Volume 9, Issue 5, May – 2024 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24MAY1004

The Impact of Pit Latrines on the Pollution of Groundwater in the District of Rwamagana, Rwanda

NDAGIJIMANA INNOCENT
Department of Environmental and Development Studies,
University of Lay Adventists of Kigali, P.O Box 6392 Kigali, Rwanda

Abstract:- The composition and condition of a water body change over time and across different locations due to internal and external factors. In many rural and peri-urban communities in Rwamagana, the lack of treated water has increased reliance on groundwater for various household and community needs. Groundwater sources are essential for meeting the water demand in these regions. An investigation was carried out in the Rwamagana district of the eastern province of Rwanda to evaluate the influence of pit latrines on groundwater quality. The research examined the water quality of four boreholes with hand pumps and 18 improved springs located near pit latrines. The evaluation specifically looked at total coliforms (TC), electrical conductivity (EC), turbidity, and pH. The proximity of the pit latrines to the boreholes or springs was considered in order to determine the presence of fecal coliforms in the groundwater, with the goal of establishing a minimum safe distance between the pit latrines and water sources. The physicochemical indicators of the water samples met the drinking water quality criteria set by the World Health Organization (WHO). However, the levels of biological contaminants exceeded the WHO's drinking water quality standards. The highest coliform counts detected in the study were 99cfu/100ml of water. The research findings suggest a clear relationship between fecal microbes from pit latrines and their impact on groundwater quality, with the contamination effect extending up to 322.4m for improved springs and 266.2m for boreholes with hand pumps.

Keywords:- *Contamination; Water Quality; Pit Latrines; Boreholes with a Hand Pump.*

I. INTRODUCTION

Safe drinking water is often seen as a fundamental human requirement and a crucial element of civilization. Developed countries have started assessing and categorizing water quality as water is a finite natural resource. Many people in underdeveloped nations residing in unplanned areas like slums do not have access to sufficient and safe water (Cronin, A. A., Hoadley, A. W., Gibson, J., Breslin, N. and F. K., Haldin, L., 2007). Such people rapidly increase due to high population growth, particularly in peri-urban and rural regions. The United Nations has predicted a fast urban population growth between 2000 and 2030, leading to a decrease in municipal sanitation and the availability of safe drinking water (WHO, 2011b). Rwanda's rapid expansion and economic progress have caused an increase in the number of impoverished individuals living in informal settlements, putting strain on the country's environmental health resources (MININFRA, 2016).

Communities in informal settlements lack essential government services such as clean water, sewage, and waste disposal. This results in poor environmental and sanitary conditions, endangering people's health. It's widely known that children from underprivileged families in urban or densely populated areas have worse health outcomes compared to children from affluent households. According to a recent survey, 27.6% of urban Rwandans lack access to safe drinking water. The situation is even more dire in rural areas, where only 56.8% of the population can obtain safe drinking water (NISR, 2018). Consequently, providing clean, dependable, and safe drinking water in rural areas and urban slums remains challenging despite the larger population. When clean water is unavailable, people are compelled to consume contaminated water, spreading water-borne diseases (Haruna, R., Ejobi, F., & Kabagambe, 2005).

Human excrement is disposed of without treatment at on-property disposal sites such as pit latrines. By their very design, pit latrines create concerns about contamination of groundwater, particularly boreholes and springs on the land that are used as drinking water sources. Pit latrines are not recommended in this situation unless the water table is shallow and the soil characteristics are unlikely to contribute to the sensitivity to groundwater pollution (Kulabako, N. R., Nalubega, M., & Thunvik, 2007). One of the essential variables affecting pathogenic organism removal and eradication from groundwater is the adjustment of wastewater's initial concentration between the source of contamination and the point of water abstraction. Due to very low unsaturated flow velocities, the unsaturated zone contains the key to defense against fecal pollution of aquifers (Majuru B, Michael MM, Jagals P, 2011). The water well should be located topographically higher than the pit latrine site, at least 322 meters away from the pit latrine, and at least 2 meters above the water table, despite the difficulty of providing a general guideline for all soil conditions. Pit latrines and groundwater aquifers coexisted in the past, mostly in rural locations where land was not a limitation for the necessary distance between pit latrines and boreholes, according to JICA's Rwasom project (JICA, 2019). Poor hygienic practices, such as open defecation by children and waste dumping near wells, allow bacteria and other organisms to migrate from fecal contents into underground water due to the proximity of pit latrines to boreholes in urban slums. Contamination and the spread of water-borne diseases could arise because of this.

The presence of biological, chemical, and physical impurities and environmental and human activities in drilled well water affects its quality. Previous studies on groundwater quality in Rwanda have primarily focused on the impact of leachate from waste dump sites, with little or no consideration given to other on-site sanitary conditions, particularly the effects of pit latrines, according to literature data. There are no specific guidelines for placing wells near pit latrines, and acceptable distances must be determined for each case due to the varying dynamics of different contaminants in different subsurface soils. In the Rwamagana district, appropriate intervention options should be identified to enhance groundwater protection, including measures related to pit latrines and boreholes to ensure water potability.(Reddy, D. V., Nagabhushanam, P., & Peters, 2011).

II. MATERIALS AND METHODS

A. *Study Area*

RWAMAGANA is a district in Eastern Province, Rwanda. Its capital is KIGABIRO city, which is also the provincial capital.

- Its total area is 682km^2,
- Population (2012 census): 313,461
- Density: 460/km^2

Water samples have been taken from 24 springs and nine boreholes in 10 sectors, namely: MUYUMBU, FUMBWE, KIGABIRO, KARENGE, GISHARI, GAHENGERI, MUNYAGA, MUHAZI, NZIGE, and NYAKALIRO.

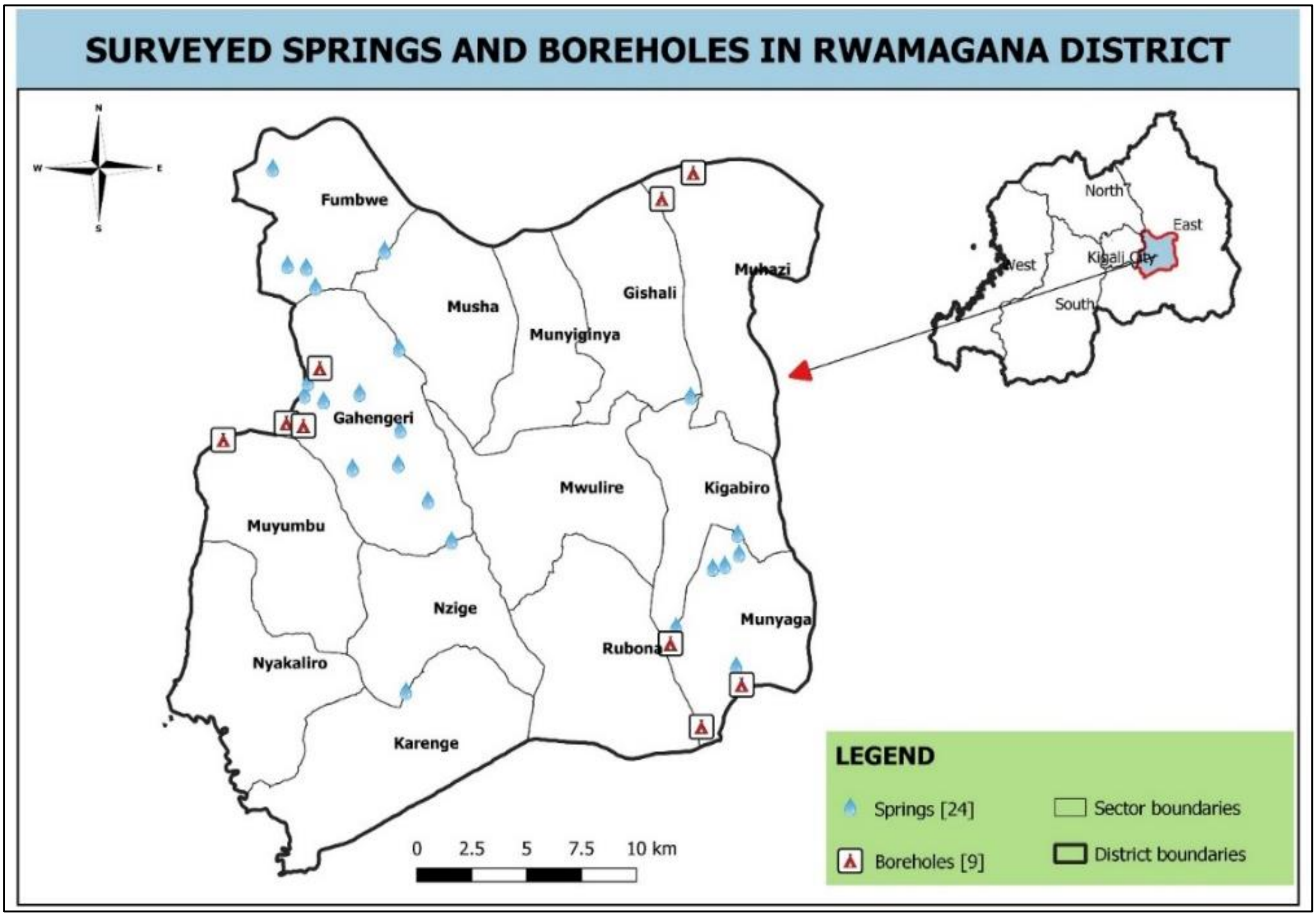

Fig 1: Map of Surveyed Springs and Boreholes

B. *Water Resources*

RWAMAGANA District disposes of essential resources in water issues because water sources are rare, and the identified sources are at a lower elevation than the position of villages to be served, which requires the use of pumps.

The most significant water source is the lake MUHAZI, located near RWAMAGANA. Water was treated and distributed through the pipeline. Due to the topography of this district, the water failed to reach all villages. Therefore, boreholes and protected springs are used as an alternative source of drinking water.

Table 1: Number of Sampled Springs and Boreholes

Sector	Number of boreholes	Number of springs
Fumbwe	0	5
Gahengeri	3	10
Kigabiro	0	1
Muhazi	2	0
Munyaga	3	6
Muyumbu	1	0
Nzige	0	2
Total	9	24

C. *Fieldwork*

- *Preliminary Survey*

In August 2019, an initial investigation of the study area was conducted. The survey involved gathering current groundwater data to determine the main characteristics of the natural groundwater quality within the specific area and to serve as a reference for assessing variations over time, potentially influenced by pit latrines.

- *Sampling*

A total of 33 samples were taken from groundwater, nine from boreholes, and 24 from springs, as indicated in the table provided. Sampling stations were chosen near pit latrines. The stations were sampled both during the wet (short rains) and dry seasons. Water samples were gathered in clean 500ml plastic bottles after being cleaned with O.1m HN03 (aq) and rinsed three times with the water being sampled. When collecting samples from each borehole, a hand pump was used to pump at least three casing volumes of water to waste before collection. In wells, samples were collected by lowering a weighted bottle (a bottle with weights inside to aid sinking) to the water level, while in springs, samples were collected from the reservoir pipe.

D. *Analytical methods*

Measurements of dissolved oxygen, pH, and conductivity on-site were carried out using a pH meter (Oenway Model 3100), an oxygen meter (Jenway Model 9010), and a conductivity meter (Jenway Model 4070) respectively. The temperature was gauged using a temperature probe connected to the pH meter. The chemical oxygen demand was established using the dichromate reflux method. Biochemical oxygen demand (BOD) was computed based on the variance in dissolved oxygen levels over five days of sample incubation. Before incubation, aeration was conducted using an aerator.

TSS was determined by filtering 100ml of a sample using 0.45µm filter paper, followed by drying the filter paper with solids in a 60°C oven for 30-50 minutes before weighing. The samples for chemical and bacteriological analysis were transported to the laboratory in an ice pack at approximately 4oC. The reagent containers were rinsed with distilled water prior to being filled with the water samples for chemical analysis. The water samples collected were stored in a sterile 500mL container that had been rinsed three times with the sample water before being collected for analysis. The chemical and bacteriological parameters of the water samples were examined using membrane filtering methods. A membrane filtration approach was used for bacteriological analysis, and an Inductively Coupled Plasma (ICP) spectrophotometer was used for hydrochemical analysis. To perform total and fecal coliform tests, 100 samples were filtered using a 0.45 m Millipore membrane filter and a vacuum pump. The membrane was cultured for 24 hours on Slantez and Bartley media at 37°C and 45°C, respectively, for fecal and total coliform, and for 48 hours on Membrane Lauryl Sulphate broth (MLSBOXOID MM0616) at 45°C for fecal streptococci, after a one-hour recovery period. Bacteria on the membrane developed visible colonies. These colonies were counted and converted to a count per 100ml using a membrane counter. Cations and anions were studied at low concentrations (0.01g/L) using coupled plasma-mass spectrography (ICPMS- Japan 7500). Major cations (0.1 mg/L) were determined using Coupled Plasma Optical Emission Spectrography (ICP-OES-5300, DV, USA). After removing the outliers, the fecal coliform (FC) values were regressed against the measured distances from the groundwater to the pit latrines to determine the minimum distance between the pit latrines and the groundwater.

III. DISCUSSION OF THE RESULTS

A. *Physico-Chemical Quality*

The results showed that the samples' physicochemical parameters were typically aligned with WHO drinking water quality criteria. Turbidity was only detected in a sample taken from a borehole in the Gahengeri sector, which was determined to be 9NTU. Turbidity in drinking water is caused by particle matter in the water source due to insufficient filtering. These particles can both shield germs against disinfection and accelerate bacterial growth. The nitrate levels were under the WHO's 50 mg/l nitrate in drinking water recommendation. A high nitrate concentration in surface and shallow groundwater often indicates contamination and can be attributed to poor sanitation and latrine building. The pH ranged from 6.1 to 8.4 on the scale. The highest pH value was found in a sample taken from a borehole that had been adequately capped at the top. On the other hand, the observed pH levels were within the acceptable range for drinking water quality recommendations. Electrical conductivity measurements varied from 325 to 989 S/cm within WHO standards.

B. Bacteriological Quality

Total coliform and fecal coliform in drinking water should have zero readings (0cfu/100ml) (WHO, 2011a). According to the findings, bacteriological parameters (total coliform) in 60 percent of springs and 55 percent of borehole samples studied were considerably over-acceptable, making them unfit for drinking without treatment. The sample had a maximum total coliform bacteria count of 99cfu/100ml. The closeness of pit latrines to wells was found to play a significant role in the bacteriological contamination of groundwater. Contamination is less likely with sources appropriately covered at the top and lined outside the Borehole. In both springs and boreholes, there is a strong link between total coliform and pit latrine distance. According to the findings, bacteria were found in almost all springs and borehole samples near pit latrines. Backfilling, drainage, inadequately submerged infiltration pipelines, and fecal matter infiltration are all possible causes of spring pollution.

My findings are consistent with those of Ahaneku and Adeoye's research (Adeoye, 2017). The difference is the greater distance between pit latrines and groundwater in my study. The high coliform count could be linked to the groundwater's closeness to pollution sources such as open defecation, pit latrines, and waste dumps, which allowed contaminants to migrate quickly, particularly those upstream of the spring and boreholes. According to that study, a distance of up to 19.7 meters between the pit latrine and the groundwater source can improve groundwater quality. Boiling is the suggested approach for treating total coliform-contaminated water because bacteria cannot resist high temperatures.

Table 2: Total Coliform Distribution (per 100 ml) for Boreholes and Springs

Number of colonies (CFU/100 ml)	Boreholes (Number)	Mean distance (m)	Springs (Number)	Mean distance (m)
0-20	8	80.59675	22	151.262
21-40	0		0	
41-60	0		0	
61-80	0		0	
81-100	1	49	2	25.1445

C. Minimum Distance between Pit Latrine and Groundwater Source

- *Minimum Distance between Pit Latrine and Springs*

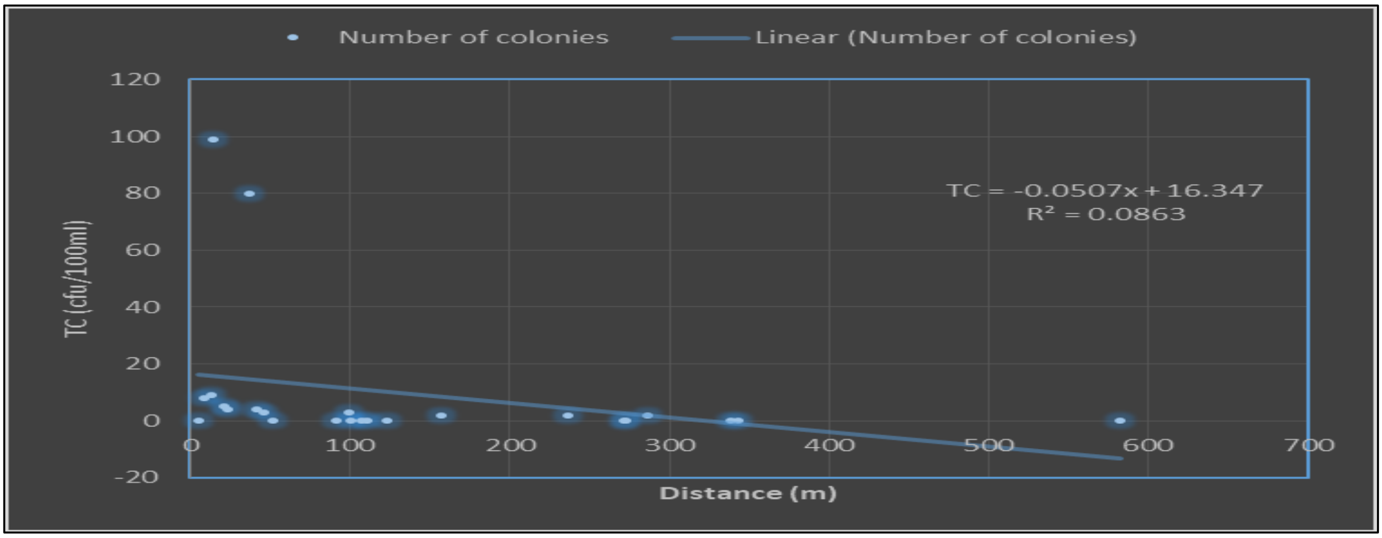

Fig 2: Minimum Distance between Pit Latrine and Springs

The graph of the distance between spring and pit latrines against total coliform is shown in this graph, and the relationship's regression equation is as follows:

$$TC = -0.0507*distance + 16.347$$

$$R^2 = 0.0863 \quad (1)$$

A negative linear function is Equation (1). As the distance between the pit toilet and the pit latrine grows, FC reduces and vice versa. For a shallow well to be TC-free, TC must be set to zero [18]. As a result, if we set equation (1) to zero, we get:

$$-0.0507*distance + 16.347 = 0 \quad (2)$$

Equation 2 shows that in the Rwamagana district, a minimum distance of **322.4 meters** is required between pit latrines, open defecation, waste dumping, and springs to achieve TC-free water.

➢ *Minimum Distance between Pit Latrine and Boreholes*

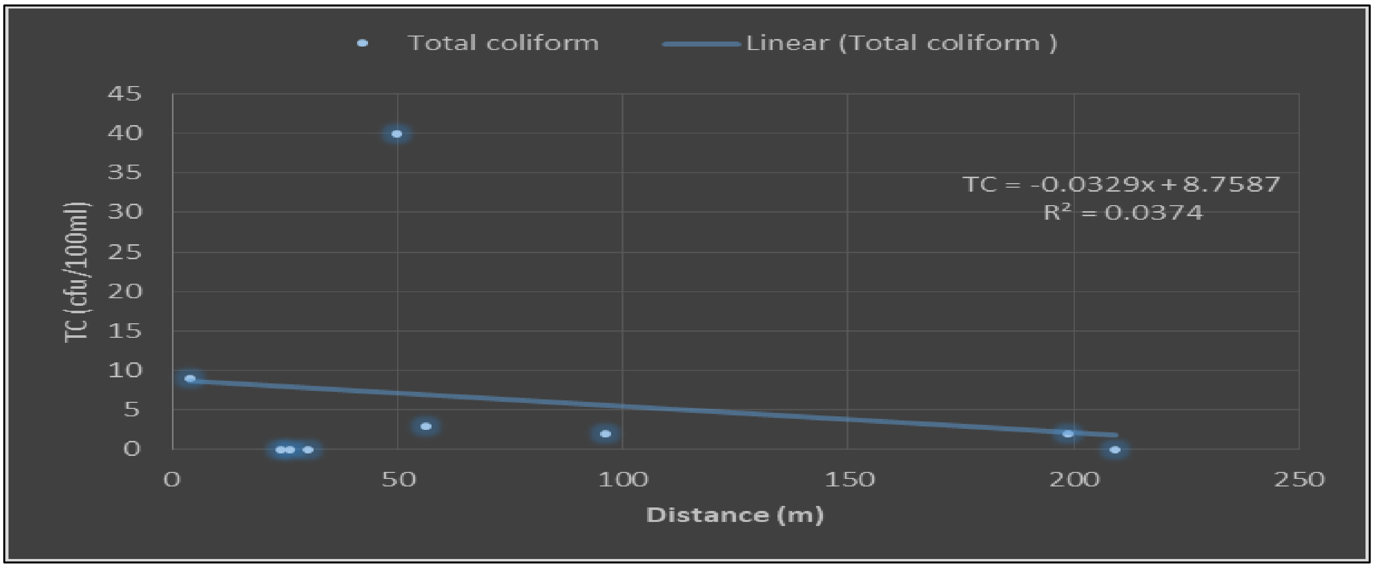

Fig 3: Minimum Distance between Pit Latrine and Boreholes

The graph of the distance between spring and pit latrines against total coliform is shown in this graph, and the relationship's regression equation is as follows:
TC = -0.0329*distance + 8.7587

R2 = 0.0374 (3)

Therefore, setting equation (1) to zero, we have:

TC = -0.0329*distance + 8.7587 = 0 (4)

Equation 4 shows that a minimum distance of 266.2 meters is required between pit latrines, open defecation, waste dumping, and boreholes in the Rwamagana district to achieve TC-free water.

Furthermore, poorly designed pit latrines and insufficient protective measures taken during healthy building may cause groundwater contamination to escalate once more. Water-borne illnesses, including diarrhea and typhoid, are constantly increased in such settings.

IV. CONCLUSION AND RECOMMENDATIONS

A. *Conclusion*

The data and conversations indicate that 60% of the springs and 55.6% of the boreholes surveyed in the Rwamagana district are polluted due to coliform bacteria seeping from pit latrines, open defecation, and waste disposal. The results demonstrate that a minimum horizontal distance of 322.4m and 266.2m is necessary between pit latrines and springs and boreholes, respectively, to reduce the risk of groundwater fecal contamination. Additionally, it is determined that the springs are the most contaminated, while boreholes show the least amount of contamination.

B. *Recommendations*

➢ *It is Advised to Implement the following Steps to Minimize the Contamination of Springs and Boreholes:*

- Communities with contaminated springs and boreholes should receive support to purify their water sources using chlorination. In the absence of chlorine, communities can boil water before consuming it.
- Make sure to keep the area surrounding the apron dry and tidy and ensure that the drainage functions correctly.
- Ensure a minimum separation of 322.4m between springs and boreholes and 266.2m between springs and pit latrines. If feasible, position pit latrines on the lower side of the slope.
- Fencing should be carried out at least one hundred meters upstream from the collection area to prevent cattle and other animals from contaminating the water in places where surface water is present.

REFERENCES

[1]. Adeoye, P. (2017) 'Impact of Pit Latrines on Groundwater Quality of Fokoslum, Ibadan, Impact of Pit Latrines on Groundwater Quality of Fokoslum, Ibadan, Southwestern Nigeria', (November 2013).

[2]. Cronin, A. A., Hoadley, A. W., Gibson, J., Breslin, N., K. and F. K., Haldin, L., et al. (2007) 'Urbanisation effects on groundwater chemical quality: findings focusing on the nitrate problem from 2 African cities reliant on on-site sanitation.', *Journal of Water and Health, 5, 441–454.*

[3]. Haruna, R., Ejobi, F., & Kabagambe, E. K. (2005) 'The quality of water from protected springs in Katwe and Kisenyi parishes, Kampala City, Uganda,' *African Health Sciences, 5, 14–20.*

[4]. JICA (2019) 'PROJECT FOR STRENGTHENING OPERATION AND MAINTENANCE OF RURAL WATER SUPPLY SYSTEMS IN RWANDA'.

[5]. Kulabako, N. R., Nalubega, M., & Thunvik, R. (2007) 'Study of the impact of land use and hydrogeological settings on the shallow groundwater quality in a peri-urban area of Kampala, Uganda', *Science of the Total Environment, 381, 180–199.*

[6]. Majuru B, Michael MM, Jagals P, H. P. (2011) 'Health impact of small-community water supply reliability,' *Int. J. Hyg. and Env. Health. 2011;214(2);162-166.*

[7]. MININFRA (2016) *National Water Supply Policy*.

[8]. NISR (2018) *The fifth integrated household living conditions survey EICV5 2016/17: Thematic report-Utilities and amenities*. Available at: http://www.statistics.gov.rw/publication/ %0Aeicv5-thematic-report-utilities-and-amenities.

[9]. Reddy, D. V., Nagabhushanam, P., & Peters, E. (2011) 'Village environs as a source of nitrate contamination in groundwater: a case study in basaltic geo-environment in central India,' *Environmental Monitoring and Assessment, 174, 481–492.*

[10]. WHO (2011a) 'Guidelines for Drinking-water Quality, second edition,' *World Health*, 1(3), pp. 104–8. doi: 10.1016/S1462-0758(00)00006-6.

[11]. WHO (2011b) 'Guidelines for drinking-water quality (4th ed.)', *Geneva: World Health Organization.*