006) due to the high cost involved in construction, operations and management of the latter which often requires conventional sewerages (Pujari et al, 2012). The chemical contaminants and pathogenic bacteria released from these onsite sanitation system infiltrates into groundwater sources (Lewis.et.al 1980).

In peri-urban settlements where there is over reliance on ground water, the threat of ground water pollution is more severe where both onsite sanitation and ground water resources are barely apart (Lewis.et.al 1980). The extent of groundwater pollution depends on hydro geological and soil condition of surrounding environment, depth to water table and distance between groundwater source and onsite sanitation system. In addition to the above, ground water pollution increases by the type of storage facilities, livestock, stored manure, solid waste landfills and leakage from wastewater pits (Banks et al 2002).

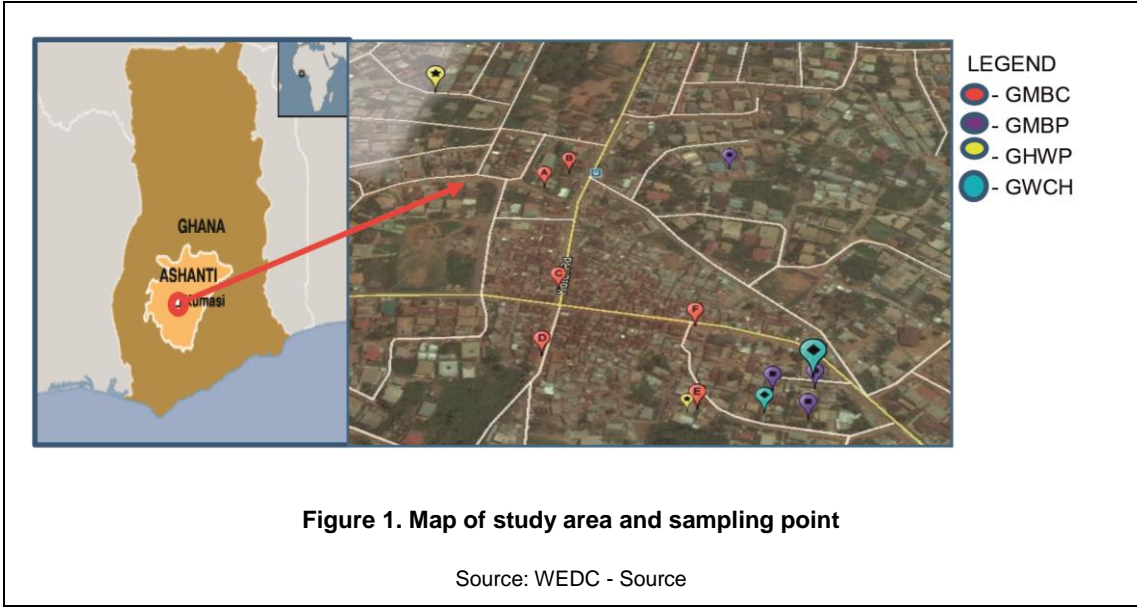
Results from Godfrey et al suggest that contamination of wells for instance, has occurred through alternative localized pathways. These include identified weaknesses in the engineering headworks such as cracks at the base of hand-pumps, inadequate drainage, seepage through the annuli of concrete caissons or ingress through pumping mains (Godfrey et al,2005).

This paper assesses groundwater quality by establishing the influence on-site sanitation facilities have on groundwater quality. This will be done by determining the level of microbial contamination and risk to contamination by on-site sanitation facilities. Contamination pathways of groundwater with different levels of storage will also be determined.

Study area

Kotei is the study area which is located in Kumasi, the Ashanti Regional capital. The population of Kotei is 15,637 (GSSD, 2010) and it is inhabited by both indigenes and students from the Kwame Nkrumah University of Science and Technology (KNUST). The study was conducted at the area where indigenes reside.

Kotei is located at latitude 6°39.523’N and longitude 1°33.435’W at an elevation of 254 m. Their main source of water is ground water which is made available through communal boreholes/hand-dug well or individually owned boreholes/hand-dug well. Individual and Communal boreholes pump groundwater directly into storage tanks without treatment before usage. Inhabitants who fetch from communal point source store water in barrels or gallons in their homes before usage. Inhabitants are mostly petty traders with few having white collar jobs. The community is unplanned with low sanitation coverage.



Methodology

Sample collection

Water Samples were collected using sterilized 500ml plastic sampling bottles. Samples were immediately placed in an insulated box containing ice-packs. The samples were collected randomly from ground water source for the community and individual homes with different storage facilities. Samples collected from hand dug wells with no storage were classified as Source. Groundwater from mechanised boreholes stored in either individual or communal elevated storage tanks were classified as primary storage. Water fetched from primary storage and stored in households using containers of varying types and sizes were classified as secondary storage. Two samples were collected from each sampling points for Physical, Chemical, Microbiological and Heavy metal analysis. The sampling points were classified and labelled as shown in the table below:

| Sample name | Abbreviation | Numbers of samples | Storage Levels |
|--|--------------|--------------------|---------------------|
| Groundwater from Mechanized Borehole stored in elevated storage within Community | GMBC | 6 | Primary Storage |
| Groundwater from Hand dug Well without storage located in Private homes | GHWP | 2 | No Storage (Source) |

| | | | |
|--|------|---|-------------------|
| Groundwater from Mechanized Boreholes stored in storage tanks for Private homes. | GMBP | 4 | Primary Storage |
| Ground Water fetched from communal point source and Stored at Homes | GWCH | 2 | Secondary Storage |

Water quality analysis

Samples were analysed at the environmental quality engineering laboratory of the Civil Engineering department in KNUST. The physical parameters were tested following standard aseptic procedures as stated in WHO water quality analysis guide (1997). Three microbiological parameters were tested; total coliform, Escherichia coli and Salmonella. 100 ml samples were filtered using membrane filters. Chromo cult Agar nutrients prepared the previous day and stored in an incubator at temperature of 21 ° C was used as the growth medium for microbes. Membranes used for the filtration process were placed in the media and stored in an incubator at a temperature of 32° C for 24hrs.

Risk to contamination assessment

This was carried out using a questionnaire for assessing the risk of groundwater contamination from on-site sanitation system, developed by Howard et al, (2003). This questionnaire had ten questions with each sampling point been scored out of ten. Base on the score obtained by a sampling point, the risk of contamination was described as: 9-10 = Very High; 6-8= High; 3-5 = Medium; 0-3 = Low.

Results and discussion

The results show the physical and chemical quality of groundwater stored at different storage level compared to WHO and Ghana Standard Authority Standards, microbiological analysis compared to the risk to contamination and the associated pathways to contamination.

Physio - chemical quality analysis

The average measured physical and chemical parameters of samples is shown in table 2 below as against WHO and Ghana Standards Authority guideline values. All physical and chemical parameters met the WHO and Ghana Standard Authority guideline for drinking water quality.

| Parameter | Kotei | WHO | GH Std |
|----------------|-------|------|--------|
| PH | 5.555 | 7.5 | 7 |
| Turbidity(NTU) | 0.51 | 5 | 5 |
| EC(µs) | 273 | 500 | 500 |
| TDS(ppm) | 138.5 | 1000 | 1000 |
| ALK | 0.27 | N/A | N/A |

Microbial and risk to contamination level analysis

The greatest risk to public health from microbes in water is associated with consumption of drinking-water that is contaminated with human excreta (WHO, 2011). The level of microbial contamination is highly influenced by location and type of on-site sanitation systems (Pujari et al, 2011). In this analysis, there is comparison between the level of microbial contamination and the risk to contamination, on-site sanitation systems posse to groundwater at different storage levels. This will help establish the influence these facilities have on ground water quality with respect to their type of storage.

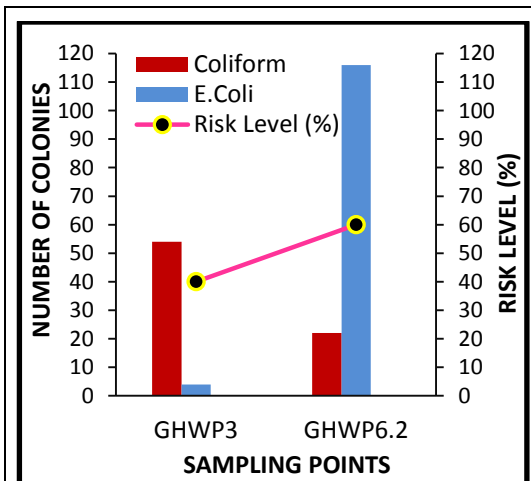


Fig 2A. Microbial contamination levels and risk to contamination at source

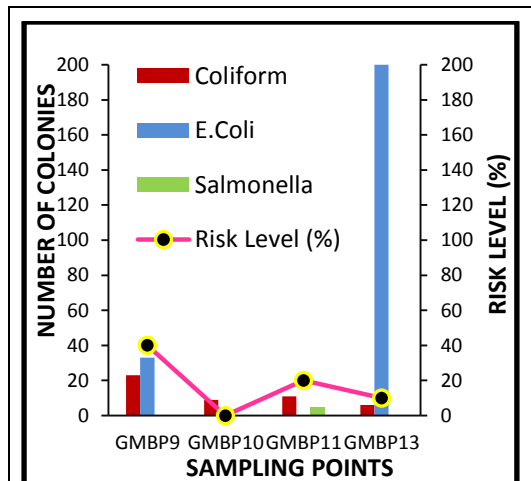


Figure 2B. Microbial contamination levels and risk to contamination in household primary storage

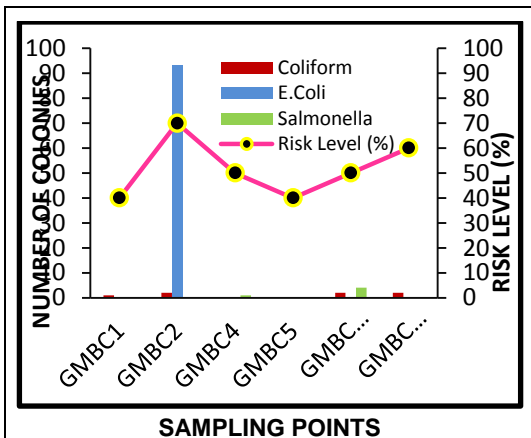


Figure 2C. Microbial contamination levels and risk to contamination in communal primary storage tanks

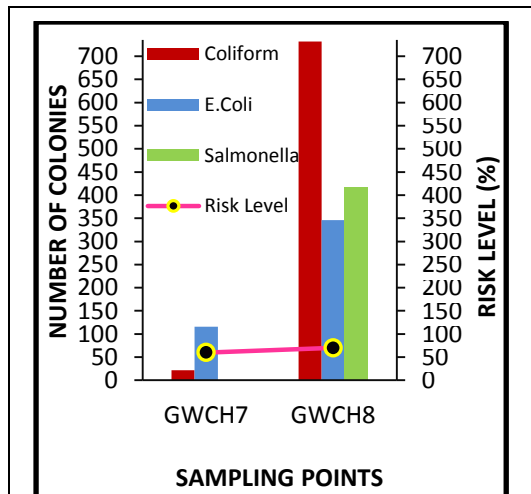


Figure 2D. Microbial contamination levels and risk to contamination at household secondary storage tanks

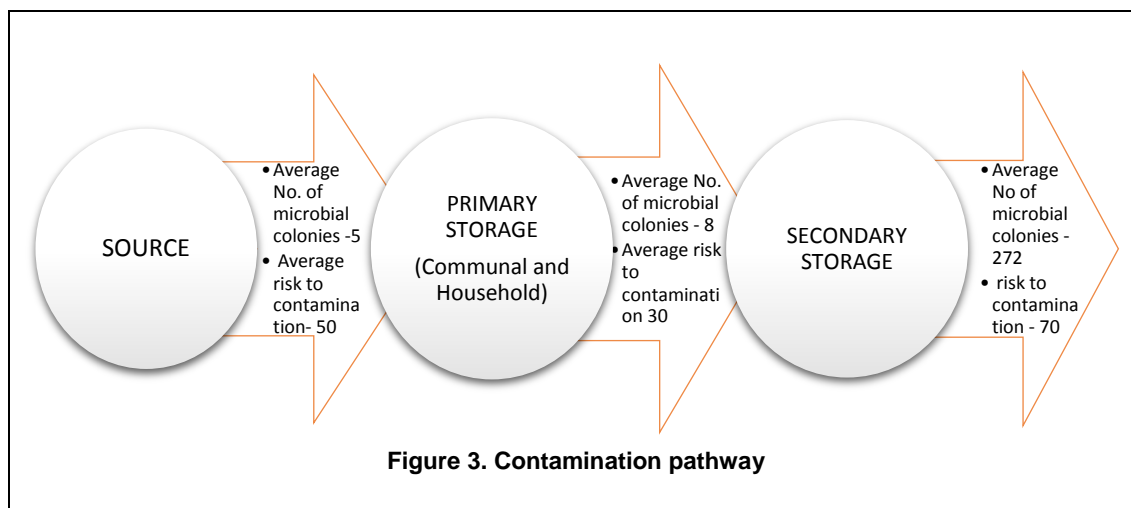
Figure 2. Microbial and risk to contamination level

The graphs were plotted based on the categories of samples collected as defined in table 1. In fig 2A, microbial contamination level was high and the risk to contamination level ranges from high - medium risk of contamination. This suggests that, source of contamination for direct source of water is mainly due to on-site sanitation systems.

The results shown in fig 2B, 2C and 2D shows low risk to contamination but very high microbial contamination. This implies that, the possibility of direct contamination of groundwater stored at primary storage levels is low. Hence, the source of contamination is not directly from on-site sanitation systems but other determined factors. There is the need to then identify contamination pathways for primary and secondary storage levels.

Contamination pathway

The figure below compares quality of groundwater between direct source, Primary Storage and Secondary storage levels.



The above figure suggests that, contamination levels increases at primary and secondary storage. This is very alarming since direct usage of water occurs at this level. The identified risk factors at primary storage are;

- Delayed cleaning of storage tanks – All primary storage tanks have not been cleaned for over an average period of 3years.
- Inappropriate and Irregular use of disinfectant – Only one out of fourteen sampling points use sodium hypo chlorate as disinfectant at the primary storage level. But for this one household, application is solely base on personal decision (i.e. applying when household members feel the need to). Wrong usage of disinfectant type and disinfectant level can cause coliform regrowth in water (LeChevallier et al,1996)
- Wrong methodology for washing of storage- Residents use detergents containing phosphates to wash tanks. Tanks. This can lead to coliform regrowth because, coliform bacteria are generally considered to be more copiotrophic (e.g., requiring higher nutrient levels), it is expected that higher nutrient levels will be required to initiate coliform regrowth (LeChevallier et al,1996).

Household items such as gallons, barrels and other containers were used as secondary storage facilities. Therefore, direct risk of contamination by on – site sanitation systems was insignificant. Domestic hygiene at household levels was poor. This posed high risk of contamination which is noticeable in the microbial contamination levels. The identified poor domestic hygienic conditions were; use of dirty hands to handle storage facilities and uncovered storage facilities. Other risk factors observed were;

- Mode of collection at source - Containers for storage/collection are not clean. Also, Individuals ignorantly place dirty hands in water while fetching. Faecal coliforms on both hands and household utensils appeared to contribute to point-of-use contamination, highlighting the need for improved personal and domestic hygiene practices (Oswald et al,2007).
- Form of storage – Household containers are not/properly covered thus exposing water to contamination. In addition, household containers are not washed before storage and when washed, they are not washed with appropriate detergents.
- Storage period - Storage of water in a single container over a long period of implies more opportunity for contamination, because according to Oswald et al, hands and the handle or outer surface of collecting utensils frequently carry harmful microbes.
- Mode of transportation from community -water fetch in containers are usually carried on individuals' head and do not have a lid and handle, this exposes the water to contamination. In an attempt to balance water containers on their head, residents tend to contaminate water with their dirty hands.

Heavy metals analysis

All sampled water sources were free of Fe, Mn, Zn and is acceptable for drinking water quality except for lead concentration. Lead concentrations detected above the drinking water standards are 0.013mg/l,

0.066mg/l, 0.019mg/l and 0.013mg/l for samples GMBP11, GMBC5, GMBP13 and GMBP10 respectively as against the recommended value of 0.01mg/l.

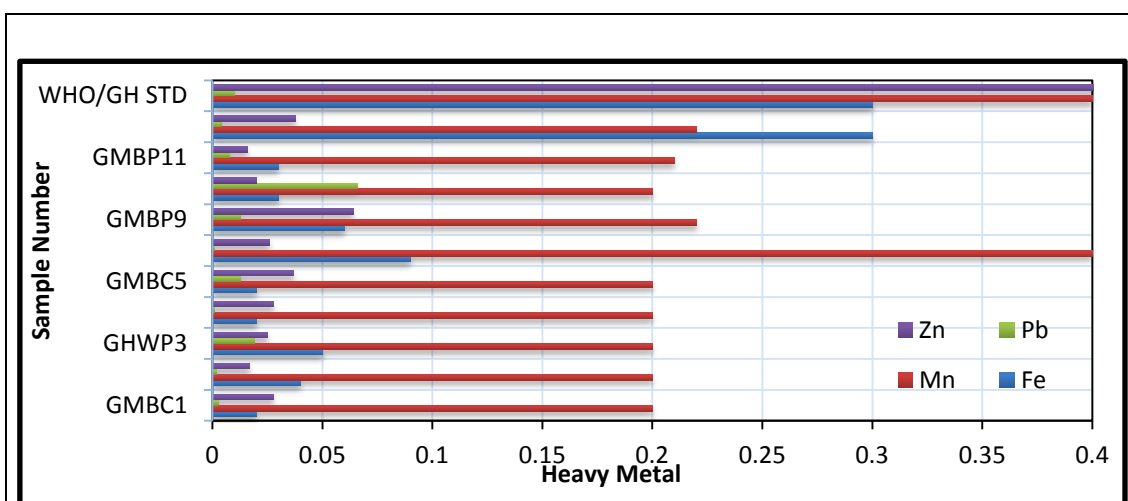


Figure 4. Results of heavy metal analysis

From the heavy metals analysis, there is lead contamination in the region indicated below. Lead in drinking water can be harmful to our health. High level of lead contamination in children can result to convulsion, major neurological damage, organ failure, coma to death. While moderate levels of exposure may result also in hearing loss, inhibit growth and cause hearing disability (Oram, 2014).

Recommendation and conclusion

Unless boreholes or on-site sanitation facilities are abandoned, risk posed by on-site sanitation systems close to ground water sources can be barely controlled or reduced. This can be achieved through education of residents on safe water storage and usage, cleaning of storage within recommended period, regular disinfection using appropriate disinfectants at the appropriate dosage and practice of good domestic hygiene. From the results, there was contamination of groundwater at the various levels of storage but high levels of contamination occur at primary and secondary storage levels, which is not acceptable because, international water-quality standards permit no detectable level of harmful pathogens at the point of usage (WHO, 2004). From the results, it can be concluded that, the higher the proximity of on-site sanitation systems, the higher the risk to contamination which is the same results Lewis et al had from their study. With the exception of lead, heavy metals (Fe, Zn and Mn) occur in concentration within the drinking water standard. Further research should be done to expand the scope of study and trace the source of lead contamination in parts of the study area.

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