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The impact of septic systems density and nearness to spring water points, on water quality

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Worldwide, 1.1 billion people do not have access to clean water and as a result, 2 million children die annually due to preventable waterborne diseases. In Uganda, 440 Children die every week of waterborne diseases. High prevalence of this death is reported in the peri urban areas. It is still unclear however the causes of water pollution in the peri-urban areas. The improper use of onsite sanitation facilities such as latrines and septic systems may lead to groundwater contamination. It is true that drain field of septic system located too close to water point, and or over population of the septic systems in a small area can lead to pollution of groundwater. Our study investigated the impact of septic systems density and nearness to water points on spring water quality. Samples from 15 spring wells were analysed for pH, nitrate and faecal coliform contamination. Locations and distances of spring from septic systems were determined using global positioning system (GPS) device and ArcGIS software, respectively. Water samples from all the spring wells had pH value less than 6.5, 66.7% had faecal coliform and 53% had nitrate above 2 mg L^{-1}. While sample from one of the springs had nitrate concentration above the United States Environmental Protection Agency (US EPA) standard of 10 mg L^{-1}. It was also noted that coliform counts and nitrate concentrations increases with increase in number of septic systems surrounding the spring well. In addition, increase in distance between spring wells and septic systems indicated decrease in both coliform counts and nitrate concentration. It is therefore concluded that improper use of septic systems is one of the causes of groundwater pollution in the peri urban areas. The study recommends treatments of water from groundwater sources, regular monitoring of groundwater sources and proper design and siting of septic systems using more robust methodologies.

Key words: Spring water quality, septic systems density, proximity to spring, coliform, nitrate.

INTRODUCTION

Worldwide, 1.1 billion people do not have access to clean water, and so 2 million children die yearly due to avoidable water borne diseases. The water and Sanitation Program Africa (WSP-AF) reported that 440 children die every week of waterborne diseases (Banya and Zajda, 2015). Study by Lawrence et al. (2001) point on site sanitation facilities as one cause of spring water pollution in urban settings. Howard et al. (2003) and Ali and Balgehan (2006) have confirmed the exposure of groundwater sources to pollutants from sanitation facilities. In Gulu municipality, septic systems pose a significant threat to groundwater safety because of over dependence on this systems. The National Water and Sewerage Cooperation (NWSC) annual activity report (NWSC, 2010), indicates only 7% sewer network coverage in the municipality.

Pollution of water resources is a result of faecal matters from the drain field of septic systems leaching into groundwater. Naturally the soil is a medium for the removal or reduction of the contaminant before reaching groundwater through adsorption to the surface of soil particles and degradation into harmless material by microorganism that lives in soil particles (Engle, et al.,1991). However, if there is high concentration of pollutants, the soil cannot purify the waste primarily where the drain field is very close to water source. Dependence on contaminated water is the major cause of water borne diseases such as Hepatitis A, Typhoid, dysentery, ear infection, Bilharzia and methemoglobinemia (Yates, 1985; Nolan et al., 1988; Skipton and Hay, 1998). This study assessed the impact of septic systems density on spring water quality using the spatial distribution of septic systems and their nearness to water points.

MATERIALS AND METHODS

Scope of the study

The study was conducted in Gulu municipality located at Latitude 2° 46' 0" North, and longitude 32° 18' 20" East in Gulu District, Northern Uganda. It has an area of about 61 km^2 (Figure 1). Analysis of 15 water samples for Nitrate and faecal coliform loads were done between February and March, 2013. Duplicate samples were collected for each analysis. Field determinations of pH were done using a Wagtech WTW 33oi model pH meter. Samples were collected in sterilized glass and stored in ice-cold containers for transport to the laboratory. All analyses were done within 6 h after sample collection.

Septic systems population

Using Google map, 500 × 500 meter grids covering the study area were developed. Septic systems population per grid were derived by counting septic tanks within each grid using high resolution image of Google map. Arc Map was used to develop the map of septic systems population (Figure 1).

Nitrate concentrations

Cadmium reduction method 8192 was used to determine the nitrate load in water. To a 25 ml measuring cylinder, 15 ml of water sample was added. To the sample, a content of Nitraver 6 reagent powder pillow was added as a stop clock was started. The cylinder and its content were shaken for three mins before transferring 10 ml of content into a sample cell. To the content of the sample cell, a packet of Nitriver 3 powder pillow was added, shaken and left to react for 15 min. The prepared sample cell was then cleaned, inserted into the cell holder and the readings taken (Table 1).

Faecal coliform counts

Membrane filter technique according to US EPA (2003) was used to determine faecal coliform bacteria counts in water. Spring water aliquots of 100 ml were filtered through a 0.45 µm pore membrane filter using a vacuum pump. The filter was then placed on a petri dish containing m-TEC media and incubated for 24 h at 44.5°C. The red to magenta coloured colonies were counted directly, and the results calculated as microbial density (Table 1).

Spring water quality and septic population

Spatial analyses of septic systems population and water quality were used to derive the impact of septic systems population on spring water quality. ArcGIS software was used to produce the thematic maps of septic systems population, water quality parameters and to perform spatial analyses on the map layers through spatial overlay. The locations of septic systems and spring water points were determined using eTrex GPS device. ArcGIS software was used to measure distances between septic tanks and spring water points. Regression and descriptive statistics were performed using excel and SAS 9.1 software.

RESULTS AND DISCUSSION

pH

The mean value of pH obtained was 5.6 (Table 1). This result indicates that the water samples are slightly acidic. The recommended pH range for portable water is 6.5 to 9.5 (World Health Organization (WHO), 2007). The pH of a body of water is affected by several factors including the bedrock and soil composition through which the water moves, both in its bed and as groundwater. Some rock types such as limestone can, to an extent, neutralize the acid increasing the pH while others, such as granite, have virtually no effect on pH. For the case of spring water, which is derived from shallow aquifer, the bed rock effect could be minimum. Another factor which affects the pH is the amount of plant growth and organic material within a body of water. When this material decays, carbon dioxide is released. The carbon dioxide combines with water to form carbonic acid, a weak acid, which in large amounts can lower the pH. Other causes of low pH

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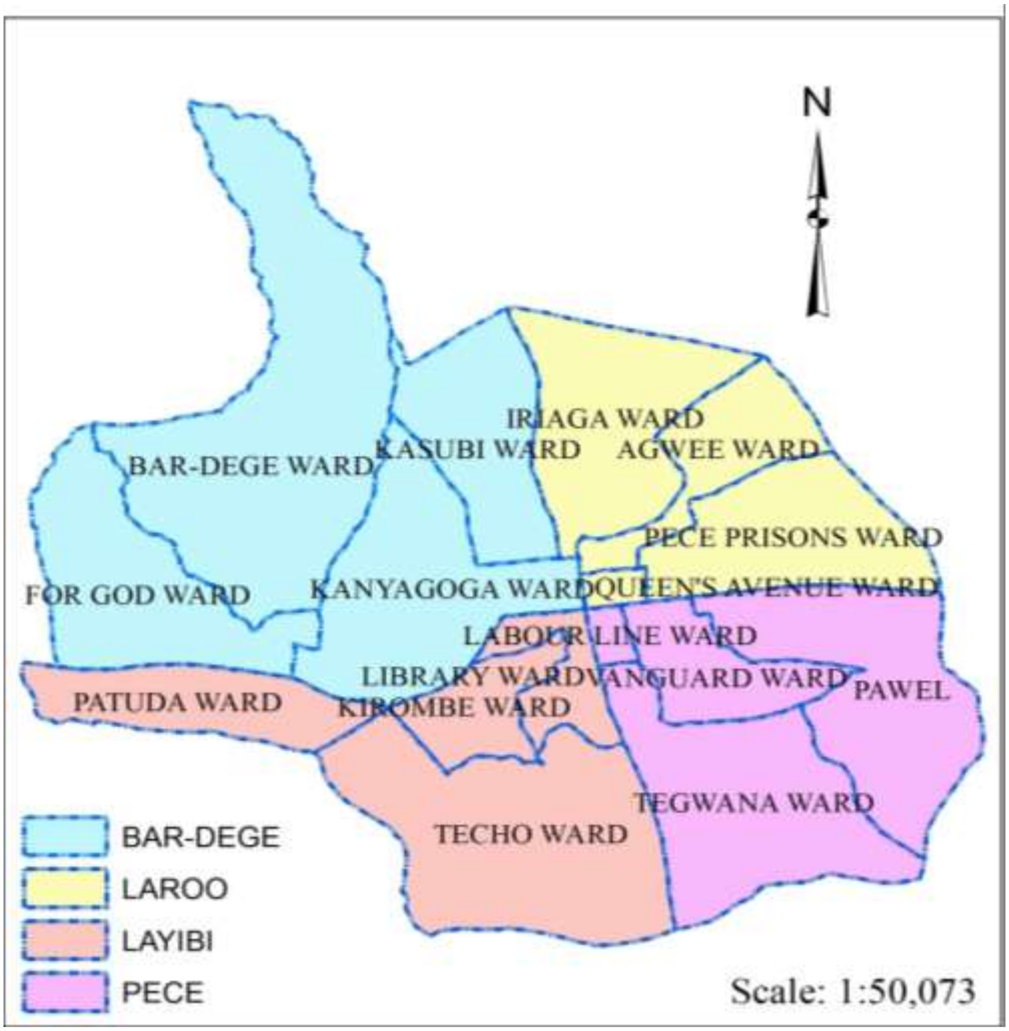

Figure 1. Study Area.

such as acid rain, mines and introduction chemicals from industries are insignificant in the study area, which is predominantly rural urban.

In the current study, it is probable that organic matter is present in the spring water. This organic matter could be coming through leachate from point source contaminants including septic systems. The low pH in the water sample confirms the presence of organic matter.

Coliform counts

Out of the 15 spring water points sampled, water sample from one spring had no coliform bacteria detected. The mean faecal contamination was 49.7 colonies per 100 ml of water (Table 1). Comparing this result with WHO (2010) health risks classification of bacteriological water quality indicates that 27% of spring water points were at high risk (> 100 colonies), 33% at intermediate risk (10 to 100 colonies) and 13% at low risk (1 to 10 colonies). Our findings agreed with those of Opio et al. (2011). In their study, all water points sampled were contaminated with faecal coliform and spring water were affected more than boreholes within the same locations. They attributed this to various land use systems and poor sanitation around water points. According to WHO (2010) and USEPA (2009) standards, water for drinking purposes must have no detectable coliform bacteria. The present of coliform bacteria in water is a sign of faecal contamination (Haruna et al., 2005) and has been linked to many water borne diseases.

Nitrate concentration

Out of the total spring water sampled, one water sample

Table 1. Water quality parameters and distance of spring from septic systems

Coordinates		Division	Faecal coliform counts/ 100 ml	pH	Electrical conductivity µS cm^{-1}	Nitrate Conc. mg L^{-1}	Proximity of septic systems (m)
2° 45′ 43″ N	32° 18′ 04″ E	Pece	113	5.6	417	5.00	67.6
2° 45′ 34″ N	32° 18′ 43″ E	Pece	70	5.7	144	2.00	38.0
2° 46′ 21″ N	32° 19′ 25″ E	Pece	71	5.4	67	1.21	97.4
2° 46′ 45″N	32° 19′ 11″ E	Laroo	58	5.6	114	1.600	132.5
2° 46′ 35″ N	32° 18′ 27″ E	Laroo	115	5.5	200	3.55	91.0
2° 46′ 31″ N	32° 18′ 03″ E	Laroo	147	5.7	341	11	33.3
2° 46 ′38″ N	32° 18′ 20″ E	Laroo	0	5.4	200	0.20	321.4
2° 47′ 25″ N	32° 18′ 31″ E	Laroo	54	5.9	185	2.18	74.9
2° 46′ 41″ N	32° 17′ 35″ E	Bardege	120	5.9	223	5.50	10.3
2° 46′ 18″ N	32° 16′ 55″ E	Bardege	50	5.9	200	1.06	111.4
2° 46′ 39″ N	32° 16′ 40″ E	Bardege	0	5.7	200	1.08	262.5
2° 45′ 40″ N	32° 16′ 02″ E	Layibi	9	5.7	164	2.16	281.3
2° 45′ 11″ N	32° 16′ 49″ E	Layibi	0	5.5	100	0.01	461.8
2° 45′ 23″ N	32° 17′ 14″ E	Layibi	0	5.4	109	1.42	213.8
2° 45′ 28″ N	32° 17′ 38″ E	Layibi	5	5.5	139	2.41	279.6

had nitrate concentration above the USEPA's drinking water standard of 10 mg L^{-1} (US EPA, 2014). The nitrate concentrations ranged from 0.01 to 11 mg L^{-1} (Table 1). The levels found in this study were however, below the Uganda's and World Health Organisation's guidelines whose maximum nitrate levels in drinking water are at 50 mg L^{-1} (UNBS, 2008; WHO, 1996). Studies by US Geological Survey (USGS) defined concentrations of nitrate in water beyond 2 mg L^{-1} as the level indicating human impact on water quality (Hanchar, 1991).

Water quality and septic system population

Spatial surface maps (Figures 2 and 3) showed greater contaminant loads in areas highly populated with septic systems compared to those with low population. Spring water points found in areas with less than twenty septic systems per 250,000 $m^{2,}$ had coliform loads ranging from 0 to 14 counts per 100 ml of water while nitrate concentration ranged from 0.01 to 5.83 mg L^{-1}**.** But those situated in areas with septic systems density greater than thirty per 250,000 m^2 had more contaminant loads. The contaminant loads ranged from 15 to 147 and 5.82 to 11 mg L^{-1} for coliform and nitrate, respectively.

There was a negative correlation -0.84 (R^2 = 0.71) between distance from septic systems to spring water points and faecal coliform counts in water (Figures 4 and 6). Similar trends were observed for nitrate concentrations (Figures 5 and 6). Analysis showed an exponential correlation (R^2 = 0.67) between nitrate concentration in water and the distance from spring to septic systems. In addition, a positive correlation of 0.80 between nitrate concentration and faecal coliform counts in spring water was found.

The negative correlations obtained between the distance from septic systems and contaminants loads in water suggest that, the amount of contaminants in water would drop with increasing distance. Comparable observations were reported by previous researchers (Arnade, 1999; Taylor, 2003). They reasoned that sufficient nitrate dilution in groundwater would be possible if separation between wells and septic systems were adequate.

The positive correlations of 0.80 between nitrate concentration and faecal coliform counts in spring water implies that faecal coliform counts in water increases as nitrate concentration rises. Perhaps this is a sign that the two contaminants are originating from the same source (Odetokun and Adetunji, 2011), the septic system in this case. The results showed that contaminations of water resources relied on the position of the spring. Springs located in region of high septic systems density had more contaminant concentrations than those in areas with fewer septic systems. This result agreed with that of Yates (1985) who also noted that groundwater contamination from septic systems can only be minimised by limiting the number of septic systems within a given area. Further, in Nigeria, contaminations of shallow wells were demonstrated to correlate with high human population density (Odetokun and Adetunji, 2011). However, in this study some springs had high nitrate concentrations even if the levels of coliform counts were low. Haruna et al. (2005) reported similar outcomes. This

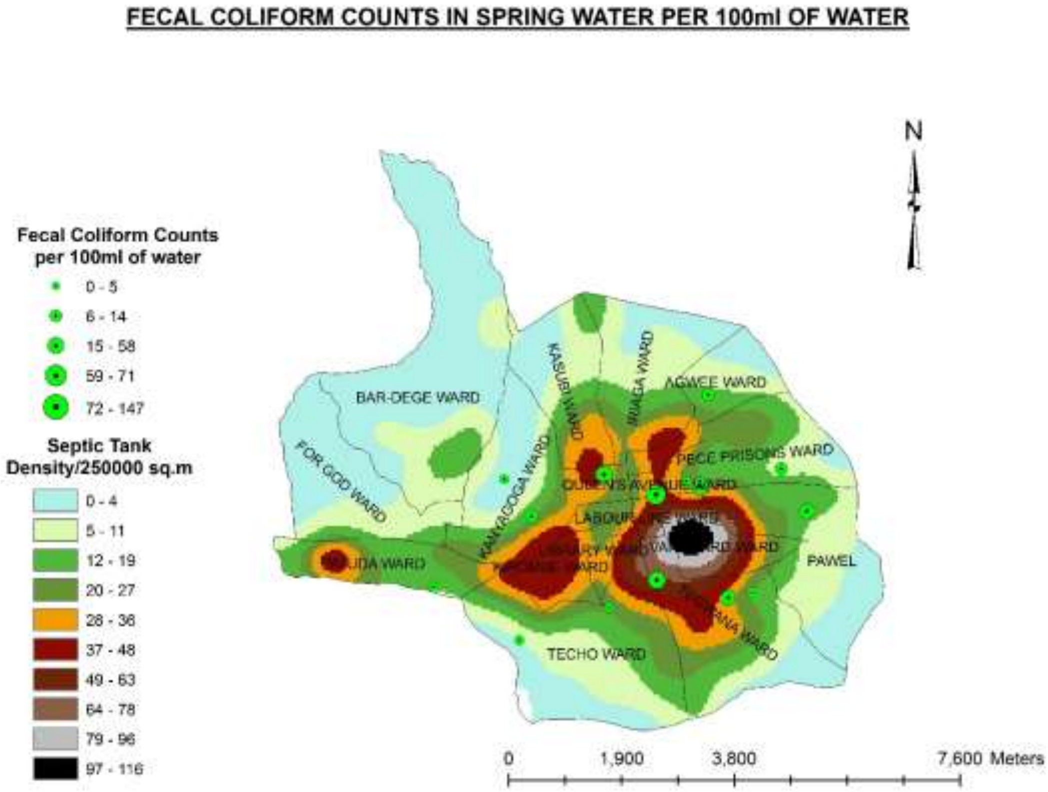

Figure 2. Map of Gulu Municipality showing effect of septic systems density on faecal coliform counts in spring water.

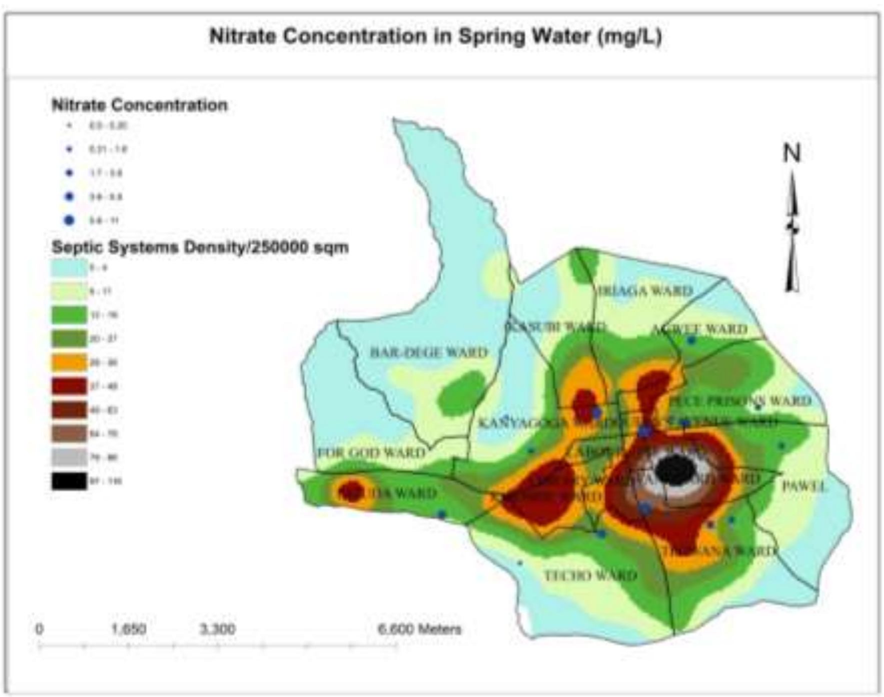

Figure 3. Map of Gulu municipality showing effects of septic systems density per 250000 m^2 on Nitrate concentration in spring water.

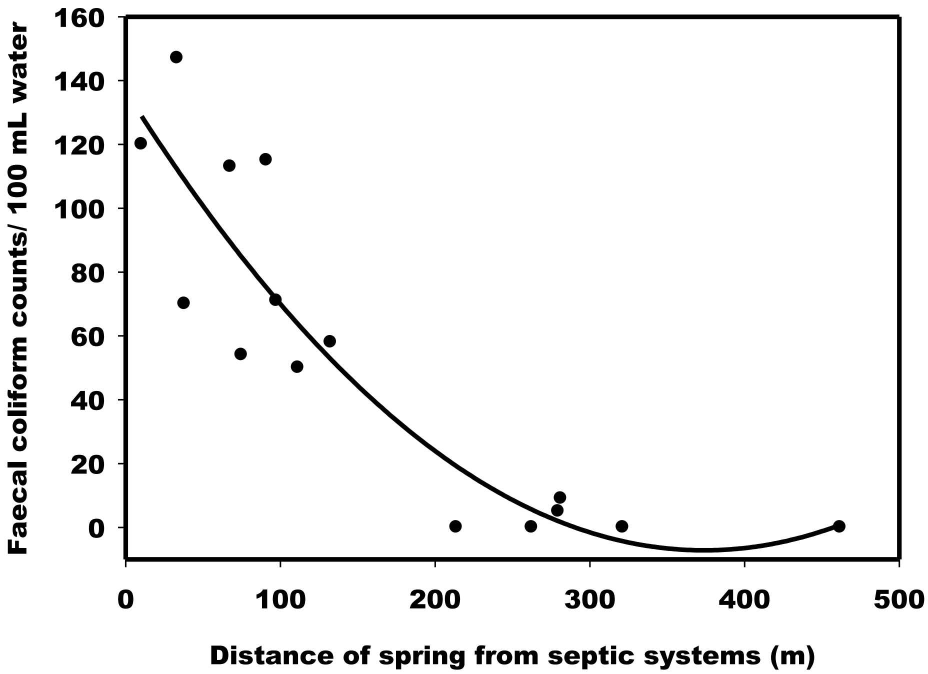

Figure 4. Effect of distance on faecal coliform counts in spring water samples.

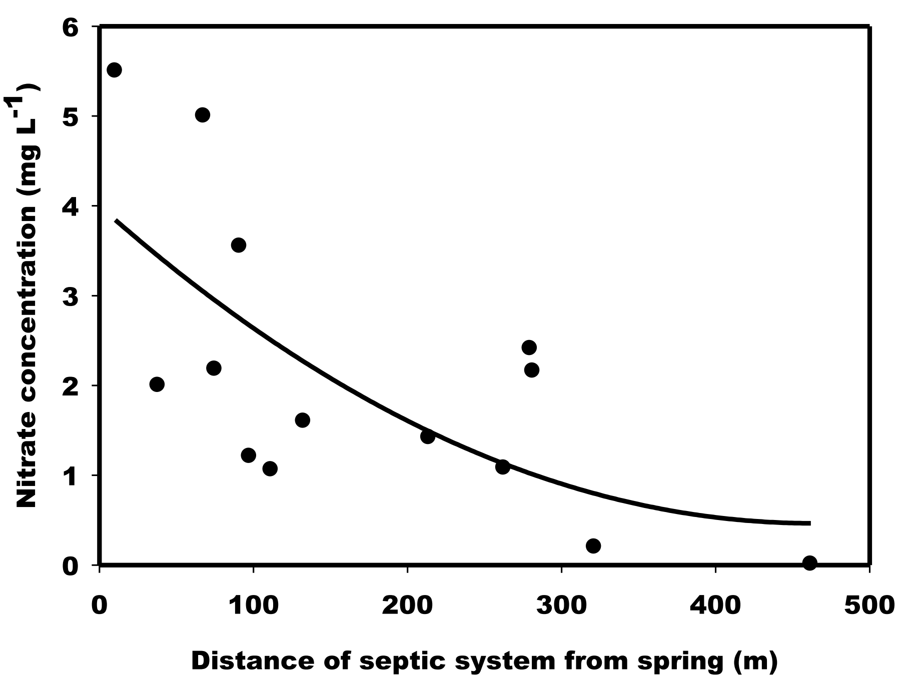

Figure 5. Effect of distance on Nitrate concentration in spring water samples.

is possibly due to variations in soil type and depth to water table at different sites. The presence of both nitrate and faecal coliform in water according to Haruna et al. (2005), showed wastewater contaminations.

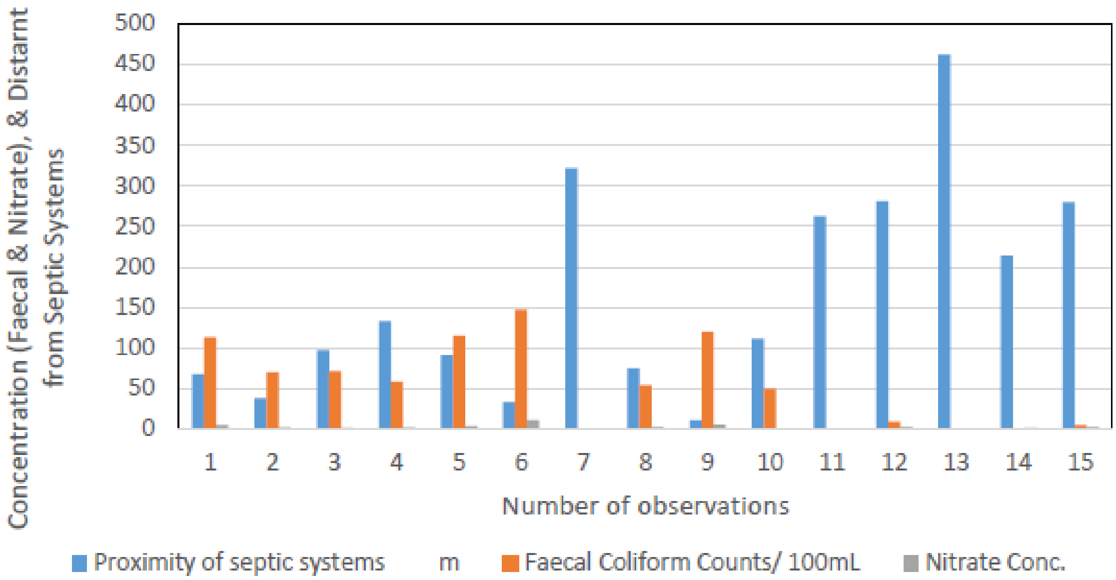

Figure 6. Effect of distance of Spring from septic system on Coliform counts and Nitrate concentration in spring water.

CONCLUSIONS AND RECOMMENDATIONS

All spring water wells sampled had their pH below the recommended value of 6.5. Our study suggested organic matter from leachate as the most probable cause of the low pH. Also, it was observed that, 53% of springs water points had nitrate concentration ranging from 2 to 11 mg/L and 66.7% were contaminated with faecal coliform. The concentration of the contaminants corresponded to the density of the septic systems. In addition, concentration of the contaminants intensified as spring water resources become closer to septic systems. Ingestion of this water would therefore mean putting one's health at risk. Regular monitoring should be done to avoid consumption of contaminated water and its associated health effects. The placement of septic systems and the separation distance between septic systems and drinking water sources should be regulated through policies governing the use of septic systems. There is need for friendly tool which can be used to optimize septic population in a given area and for a given geologic condition.

Conflict of Interests

The authors have not declared any conflict of interests.

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