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ENVIRONMENTAL AND PUBLIC HEALTH IMPACTS ASSOCIATED WITH SEPTIC TANK SYSTEMS (SOAK AWAYS) AT NKWABEN SOUTH IN THE SUNYANI MUNICIPALITY

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ABSTRACT

Septic tank systems are widely utilized to dispose of wastewater in in urban, rural and peri-urban areas. When constructed and operated correctly, septic tank systems eliminate several contaminants and provide some protection for human health and the environment. When septic tank system failure occurs, it seeps through subsoil and contaminates groundwater unnoticed and this wreaks environmental and public health havoc. The study assessed environmental and public health impacts associated with septic tank systems at Nkwaben South in the Sunyani Municipality**.** This study was based on a mixed method research approach. Laboratory analysis of water and soil samples, structured questionnaire, observations and interviews were used. Purposive sampling was adopted to identify houses with septic tank systems and groundwater sources. Snowball technique was used to identify formally and informally trained professionals. Simple random sampling was used to collect sampled water and soil for laboratory analysis. Microsoft Excel 2016 version and SPSS version 23 were used for data analysis. Findings from the study revealed that, there was microbial contamination of groundwater due to septic tank systems. Also, the study found significant association between the quality of groundwater (temperature, BOD, and Escherichia coli*)* and the distance between groundwater and septic tanks (soak away). Again, Nitrate and total coliform were not affected by seasonal variation. The study also revealed that Soil colour, texture, structure, and permeability were found to influence sewage treatment. Again, the study revealed that water table, distance between water table and bottom of septic tanks, topography and distance between septic tank and groundwater, design life span, family size, topography and climatic conditions were very critical factors considered by building professionals during the design of septic tank system. The result of this study is useful to policymakers in policy promulgation and strengthen sensitization of communities on best practices to minimize or eliminate septic tank system failure and their adverse environmental and public health effects.

Key words; Environmental and public health, groundwater quality, borehole, septic tank, soakaway

1.0 Introduction

Septic tank systems, also referred to as 'on-site wastewater treatment systems,' are extensively adopted in rural and peri-urban areas to discharge wastewater (Selvam et al., 2013a). Septic tank systems eliminate many contaminants and offer some level of protection for human health and for the environment when constructed and functioning well, (Nnaji, 2011). As population increases and aquifers tendency to treat wastewater from increasing quantities of septic tanks is exhausted, water quality progressively deteriorates (Selvam et al., 2013b). Most countries, including local authorities have guidelines promulgated to protect public health against menace caused by septic tank systems. Only few states have enacted effective measures to curtail the increasing menace that septic tank failure poses to water sources. Many countries depend completely on groundwater sources for diverse uses (Thirumalaivasan et al., 2003). Major contaminants of septic tank system failure are nitrogen, phosphorus, ammonia, total dissolved solids, and associated complex organic substances which may be hazardous to human health (Imran et al., 2009). However, increase in population and demand for food and water supplies account for excessive pressure on the groundwater quality and quantity where over-extraction reduces the accessible quantity of groundwater (Selvam et al., 2013c). High levels of nitrate in drinking water may wreak public health threat to humans, particularly in sensitive individuals and infants (Selvam et al., 2013d).

On-site systems are major source of nitrate pollution. No single organization has a comprehensive data to estimate the degree of septic tank failure (Wood & Lee, 1999). Some states have estimated rate of septic tank system failure, but no state has accurate measurement on the rate of failure and failure definitions differ (Nelson et al., 1999). Mostly, available data on septic tank system failure are the results of occurrences which adversely cause public health menace or are attained from house owners' applications for permits/approvals to repair or replace failing septic tank systems (Brown, 1998). Sewage composition may differ from region to region, from place to place due to their composition. Earlier research in Ghana and other countries show a developing trend indicating that, on-site systems regularly discharge pathogens, consumer product chemicals, pharmaceuticals, and other likely disruptive chemicals into the environment. When discharged, these end up in water sources (Ground and surface water supplies), raising health problems (Coleman, 2017).

Most households in Fiapre, a suburb of Sunyani municipality, have toilet facilities without septic tank systems and some adopt a shared septic tank system (Attiogbe et al., 2019). Most households in the study area (Nkwaben South) are connected to Ghana water pipelines while some use hand-dug wells which are close to septic tank systems. Also, excessive nitrogen in water and soil may wreak serious health problems in human species and aquatic lives (Kacaroglou and Gunay, 1997). These diseases can be averted when a systematic approach to the design, construction, and maintenance of the septic tank system is adopted. Water moves easily through coarse-textured soils like sandy soil (Joosten et al., 1998). Water is a finite resource that must be preserved and used wisely considering the increasing population in Ghana.

In order to achieve Ghana’s Sustainable Development Goal 6 (SDG 6), ‘’ to increase the available water resource and achieve high water quality and better wetland resource management, improve sanitation, and the effective management of liquid and solid waste by 2030 (GoG, 2019); water resources must be preserved and not contaminated especially in the rural areas where residents mostly rely on groundwater (hand-dug wells and boreholes) and surface water as main drinking sources. Recent research studies conducted, made an analysis on nitrogen contamination in water and soil samples but did not consider the design of the septic tank system, and maintenance culture of the studied area (Selvam et al., 2013e). This research therefore assessed various contaminants emanating from the negative impacts of septic tanks and their adverse environmental and public health impacts.

2. MATERIALS AND METHODS

2.1 Study Area

The study took place in the Sunyani Municipality (Figure 1). Sunyani is projected to have a population of 151,378 (Ghana Statistical Service, 2019). Sunyani Municipality has a total land area of 506.7 kilometers square. It is the capital of the Bono region, located at 7^{o} 20' 0" N, 2^{o} 20' 0" W. (Google earth). It is bounded on the north by the Sunyani West District; on the west by the Dormaa East District; on the south by the Asutifi District; and on the east by the Tano North District. The district has a bimodal rainfall pattern, with the primary wet season occurring between March and September and the secondary wet season occurring between October and December. The Tano, Amoma, Kankam, Benu, Yaya, and Bisi rivers are seasonal (Ghana

Statistical Service, 2014). Due to its rapid population increase, the Sunyani municipality is currently confronting some environmental and water pollution concerns (Anane, 2013). According to Sunyani Municipal Assembly's Planning Committee Unit (2020), the study area Nkwaben South has a total population of 987, with about 96 houses. 25 houses use groundwater sources while 71 are connected to Ghana water Company.75 houses use water closet connected to septic tank systems,7 houses use VIP latrines and 14 houses use water closet connected to bio digester.

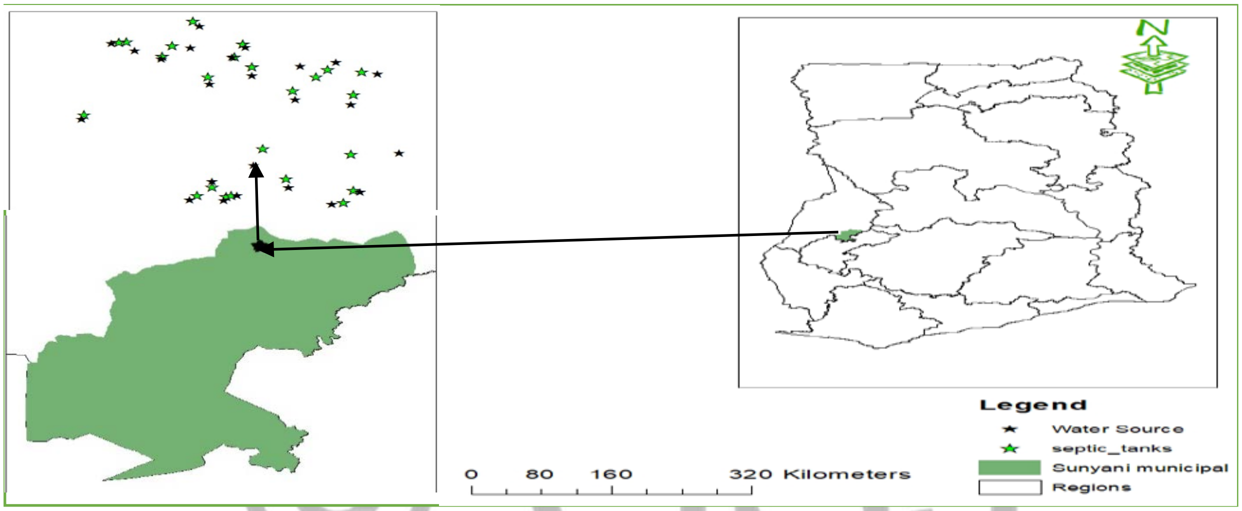

Figure 3.1 Map of Sunyani Municipality showing sampled locations
Source: Author's Construct (2021)

2.2 Study Design

The study adopted a mixed design. Quantitative (laboratory analysis for water and soil samples, and structured questionnaire) and qualitative (interviews and observations).

2.3 Sample Size and Sampling Techniques

Out of 25 houses which had groundwater and septic tanks, 24 water samples were collected. Soil samples were collected from 17 out of 24 sites since 7 sites were paved/concreted, and 20 construction professionals were interviewed. A purposive/judgmental sampling was adopted to identify houses with septic tank systems and groundwater. Simple random sampling was used to select houses for water and soil samples. This provides equal chance of being chosen. Snowball technique was used to identify formally and informally trained professionals for interview on current design criteria of septic tank systems.

2.4 Data collection methods

Measurement of distance between septic tanks and water sources was taken using a tape measure. Depth of the water sources were taken using a filled bottled water prewashed with distilled water and tied to a rope and slowly dunk into the water source. The length was then recorded using a tape measure. Structured questionnaire and interviews were conducted to gather information on the current factors that construction experts consider.

Water sampling was carried out between December 2020 and February 2021 for the dry season and April 2021 and June 2021 for the wet season. Water samples were collected after disinfecting the water tap of mechanized hand dug wells using cotton wool soaked in 70 percent (v/v) ethanol and water allowed to run for 1 minute. Samples were collected in clean, transparent, and sterile 1.5-liter plastic bottles pre-washed with distilled water and rinsed three times with the water sample prior to filling and labelling accordingly. All samples (including multiple/duplicate samples) were preserved at 4 degrees Celsius in an insulated icebox in the field for 2 hours after sample collection and transported to the laboratory for further analysis (Minnesota Pollution Control Agency, 2018). Soil samples were collected in May 2021**.** Soil samples of at least 500g was collected using soil auger at a distance 600 mm away from the soakaway of the septic tank at the depth between 600mm and 1200mm and preserved in polythene bags immediately after collection, stored in ice cool-box and transported to the laboratory for further analysis (USEPA, 1980). Also, undisturbed core samples were taken with a 100 cm^3 aluminium core sampler for bulk density determination.

2.5 Laboratory Analysis

2.5.1 Physicochemical analysis of water

Physicochemical parameters of water samples such as pH, electrical conductivity (EC), temperature, alkalinity, turbidity, ammonium, total hardness (TH), total dissolved solids (TDS), chloride (Cl^-), nitrate (NO_3^-), phosphate (PO_4^{3-}), and biological oxygen demand (BOD_5) were determined in the laboratory using the American Public Health Association's standard methods (APHA 1995, 1998; APHA, AWWA and WEF, 2005). Temperature, pH, Turbidity, EC, and

TDS concentrations were determined with portable water quality analyzers such as a thermometer, pH meter, turbidity meter, electromagnetic induction, and gravimetric. Total hardness (TH) was determined using a volumetric method, whilst chloride (Cl^-) was determined using a volumetric titration method utilizing $AgNO_3$ and K_2CrO_4, HCO_3^-. Nitrate concentrations were determined using the Na.Salicylic technique in conjunction with a UV-VIS Spectrophotometer (APHA, AWWA, WEF 1998). Sulphuric acid titration was used to estimate alkalinity, while a nephelometer and a standard turbidity suspension of 40 NTU were used to determine turbidity. Ammonium concentrations were determined using a 1 cm and 4 cm cells, whereas phosphate concentrations were obtained by adding 400 µL of ammonium molybdate reagent and 400 µL of ascorbic acid reagent to 10 mL of water sample and measuring the developed colour photometrically at 880 nm and determining the phosphate value by absorbance of sample with standard curve and expressed as mg/L. BOD_5 was determined using a bioassay approach, which quantifies the oxygen absorbed by bacteria during the decomposition of organic materials (Sawyer and McCarty, 1978; APHA, AWWA, and WEF, 1992)

2.5.2 Physicochemical analysis of soil

Fresh soil samples were air dried in the laboratory, crushed in a porcelain mortar with a pestle, and sieved through a 2 mm sieve (Benton, 2003). The sieved soil (<2 mm) was analyzed for physicochemical properties of interest using international standard methods (Benton, 2003). All chemicals used for the analysis were of analytical grade. The bulk density of the soils was determined over a soil volume of 100 cm^3. Bulk density is the oven dry (105 ℃) weight of soil per unit volume. It is expressed in g/cm^3 and was calculated from the equation: bulk density = mass of oven dry soil/volume of soil core (100 cm^3). Soil pH was measured with pH meter in a 1:2 soil: distilled water solution ratio in 50 mL disposable centrifuge tubes. Electrical Conductivity (EC) was determined after extraction with distilled water in the ratio 1:5 with a conductivity meter (WTW model). Soil texture and structure was determined by dispersion of soil particles by adding sodium hexametaphosphate (HMP) and using hydrometer to measure the concentrations of various particle sizes using simplified calculation (Gee and Bauder, 1979). Soil horizons were determined after textural classification and various depths recorded in the field while the clay content was calculated from the textural measurement (ie. Clay content = Total depth of soil - (depth of sand + depth of silt). Soil permeability was calculated using $\text{Coefficient of Permeability (k)} = \text{Q x} \frac{\text{L}}{\text{A}} \text{x t x h}$ and corrected to 20 ℃ by multiplying the permeability coefficient (k) by the ratio of the viscosity of water at test temperature to the viscosity of water at 20 ℃. Munsell Color (2000) was used to determine colour content of the soils.

2.5.3 Microbial analysis of water

Microbial contamination of water samples was determined using membrane filtering (Millipore EZ-Pak, 0.45 µm pore size). *E. coli* were counted by incubating on mFC agar (BBL) for 24 hours at 44.5 ℃ (American Public Health Association, 1998). *E. coli* colonies were identified as faecal coliforms with a ring of fluorescence *E. coli* (USEPA, 1991). Using a sensitive and differential membrane filter medium based on MI agar, total coliforms (TC) were detected and counted in 24-hour water samples based on their unique enzyme activities (APHA, AWWA and WEF, 2005). Gram staining was used for sub-culturing and the Gram reaction, shape and arrangement of the bacteria were observed under the oil immersion lens and recorded.

2.6 Data analysis

Water samples were analyzed using descriptive statistics, specifically mean and standard deviations and analysis of variance (ANOVA) while soil samples analysis were assessed using descriptive statistics, specifically mean and standard deviations. Multivariable regression analysis was conducted to see whether there was any correlation between the variables that were found to be significant (distance between septic tanks and groundwater sources and microbial contamination). A 95% confidence interval was employed with p-value of 0.05 as significant.

The socio-demographic characteristics of respondents was sorted for proportions using Microsoft Excel 2016 version and each variable was summarized using descriptive statistics specifically frequency and percentages. Recorded interview was transcribed and analyzed thematically.

3. RESULTS AND DISCUSSION

3.1 Physicochemical and microbial contamination of groundwater

The physicochemical and microbial contamination of groundwater during the dry and wet seasons are shown in Table 3.1. Generally, all the physicochemical parameters, except alkalinity, pH, and BOD assessed were within WHO (2017) guideline for water quality and Ghana Standard Board (GSB, 1997) permissible limits for groundwater. The high levels of BOD during the wet/rainy season could be attributed to the fact the rainy water may flush the waste products into groundwater unnoticed.

The current finding is consistent with a study conducted by Sirajudeen et al., (2013) on ground water in the Ampikapuram area near the Uyyakondan channel in the Tiruchirappalli district of India, which concluded that BOD, among other parameters, is above the WHO's permissible limit for human consumption and domestic use. This could be as a result of rain producing high water table in groundwater which contributes to biodegradable organic contaminants increasing the BOD concentrations. The finding suggests that the groundwater in the area requires some form of treatment before consumption, as well as protection from contamination.

In general, groundwater microbial content exceeded the Ghana Standard Board and WHO acceptable limit of 0. Specifically, during the wet season, total coliform, faecal coliforms, and *E. coli* concentrations were higher than the dry season. Considering the fact that total coliform, faecal coliform and *E. coli* are harmless and found in the intestines of man, the elevated levels of these microorganisms during the wet season is an indication that most septic tanks may be leaking into groundwater. The findings are in line with a groundwater study undertaken in 2010 at Lusaka's high-risk districts, which revealed high levels of bacterial pollution in the groundwater. According to statistics, 60 percent of these groundwater sources had contamination levels of more than 10 total coliforms per 100mL of water, while 30 percent had *E. coli*, a faecal contamination indicator (Andrea et al., 2010). The findings are similar to a research conducted in Bangladesh's Noakhali Region, which found that total coliform and faecal coliform levels are above the WHO's permitted limit.

Four (4) different microorganisms (*Pseudomonas aeruginosa*, *Yersinia spp, Acinetobacter spp and Shigella spp*) with varying health effects detected (Table 3.2). Each year, over 2 million *Shigella spp* infections occur, resulting in roughly 600,000 deaths, the majority of which occur in developing countries (Alamanos et al., 2000). This result corroborates a study conducted by Dissanayake et al. (2004), which discovered that contaminated drinking water accounts for around 80% of all diseases and fatalities among children worldwide. The World Health Organization emphasizes the dangers of drinking contaminated water by children under the age of five, noting that a kid dies every eight seconds as a result of contaminated water consumption (WHO, 2003).

Table 3.1 Descriptive Analysis of Physicochemical and microbial contamination of groundwater

Parameters	Dry season		Wet Season		WHO/Ghana Water Standard
	Mean ± Sd	Min – Max	Mean ± Sd	Min – Max	
pH	6.06 ± 0.32	5.32-6.65	6.48 ± 0.68	4.98-7.73	6.5-8.5
Turbidity (NTU)	1.35 ± 1.38	0-4.31	0.08 ± 1.34	0-0.5	5
Alkalinity (mg/L)	26.38 ± 12.29	10.0-53	113.54 ± 40.17	64-220	20-200
TDS (mg/L)	144 ± 25.69	111-179	166.79 ± 32.53	116-221	600
Electrical Conductivity(µS/cm)	295.21 ± 51.51	220-358	334.25 ± 64.3	234-434	1000
Total hardness (mg/L)	34.69 ± 13.46	16.25-62.5	118.08 ± 27.87	74-175	500
Ammonium (mg/L)	0.14 ± 0.06	0.02-0.24	0.02 ± 0.04	0-0.15	1.5
Phosphate (mg/L)	0.04 ± 0.02	0.02-0.09	0.29 ± 0.08	0.2-0.6	-
Nitrate (mg/L)	2.57 ± 1.55	1.2-8	3.19 ± 1.68	0.01-6.02	10
Chloride (mg/L)	69.48 ± 10.4	52.8-88.75	38.71 ± 16.32	18-68	250
BOD (mg/L)	3.98 ± 0.67	2.91-5.84	5.29 ± 1.09	4.0-8	<5
Temperature	22.88 ± 7.62	26-27.04	28.46 ± 0.36	28-29	acceptable
Total coliform (CFU/100ml)	17.25 ± 14.88	1.0-56	23.42 ± 17.2	2.0-62	0
E. coli (CFU/100ml)	0.63 ± 0.88	0-3	2.33 ± 3.07	0-10	0
Faecal Coliform (CFU/100ml)	1.18 ± 0.15	0-2.6	3.13 ± 2.77	1.1-8	0

(Source: Field work, 2021)

Table 3.2 Microorganisms detected in Sampled Groundwater

Sample (S)	Organism detected	Health Risk/Effect
S2	*Pseudomonas aeruginosa*	Colonizes injured locations including burns and surgical wounds, producing sores, septicaemia, and meningitis.
S5	*Yersinia spp*	acute gastroenteritis with diarrhea, fever and abdominal pain, necrotizing enterocolotis in infants
S6	*Acinetobacter spp*	Infections of the urinary tract, pneumonia, bacteremia, secondary meningitis, and wound infections are all common.
S9	*Shigella spp*	Fever, watery diarrhea, abdominal cramping, nausea and vomiting, bacillary dysentery

(Source: Field work, 2021)

3.2 Level of contamination of groundwater with seasonal variation

Analysis of Variance (ANOVA) was undertaken to assess the level of contamination of groundwater with the seasonal variation. This is shown in Table 3.3. The result shows that there is statistically significance between the physicochemical and microbial parameters of groundwater based on seasonal variation except for Nitrate and Total Coliform. High levels of nitrate in drinking water may wreak public health threat to humans, particularly in sensitive individuals and infants (Selvam et al., 2013f). In a study conducted by Selvam et al. (2013g), nitrates in groundwater source may emerge from natural sources like bedrock, organic material, and soil. The high levels of nitrates may be attributed to anthropogenic sources, mainly agricultural activities and domestic septic tank systems (Selvam, 2012). Nitrate is converted into nitrite in the digestive system, which causes methaemoglobinemia (a rare condition in which the haemoglobin iron is in the ferric or oxidized state and may not reversibly bind oxygen and could cause hypoxemia and death).

The findings are in line with groundwater study undertaken in 2010 at Lusaka's high-risk districts, which revealed high levels of bacterial pollution in the groundwater. According to statistics, 60 percent of these groundwater sources had contamination levels of more than 10 total coliforms per 100 mL of water, while 30 percent had *E. coli*, a faecal contamination indicator (Andrea et al., 2010). The findings are similar to a research conducted in Bangladesh's Noakhali Region, which found that total coliform and faecal coliform levels are above the WHO's permitted limit of 0.

Table 3.3 Analysis of variance of physicochemical and microbial contamination of water

		Sum of Squares	df	Mean Square	F-Stats	P-values
pH	Between Groups	3.76	1.00	3.76	26.07	0.00
	Within Groups	6.63	46.00	0.14		
	Total	10.39	47.00			
Turbidity (NTU)	Between Groups	19.46	1.00	19.46	20.36	0.00
	Within Groups	43.95	46.00	0.96		
	Total	63.41	47.00			
TDS (mg/L)	Between Groups	4820.02	1.00	4820.02	5.60	0.02
	Within Groups	39566.96	46.00	860.15		
	Total	44386.98	47.00			
Alkalinity (mg/L)	Between Groups	91176.33	1.00	91176.33	103.33	0.00
	Within Groups	40587.58	46.00	882.34		
	Total	131763.92	47.00			
E. conductivity (µS/cm)	Between Groups	22403.52	1.00	22403.52	6.59	0.01
	Within Groups	156453.79	46.00	3401.17		
	Total	178857.31	47.00			
T. Hardness (mg/L)	Between Groups	83416.69	1.00	83416.69	174.08	0.00
	Within Groups	22043.17	46.00	479.20		
	Total	105459.85	47.00			
Ammonium (mg/L)	Between Groups	0.16	1.00	0.16	55.60	0.00

	Within Groups	0.13	46.00	0.00		
	Total	0.29	47.00			
Phosphate (mg/L)	Between Groups	0.77	1.00	0.77	234.21	0.00
	Within Groups	0.15	46.00	0.00		
	Total	0.93	47.00			
Nitrate (mg/L)	Between Groups	4.59	1.00	4.59	1.75	0.19
	Within Groups	120.58	46.00	2.62		
	Total	125.18	47.00			
Chloride (mg/L)	Between Groups	11365.82	1.00	11365.82	60.69	0.00
	Within Groups	8615.35	46.00	187.29		
	Total	19981.17	47.00			
Temperature (℃)	Between Groups	81.07	1.00	81.07	94.82	0.00
	Within Groups	39.33	46.00	0.85		
	Total	120.40	47.00			
BOD (mg/L)	Between Groups	20.61	1.00	20.61	24.89	0.00
	Within Groups	38.09	46.00	0.83		
	Total	58.69	47.00			
Total Coliform CFU/100mL	Between Groups	456.33	1.00	456.33	1.77	0.19
	Within Groups	11892.33	46.00	258.53		
	Total	12348.67	47.00			
E. Coli CFU/100mL	Between Groups	35.02	1.00	35.02	6.92	0.01
	Within Groups	232.96	46.00	5.06		
	Total	267.98	47.00			
Fecal coliform CFU/100mL	Between Groups	45.44	1.00	45.44	11.11	0.00
	Within Groups	188.04	46.00	4.09		
	Total	233.48	47.00			

(Source: Field work, 2021)

3.3 Groundwater quality in relation to distance from septic tank system

A multivariable regression test comparing the differences that exist in microbial and physicochemical parameters of septic tank sample in the dry season and wet season was assessed (Table 3.4). The result shows that there is no statistically significance between the physicochemical parameters and quality of ground water based on distance except for temperature at 0.05 significance level. A statistical significance was observed between *E. coli* and distance to ground water (β=0.041, $p=0.008<0.05$). That is, the quality of groundwater is affected by the variation in distance. Again, a statistical significance was observed between BOD (β=0.323, p=0.008<0.05) and distance from ground water. No statistical significance was established between faecal coliform and total coliform at 0.05 significance level.

E. coli has been demonstrated to have a significant impact on the quality of groundwater. That is, the presence of the microorganism *E. coli*. The wet season has a higher concentration of *E. coli* than the dry season. *E. coli* is believed to be of faecal origin since it is always found in high concentrations in the feces of humans (Fujioka et al., 1999). This result corroborates a study conducted by Dissanayake et al. (2004), which discovered that contaminated drinking water accounts for around 80% of all diseases and fatalities among children worldwide. The World Health Organization emphasizes the dangers of drinking contaminated water by children under the age of five, noting that a kid dies every eight seconds as a result of contaminated water consumption (WHO, 2003). Ghana is not an outlier; if this practice persists unabatedly, morbidity and mortality from water-borne infections, which have been highlighted globally as a result of drinking contaminated water, may increase. Since the presence of *E. coli* suggests faecal contamination, as discovered in this study, consideration must be given to corrective measures for consumers in Nkwaben South of Sunyani Municipality. The presence of *E. coli* indicates a failure, such as a failure of disinfection, a failure of pre-disinfection treatment, or the entrance of dirty water into the groundwater source. Immediate precautionary measures must be taken to safeguard consumers until the contamination is completely eradicated.

Table 3.4 Multivariable regression analysis of physicochemical and microbial contamination of water

Distance	Coef.[β]	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
E. Coli	.041	.012	3.49	.008	.014	.068	***
Total coliform	-.209	.135	-1.55	.16	-.52	.102	
Fecal coliform	-.28	.148	-1.89	.095	-.621	.062	*
BOD	.323	.093	3.48	.008	.109	.536	***
pH	.491	.245	2.00	.08	-.075	1.057	*
Turbidity	.094	.053	1.76	.116	-.029	.217	
Alkalinity	.02	.007	2.99	.017	.005	.035	**
TDS	-.004	.003	-1.63	.141	-.01	.002	
E. conductivity	.003	.001	2.46	.039	0	.005	**
T. Hardness	.009	.005	1.86	.1	-.002	.02	
Phosphate	4.091	3.26	1.25	.245	-3.427	11.609	
Nitrate	.005	.048	0.10	.92	-.106	.116	
Temperature	.272	.067	4.08	.004	.118	.426	***
Chloride	.01	.006	1.62	.143	-.004	.025	
Ammonium	1.114	1.177	0.95	.372	-1.601	3.828	

Constant	-13.63	2.854	-4.78	.001	-20.215	-7.053	***

Mean dependent var	0.125	SD dependent var	0.338
R-squared	0.856	Number of obs	24
F-test	3.167	Prob > F	0.052
Akaike crit. (AIC)	0.510	Bayesian crit. (BIC)	19.358

*Note: *** $p< 0.01$, ** $p< 0.05$, * $p< 0.1$*

(Source: Field work, 2021)

3.4 Physicochemical characteristics of soil around soakaways that influence sewage treatment

The physicochemical characteristics of soil around soakaways that influence sewage treatment. Soil samples (17 out of 24 samples, since 7 sites were paved) around soakways were collected (Table 3.5). From each site, three samples (horizon (H) 1, 2 and 3) were collected for analysis. Most observed soil structures were bulky, platy, or granular in nature. This demonstrates that soils with a well-structured structure and large spaces between peds will transport water more quickly than soils with no good structure of comparable texture (Bouma, 1975a). This means that fine-textured, massive or blocky soils percolate at an exceedingly slow rate; hence, good for sewage treatment. Additionally, it was observed that soil texture influences the amount of water that seeps into the soil. The soil's structure and texture help determine its permeability and bulk density which retains water and influence sewage treatment. While soils with comparable textures have comparable bulk densities, those with higher bulk densities are more compact and have smaller pore volumes. Reduced porosity reduces the hydraulic conductivity of the soil (Bouma, 1971). Additionally, a range of soil colours was observed at various locations. As a result, soil colour patterns provide excellent indicators of the likely soil's texture and drainage properties. Water mobility in soil is influenced by soil properties, topography, and climate. These variables contribute to the saturation or seasonal saturation of particular soils, reducing their capacity to absorb and treat wastewater (Bouma, 1975b).

Table 3.5 Descriptive analysis of Physicochemical characteristics of soil samples around soakaways

Sample	**Total Depth (cm)**	**colour**	**Density (g/cm3)**	**Permeability (cm/hr)**	**Clay content (%)**	**Textural class**	**Structure**	**pH**

S1	H 1	101.5	Reddish Brown	1.300	2.12	10	Silty Loam	Granular	6.54
	H 2		Dark Reddish Brown	1.489	1.97	6	Silty Loam	Granular	6.76
	H 3		Red	1.155	2.02	19	Silty Loam	Granular	6.56
	Mean ± SE			1.315 ± 0.097	2.037 ± 0.044	11.675 ± 3.721			6.62 ± 0.070
S2	H 1	98	Light Red	0.615	1.05	39	Silty Clay Loam	Blocky	5.75
	H 2		Light Reddish Brown	1.207	0.98	39	Silty Clay Loam	Blocky	5.89
	H 3		Dark Reddish Brown	0.937	0.53	44	Silty Clay	Massive	6.45
	Mean ± SE			0.920 ± 0.171	0.853 ± 0.163	40.473 ± 1.674			6.03 ± 0.214
S3	H 1	71.5	Reddish Brown	1.243	1.02	30	Silty Clay Loam	Blocky	7.23
	H 2		Light Red	1.353	1.06	37	Sandy Clay	Platy	6.98
	H 3		Light Reddish Brown	1.063	1.41	25	Sandy Clay Loam	Platy	7.35
	Mean ± SE			1.220 ± 0.085	1.163 ± 0.124	30.726 ± 3.635			7.187 ± 0.109
S4	H 1	85	Light Reddish Brown	1.467	0.25	32	Silty Clay Loam	Blocky	5.54
	H 2		Light Reddish Brown	1.253	0.32	20	Silty Loam	Granular	5.86
	H 3		Light Reddish Brown	1.272	0.19	44	Silty Clay	Massive	5.56
	Mean ± SE			1.331 ± 0.068	0.253 ± 0.038	31.895 ± 6.845			5.653 ± 0.103
S5	H 1	82.5	Light Reddish Brown	1.356	0.075	100	Clay	Blocky	6.54
	H 2		Reddish Brown	1.272	0.07	100	Clay	Blocky	6.75
	H 3		Reddish Brown	1.045	0.072	100	Clay	Blocky	6.45
	Mean ± SE			1.224 ± 0.093	0.072 ± 0.001	100 ± 0			6.58 ± 0.089
S6	H 1	92.7	Reddish Brown	1.277	0.24	18	Silty Loam	Granular	5.95
	H 2		Pale Red	1.061	0.22	100	Clay	Blocky	5.94
	H 3		Weak Red	1.390	0.2	29	Silty Loam	Granular	5.64
	Mean ± SE			1.243 ± 0.097	0.220 ± 0.012	49.034 ± 25.681			5.843 ± 0.102
S7	H 1	105.5	Reddish Brown	1.300	2.14	12	Silty Loam	Granular	6.34
	H 2		Dark Reddish Brown	1.500	1.95	8	Silty Loam	Granular	6.75
	H 3		Red	1.156	2.05	19	Silty Loam	Granular	6.65
	Mean ± SE			1.319 ± 0.100	2.047 ± 0.055	13 ± 3.215			6.58 ± 0.123
S8	H 1	102	Light Red	0.625	1.03	40	Silty Clay Loam	Blocky	5.73
	H 2		Light Reddish Brown	1.217	0.96	37	Silty Clay Loam	Blocky	5.87

	H 3		Dark Reddish Brown	0.926	0.52	42	Silty Clay	Massive	6.54
	Mean ± SE			0.837 ± 0.160	0.837 ± 0.160	39.667 ± 1.453			6.047 ± 0.250
S9	H 1	89.5	Reddish Brown	1.253	1.04	32	Silty Clay Loam	Blocky	7.21
	H 2		Light Red	1.354	1.08	37	Sandy Clay	Platy	6.95
	H 3		Light Reddish Brown	1.064	1.43	22	Sandy Clay Loam	Platy	7.53
	Mean ± SE			1.224 ± 0.085	1.183 ± 0.124	30.333 ± 4.410			7.23 ± 0.168
S10	H 1	105	Light Reddish Brown	1.478	0.24	34	Silty Clay Loam	Blocky	5.34
	H 2		Light Reddish Brown	1.254	0.35	22	Silty Loam	Granular	5.82
	H 3		Light Reddish Brown	1.262	0.23	43	Silty Clay	Massive	5.36
	Mean ± SE			1.331 ± 0.073	0.273 ± 0.038	33 ± 6.083			5.507 ± 0.157
S11	H 1	93	Light Reddish Brown	1.361	0.067	100	Clay	Blocky	6.52
	H 2		Reddish Brown	1.253	0.08	100	Clay	Blocky	6.57
	H 3		Reddish Brown	1.046	0.074	100	Clay	Blocky	6.42
	Mean ± SE			1.220 ± 0.092	0.074 ± 0.004	100 ± 0			6.503 ± 0.044
S12	H 1	109.5	Reddish Brown	1.275	0.25	21	Silty Loam	Granular	5.97
	H 2		Pale Red	1.062	0.24	100	Clay	Blocky	5.96
	H 3		Weak Red	1.390	0.2	30	Silty Loam	Granular	5.62
	Mean ± SE			1.242 ± 0.096	0.23 ± 0.015	50.333 ± 24.969			5.85 ± 0.115
S13	H 1	108.5	Light Red	0.625	1.07	39	Silty Clay Loam	Blocky	5.78
	H 2		Light Reddish Brown	1.217	0.96	39	Silty Clay Loam	Blocky	5.91
	H 3		Dark Reddish Brown	0.947	0.54	42	Silty Clay	Massive	6.46
	Mean ± SE			0.930 ± 0.171	0.857 ± 0.161	40 ± 1			6.05 ± 0.208
S14	H 1	110	Reddish Brown	1.244	1.05	32	Silty Clay Loam	Blocky	7.22
	H 2		Light Red	1.353	1.08	38	Sandy Clay	Platy	6.95
	H 3		Light Reddish Brown	1.073	1.47	22	Sandy Clay Loam	Blocky	7.3
	Mean ± SE			1.223 ± 0.081	1.200 ± 0.135	30.667 ± 4.667			7.157 ± 0.106
S15	H 1	108.8	Light Reddish Brown	1.457	0.27	32	Silty Clay Loam	Blocky	5.34
	H 2		Light Reddish Brown	1.253	0.35	22	Silty Loam	Granular	5.84
	H 3		Light Reddish Brown	1.262	0.17	43	Silty Clay	Massive	5.52
	Mean ± SE			1.324 ± 0.066	0.263 ± 0.052	32.333 ± 6.064			5.567 ± 0.146

S16	H 1	112.5	Light Red	0.615	1.04	39	Silty Clay Loam	Blocky	5.35
	H 2		Light Reddish Brown	1.207	0.95	37	Silty Clay Loam	Blocky	5.81
	H 3		Dark Reddish Brown	0.947	0.52	42	Silty Clay	Massive	6.35
	Mean ± SE			0.923 ± 0.171	0.837 ± 0.160	39.333 ± 1.453			5.837 ± 0.289
S17	H 1	113.5	Reddish Brown	1.237	1.05	32	Silty Clay Loam	Blocky	7.32
	H 2		Light Red	1.350	1.06	38	Sandy Clay	Platy	6.95
	H 3		Light Reddish Brown	1.063	1.43	22	Sandy Clay Loam	Blocky	7.29
	Mean ± SE			1.216 ± 0.083	1.18 ± 0.125	30.667 ± 4.667			7.187 ± 0.119

Note: S represent Sample and H denote Soil Horizon.

3.5 Current factors considered by professionals in the design and installation of septic tank systems

Details of the current factors considered by professionals in the design and installation of septic tanks in Nkwaben South is presented in Table 3.6. According to the study, a variety of factors influence the design and construction of septic tanks. The water table, geology, and distance between the septic tank and the water source are only a few of the factors uncovered. According to Howard et al. (2006), a biologically active layer forms in the soils surrounding soakaways and takes time to develop the ability to eliminate pathogens by predation and filtering. This indicates that groundwater from hand dug wells adjacent to newly constructed soakaways may get contaminated with faecal coliform bacteria if site selection criteria are not considered. The study discovered that prior to constructing a septic tank, design criteria such as the type of construction materials, the durability of the septic tank, the size of the household, and the climatic conditions are all relevant. As indicated by participant 2 ("*make sure it is not close to the hall, bedroom, kitchen or well and also check for where cars will park or where children will play or where erosion would not take place")*, it is consistent with Obropta and Berry (2005), who suggest that driving or parking on septic tanks and areas adjacent to soakaways compacts the soil and may cause damage to pipes, tanks, or other septic tank system components. As a result, this could have a detrimental effect on the performance of the septic tank system, as untreated effluent could leak, contaminating topsoil and eventually seeping into the ground.

Table 3.6 Descriptive analysis of current design criteria considered by professionals in designing and installation of septic tank systems

Current Factors considered by professionals during design and installation of septic tanks	**Responses (%)**				
	Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Site selection variables					
Consideration for water table	45	50	5	0	0
Separation distance between bottom of septic tank system and water table	25	65	10	0	0
Distance between septic tank system and water sources	85	15	0	0	0
Type of subsoil / Soil strata	30	35	35	0	0
Design variables					
Type of material for construction	20	40	40	0	0
Size of soakaway	10	30	60	0	0
Design life span	15	55	30	0	0
Unsaturated soil for soakaway	15	20	65	0	0
Size of family or users	25	70	5	0	0
Consideration for Topography	80	20	0	0	0
Climatic conditions	50	45	0	5	0
Maintenance practice	0	30	65	5	0
Installation/construction variables					
Construction material	20	50	30	0	0
Materials for designing the mound (layers) of a drainfield	20	50	30	0	0
Flooding by groundwater	0	5	35	55	5
Operation and maintenance variables					
Geographical location	0	0	60	35	5
Regular inspection and pumping of tank	0	10	60	30	0
Nature of the contaminant	0	10	60	25	5
Clogging by roots	0	5	35	55	5
Damage from vehicle traffic	0	5	35	60	0

(Source: Field work, 2021)

Qualitative Analysis of Current factors considered by professionals in the design and installation of septic tank systems

There is a common trend from the responses gathered on the basic requirements for constructing a septic tank. The topography of the land, that is, level ground is an essential requirement commonly considered prior to the construction of a septic tank. Also, the distance of the septic tanks from the hall and kitchen are essential considerations prior to the construction of the septic tank. The season is also an important consideration.

> *"We check for level ground, also check where will be suitable for fixing the pipe which will flow freely to see if after fixing the pipe it can flow properly. Also, we look out for a*

> *place which is not closer to the hall and we check for intervals too"* (Participant 1, male, mason).

> *"We check the land for a level ground where after laying the pipe it will go, also make sure it is not close to the hall, bedroom, kitchen or well and also check for where cars will park or where children will play or where erosion would not take place"* (Participant 2, male, mason).

Almost all the participants could provide an exact estimate for the construction of a septic tank. While some of the participants indicated they use their 'experience' to gauge a suitable distance, others use a range they consider as appropriate. One of the participants said that

"ideally 50 meters but sometimes people consider like 30 meters especially in households where you know the usage of latrines is different from public ones and you should know that the frequency in which that thing is going to be built up will be different so you consider that one too" (Participant 3, male, professional). Some of the participants are quoted as;

> *"Sometimes there'll be a well already constructed in the house so you'll calculate the proximity of the pipe to the manhole to see where will be suitable for the construction of the manhole so that there won't be any disease in the water due to leakage"* (Participant 5, male, construction Engineer)

> *"We don't take any measurement. We just eye gauge the proximity of where they've drilled their pipe to where the manhole will be to not create problems"* (Participant 4, male, mason)

Two of the participants described how they design a soak away. Apparently, the design of the soak away is reliant on the available land and the 'demand' by the customer. One of the participants explained that *"we design the soak away in such a way that the bathroom and kitchen waste comes in…we create holes in the soakaway for the water to seep out"* (Participant 5, male, mason). Another participant gave a detailed explanation on what inform the design of a septic tank as;

> *"We sometimes do a septic tank behind the manhole for just bathroom waste, we don't cover it .it is purposely for the bathroom and kitchen wastewater and those don't go into the manhole. with the division of the manhole into 3 parts, the bathroom wastewater doesn't go into that sometimes so when the 2 halves become full, the water that fills it is what spills into the soak away. So, the third one can remain empty for a long time, and it*

ends up being filled with sand. When you lay the last one on the side, nothing goes into that one until the other 2 becomes full" (Participant 7, male, contractor)

4. CONCLUSION

The study concludes that levels of physicochemical quality of groundwater due to septic tanks (soakaway) were mostly found to be within permissible limits and therefore safe. However, groundwater sources in the study area could be contaminated with microbial load due to wastewater effluent from septic tanks and therefore unsafe for consumption unless treatment measures such as boiling and treatment with chlorine is applied. It was established that the presence of soak away to a source of drinking water could expose residents to water-borne diseases such as diarrhoea, dysentery, as a result of the presence of microorganisms such as *Pseudomonas aeruginosa, Yersinia spp, Acinetobacter spp, and Shigella spp.* If treatment is not done due to the high level of microbial contaminations, continuous consumption of the drinking water sources may wreak severe public health effects in the study area. The quality of drinking water (groundwater) is influenced by its distance from the septic tank. Thus, the farther away the septic tank from the source of water, the less microbial (*E. coli*) and some physicochemical contamination and better quality of the drinking water and vice versa. Additionally, seasonal variation was found to influence quality of drinking water. That is, the level of microbial contamination during wet season exceeds contamination during dry season, though both season's microbial load exceeded permissible limits by Ghana Standard Board and WHO. Again, Nitrate and Total coliform were parameters which were statistically affected by seasonal variations. Temperature, BOD, and *E. coli*, were parameters identified to affect quality of groundwater based on distance. However, if standard distance between septic tanks and water sources are not ensured, level of physicochemical and microbial contaminations may exceed permissible limits which could have adverse environmental and public health effects. Hence, households should construct water sources within standard distance from septic tank systems (soakaways). It is imperative for District Assembly Engineers to supervise the construction of septic tanks in Nkwaben South of the Sunyani Municipality to prevent groundwater contamination. Since the physicochemical characteristics of soil are essential in sewage treatment, especially unsaturated soil, soil characteristics must be properly investigated during the design of septic tanks to avert any environmental menace.

Only one microbial parameter, *E. coli*, was observed to be affected by groundwater quality based on distance. However, if standard distance between septic tanks and water sources are not ensured, level of physicochemical and microbial contaminations may exceed permissible limits which could have adverse environmental and public health effects. Factors such as water table, distance between water table and bottom of septic tanks, topography and distance between septic tank and groundwater, design life span, family size, topography and climatic conditions are site selection criteria that influence the suitability of septic tank construction.

Suggestions for further studies.

A longitudinal study can be undertaken to estimate the effect of water-borne diseases as a result of the construction of boreholes near septic tanks (soakaways).

Conflict of interest

The author declares no conflict of interest

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

Available on request from CD

Declarations of interests

None

Submission declaration and verification

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Authors' contribution

CD developed the search strategy, screened all articles, supervised the work, and drafted the first version of the manuscript. CD conceptualized the research questions and interpreted the result of the final version of the manuscript.

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REFERENCES

Alamanos, Y. (2000). A community waterborne outbreak of gastro-enteritis attributed to *Shigella sonnei*. Epidemiology and Infection, 125:499–503.

American Public Health Association (APHA) (1998). Standard methods for the examination of water and wastewater. 20th Edition. Washington, D.C.: American Public Health Association.

American Public Health Association (APHA) (1995). Standard methods for the examination of water and wastewater. 19^{th} Edition,

Anane Edward Twum (2013). Environmental challenges facing a growing city Sunyani case study

Andrea, N., Museteka, L. & Kringel, R. (2010). Hydrochemical sampling of groundwater in the Lusaka urban area and preliminary findings technical note no. 3. Development of a Groundwater Information and Management Program for the Lusaka Groundwater Systems, Republic of Zambia Ministry of Energy and Water Development.

APHA, AWWA and WEF (2005) Standard Methods for the Examination of Water and Wastewater, centinial addition, Language Learning. doi: 10.1111/j.1467-9922.2010.00586.x.

APHA, AWWA, WEF (1992). Standard Methods for the Examination of Water and Wastewater (SMEWW). Prepared and published jointly by American Public Health Association, American Water Works Association and Water Environment Federation, 18th Edition

Attiogbe Francis., Andrews, N., & Francis, A.K. (2019). Shared household septic tank: A case study of Fiapre in the Brong Ahafo Region of Ghana

Benton, J.J.J. (2003). Agronomic handbook- management of crops, soils, and their fertility. CRC Press LLC. ISBN: 0-8493-0897-6, USA.

Bouma, J. (1975). Unsaturated flow during soil treatment of septic tank effluent. J. *Environ. Eng., Am. Soc. Civil Eng.*, 101:967-983.

Bouma, J. (1971). Evaluation of the field percolation test and an alternative procedure to test soil potential for disposal of septic tank effluent. *Soil Sci. Soc. Amer. Proc*. 35:871-875.

Brown, R.B. (1998). Soil and septic systems. IFAS Extension. University of Florida, Gainesville Bureau of Indian Standards (1993)

Coleman Paa Kwesi (2017). Septic tank systems: Major source of emerging contaminants in our drinking water

Dissanayake S, Dias S, Perera M, Iddamalgoda I (2004). Microbial quality assurance of drinking water supplies through surveillance Proceedings of the Water Professionals Symposium, (WPS'04). Colombo. Sri Lanka. pp. 141-147.

Fujioka R, Sian-Denton C, Borja M, Castro J, Morphew K (1999). Soil: the environmental source of Escherichia coli and enterococci in Guam's streams.

Gee G. W., Bauder J. W. (1979). Particle size analysis by hydrometer: A simplified method for routine textural analysis and a sensitivity test of measurement parameters

Ghana Standards Board (1997). Specification for drinking water, Part 1, Quality Requirements (GS-PT.1:1997).

Ghana Statistical Service (2014). District Analytical Report -Sunyani Municipality

Government of Ghana (2019). Voluntary national review report on the implementation of the 2030 agenda for sustainable development

Howard, G., Schmoll, O., Chilton, J., Chorus, I., World Health Organization Water, & Sanitation and Health Team. (2006). Protecting groundwater for health; managing the quality of drinking-water sources. World Health Organization. https://apps.who.int/iris/handle/10665/43186

Imran Dar A., Mithas Dar A., Sankar K. & Arab. J. G., (2009). Nitrate contamination in groundwater of Sopore town and its environs, Kashmir, India

Joosten, L.T.A., Buijze, S.T. & Jansen, D.M. (1998). Environmental pollution - Nitrate in sources of drinking water? Dutch drinking water companies aim at prevention

Kacaroglou F. & Gunay G. (1997). Nitrate pollution in the coastal aquifer system of the Korinthos Prefecture (Greece)

Minnesota Pollution Control Agency (2018). Standard operating procedures. Intensive watershed monitoring- Stream water quality component

Munsell (2000). Munsell soil color charts. New Windsor, N.Y: Gretag Macbeth

Nelson Mark, Matt Finn, Cherie Wilson, Bernd Zabel, Mark van Thillo, Philip Hawes, Rodrigo Fernandez (1999). Bioregenerative recycling of wastewater in biosphere 2 using constructed wetland: 2–year results

Nnaji, C. C. (2011). Improving septic tank performance by a new rational design approach

Obropta C, Berry D (2005). Onsite Wastewater Treatment Systems: The Maintenance and Care of Your Septic System, Rutgers Cooperative Research & Extension, Agricultural Experiment Station, Rutgers, the State University of New Jersey,

Sawyer N. Clair, Perry L. McCarty (1978). Chemistry for environmental engineering

Selvam, S., Manimaran, G., & Sivasubramanian, P. (2013). Cumulative effects of septic system disposal and evolution of nitrate contamination impact on coastal groundwater in Tuticorin, South Tamilnadu, India.

Sirajudeen, J., Manikandan, A.S., & Manivel, V. (2013). Water quality index of ground water around Ampikapuram area near Uyyakondan channel Tiruchirappalli District, Tamil Nadu, India. *Archives of Applied Science Research*, 5 (3):21-26

Sunyani Municipal Assembly (2020). Municipal planning committee unit; Medium term development plan

Thirumalaivasan D, Karmegam M & Venugopal K. (2003). Software for specific aquifer vulnerability assessment using DRASTIC Model and GIS, 18 (7), 1-12

United States Environmental Protection Agency (1991). An overview of the environmental monitoring and assessment program. EMAP monitor.EPA-600/M-90/022.US.EPA, Office of research and development, Washington, D.C

United States Environmental Protection Agency (1980). Design manual for onsite wastewater treatment and disposal systems

Wood A. Yvonne and Lee D. Brad (1999). Septic system failure

World Health Organization (2017). Guidelines for drinking water quality; first addendum to the 4th Edition.

World Health Organization and Organization for Economic Co-operation and Development (2003). Assessing microbial safety of drinking water-Improving approaches and methods.