OPEN ACCESS

AFRICAN JOURNAL OF SCIENCE, TECNOLOGY AND SOCIAL SCIENCES

AJSTSS
AFRICAN JOURNAL OF SCIENCE, TECHNOLOGY AND SOCIAL SCIENCES

Journal website: https://journals.must.ac.ke

MERU UNIVERSITY OF SCIENCE AND TECHNOLOGY

A Publication of Meru University of Science and Technology

Assessment of shallow well water quality in relation to well distance from the pit latrine a case study of Moiben Sub-county, Uasin-Gishu County

Leah Wangari Wang'ondu,[1*] Erastus Mwangi[1] and Jane Mberia[2]

[1] Sanitation Research Institute, Meru University of Science and Technology. [2] Pwani University

ARTICLE INFO

KEY WORDS

Microbial contamination

Water contamination

Physiochemical parameters

Shallow well

Pit-latrine

ABSTRACT

Sustainable Informal settlements in urban areas of sub-Saharan Africa often rely heavily on shallow dug wells for their water supply. However, these wells are susceptible to contamination from various sources due to a lack of protection. This study aimed to assess the microbial quality and physicochemical parameters of shallow wells in Moiben Sub-County, Uasin Gishu County. Specifically, the study sought to: (i) determine the level of microbial contamination in shallow wells, (ii) analyze the physicochemical parameters of the water, and (iii) establish the relationship between shallow well water contamination and the distance of the wells from nearby pit latrines. The study population was 62 shallow wells in five zones of the sub-county. Stratified sampling technique was utilized in proportionally sampling wells for examination. Laboratory analysis was conducted to measure microbial indicators like fecal coliforms, E. coli, and total coliforms, and physicochemical parameters like pH, TDS, electrical conductivity, turbidity, nitrates, nitrites, and ammonia. Observational method was utilized to measure the distance of pit latrines from wells. Data was analyzed inferentially through ANOVA, while microbial contamination was quantified using the Most Probable Number (MPN) technique. Findings indicated that there was a significant correlation between distance from the well and microbial contamination ($p < 0.001$), and 72.8% of microbial contamination was accounted for by distance. Likewise, 98.7% of physicochemical parameter contamination was accounted for by distance. The results point out that shallow wells closer to latrines have greater levels of contamination, above WHO's safe drinking water guidelines. The research emphasizes maintaining a minimum distance of 50 meters between pit latrines and groundwater sources to avert fecal contamination. The final beneficiaries of these results are policymakers, members of the community, and local health administrators, who can use the data to improve public health, sanitation facilities, and water quality in the region.

Introduction

Many developing countries rely on untreated groundwater, which can be contaminated by on-site sanitation systems (Li et al., 2021). The World Health Organization states that potable water should meet standards in physical features, chemical composition, bacteriological content, and general acceptability to ensure safety for drinking and cooking (WHO, 2021). In urban areas with high

*Corresponding author: Leah Wangari Wang'ondu Email: wangari.leah100@gmail.com

https://10.58506/ajstss.v3i2.244

AFRICAN JOURNAL OF SCIENCE, TECHNOLOGY AND SOCIAL SCIENCES ISSN :2958-0560

https://journals.must.ac.ke

population density, managing on-site sanitation, such as latrines, is crucial (Aju et al., 2024). Introducing sewered sanitation systems can improve public health by reducing exposure to fecal pathogens, but sewage must be treated to prevent disease transmission.

In Kenya, achieving sustainable water and sanitation remains a distant goal, despite its inclusion in Vision 2030 (Onyango, 2023). Water quality is compromised by bacterial and fungal contamination due to various human activities (Abanyie et al., 2023). In Moiben Sub-County, Uasin-Gishu County, only 40% of the population has piped water from Eldoret Water and Sanitation (ELDOWAS), while 60% use shallow wells. These wells are often inadequately covered, leading to contamination through spillage and surface runoff, especially during the rainy season, increasing the risk of recontamination and posing health risks (Onyango, 2023).

Problem Statement

The utilization of pit latrines is increasing in developing countries as the most cost-effective method of human waste disposal, aligning with the Millennium Development Goals' sanitation targets (Gokçeku et al., 2020). In Moiben Sub-County, pit latrines are the predominant means of disposing untreated human waste, and are often located close to shallow wells, increasing the risk of water contamination. This situation raises the risk of waterborne diseases, highlighting the need to assess water quality in shallow wells in Moiben Sub-County, especially considering their proximity to pit latrines. The widespread presence of microbial contaminants, ranging from total coliforms to pathogenic bacteria, indicates serious water safety concerns. Assessing these findings underscores an urgent need for water treatment and further research to understand contamination sources, pathways, and health implications.

Methodology

The research design employed is a quasi-experimental involving laboratory experiment.

Study Area

The research was conducted in Moiben sub-county in Uasin-Gishu County. Moiben Constituency is divided into the following Wards: Moiben Ward, Sergoit Ward, Kimumu Ward, Tembelio ward and Karuna ward. Moiben Sub-County covers a total land area of 769.8 Km2. It is about 330 km northwest of Nairobi in Kenya. The centre lies on latitude 0° 35' 20" N and longitude 35° 18' 21"E. According to the Kenya National Bureau of Statistics (2019), the population of Moiben Sub-County is 181,338 persons across 45,335 households.

Target population and Sample Size Determination

The target population of this study is 45,355 households according to (KNBS 2019) within Moiben sub-county. Sixty-two shallow wells were identified and the sampling criteria determined using Cochran formula. The formula was used at a 95% confidence interval (Chaokromthong & Sintao, 2021).

$$n = \frac{z^2 \times p(1-p)}{e^2}$$

Where

z^2= standard normal deviation, 1.96

n=sample size

p= expected proportion (0.2) or prevalence

e= precision as 0.1

$$n = \frac{1.96 \times 1.96 \times 0.2(1-0.2)}{0.1 \times 0.1}$$

Sample size=62 samples

Sampling Technique

Sixty-two shallow wells were sampled from the five zones in order to analyze the presence of faecal coliforms, E. coli, Total coliforms, pH, TDS, Electrical conductivity, turbidity, nitrates, nitrites, and ammonia Simple random sampling using a table of random numbers was used to determine the shallow wells which were sampled at the ward level.

Data collection and Analysis

The analysis was done using the most probable number (MPN) method, biochemical tests to detect E. coli, total coliforms, and fecal coliform, as well as physiochemical parameters to test for nitrates, nitrites, ammonia, pH, turbidity, and electrical conductivity. Additionally, an observation method was utilized to determine the proximity of boreholes to latrines.

Ethical Considerations

An introductory letter from Meru University of Science and Technology MIRERC (Meru University Institutional Research and Ethics Review Committee) was issued and NACOSTI license given. A consent to conduct the study was sought from the National Environment Management Authority (NEMA). The residents of Moiben sub-county in Uasin Gishu County were accorded utmost respect and confidentiality during the study period.

Results and Discussion

Total Coliforms and the distance of the well from pit-latrine

The presence of total coliforms in the water samples, assessed using the Most Probable Number (MPN) method, showed that wells located within a distance range of 10 m to 30 m had the highest number of total coliforms, as shown in Figure 1.

The wells in Moiben Sub-County showed high levels of total coliforms, ranging from 540 to 1600 MPN/100ml, indicating contamination far exceeding WHO guidelines (WHO, 2022). This suggests direct contamination from nearby pit latrines. Wells situated 30-50 meters from pit latrines had moderate coliform levels, while those more than 50 meters away exhibited the lowest levels, ranging from 22 to 70 MPN/100ml, with some meeting WHO standards, indicating that greater distance from pit latrines significantly reduces contamination risk. A study in Nigeria found similar results, with 85% of shallow wells tested showing coliform counts above the WHO permissible limit of 0 MPN/100 mL for drinking water.

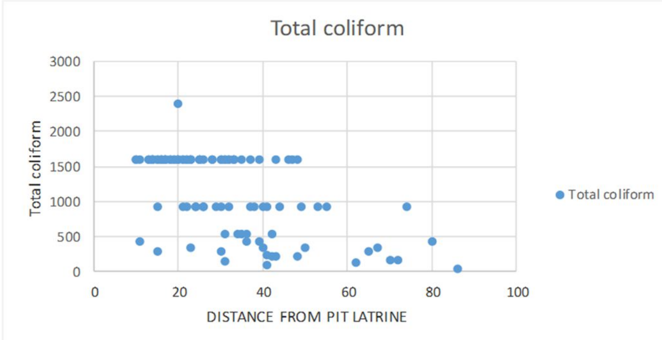

Figure 1: *Relationship between Total Coliform and the distance of the well from the pit- latrine*

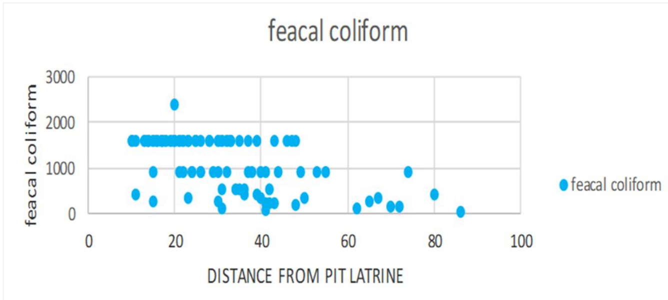

Figure 2: *Relationship between fecal Coliform and the distance of the well from pit- latrines*

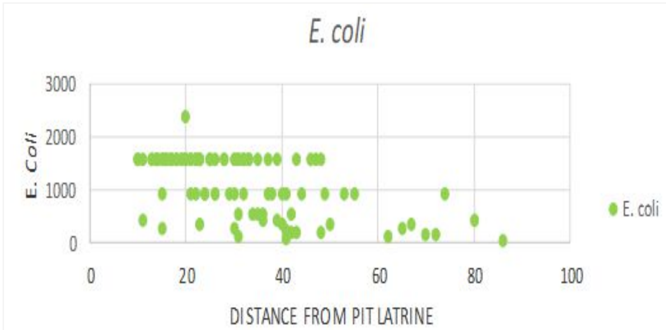

Figure 3*: Relationship between E. coli and the distances of the well from Pit- latrines*

Fecal Coliform and the distance of the well from pit - latrine

Water samples from wells located 10–30 meters from pit latrines in Moiben Sub-County showed the highest levels of fecal coliforms (340 to 1600 MPN/100ml), exceeding the WHO guideline of 0 MPN/100ml for drinking water (WHO, 2022). Wells 30-50 meters away had fewer coliforms, and those more than 50 meters away had the lowest levels (20 to 70 MPN/100ml), with some meeting WHO standards, indicating that distance from pit latrines reduces contamination risk. A study by Osiemo, Ogendi, and M'Erimba (2019) in Nairobi found 60% of wells had fecal

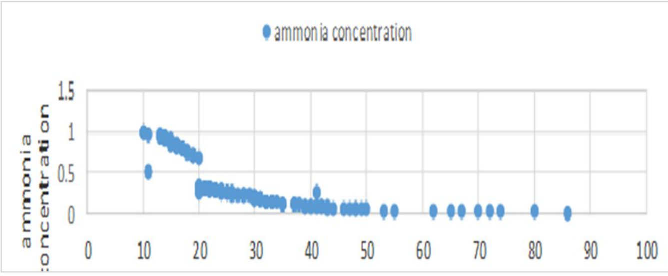

Figure 4: *Relationship between Ammonia concentration and the distance from wells to pit-latrines*

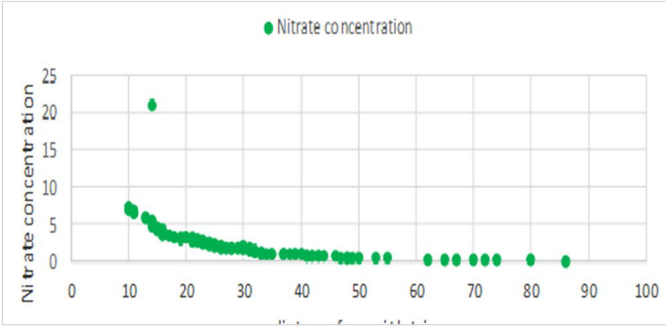

Figure 6: *pH and the distance of the well from pit – latrine*

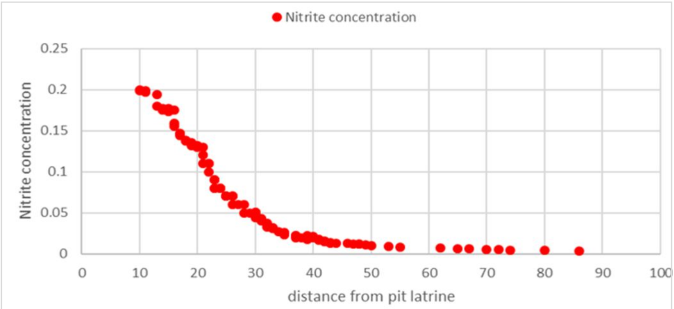

Figure 5: *Relationship between Nitrates and the well distance from the pit- latrines*

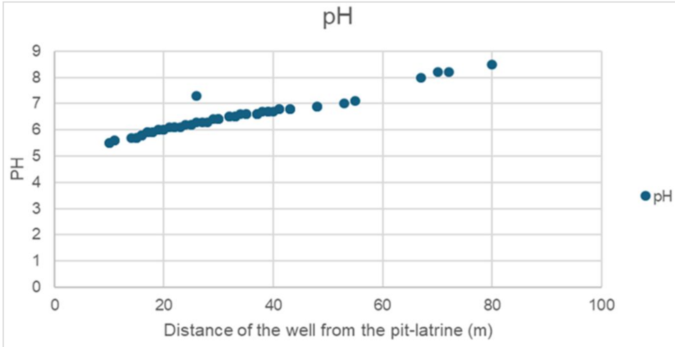

Figure 7: *-Relationship between pH and distance of well from pit latrine BSFL*

coliforms above WHO limits due to poor sanitation practices and nearby pit latrines, emphasizing the need for improved sanitation (see figure 2)

The presence of E.Coli in the water samples assessed using the Most Probable Number (MPN) method showed that wells that had a minimal distance of distances range 10 - 30m had the highest number of E. Coli as shown in figure 3.0

Wells near pit latrines had high levels of E. coli (540 to 1600 MPN/100ml), far exceeding WHO guidelines, indicating direct contamination. Wells located 30 to 50 meters from pit latrines had lower E. coli levels, while those more than 50 meters away had the lowest contamination levels (20 to 70 MPN/100ml), suggesting that increasing the distance from latrines reduces the risk of contamination.

Ammonia and the distance of the well from pit – latrine

Ammonia levels in wells were highest (0.061 to 1.0 mg/L) within 10 to 30 meters of pit latrines, with some samples exceeding the WHO limit of 0.5 mg/L, indicating significant contamination. Wells 30 to 50 meters away had moderate ammonia levels (0.5 to 1.0 mg/L), showing some impact from latrines. Wells more than 50 meters away had the lowest ammonia levels, generally below 0.5 mg/L, with some meeting WHO standards, suggesting that greater distance from pit latrines reduces contamination risk. See figure 4.

Nitrate levels in wells were highest (1 to 7 mg/L) within 10 to 30 meters of pit latrines but were still within the WHO limit of 10.0 mg/L for drinking water. Wells 30 to 50 meters away showed moderate nitrate levels (3.0 to 6.0 mg/L), while those more than 50 meters away had the lowest levels (1 to 3 mg/L) and met WHO standards. This indicates that greater distance from pit latrines reduces nitrate concentration, as shown in Figure 5.

Nitrites and the distance of the well from pit – latrine

Nitrite levels in wells were highest (0.005 to 0.2 mg/L) within 10 to 30 meters of pit latrines, exceeding the WHO limit of 0.1 mg/L for drinking

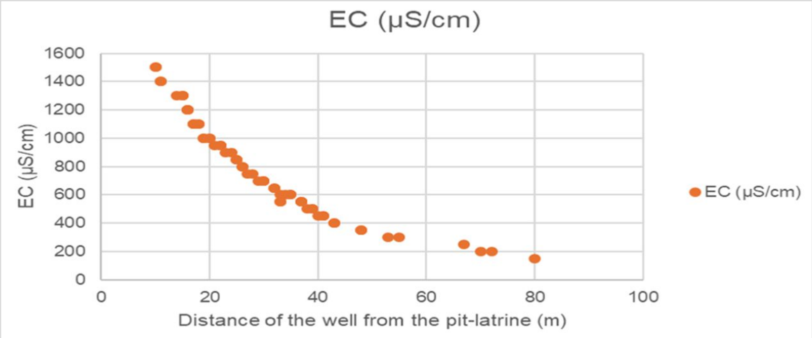

Figure 8: *the relationship between Electrical conductivity and distance of well from a pit latrine*

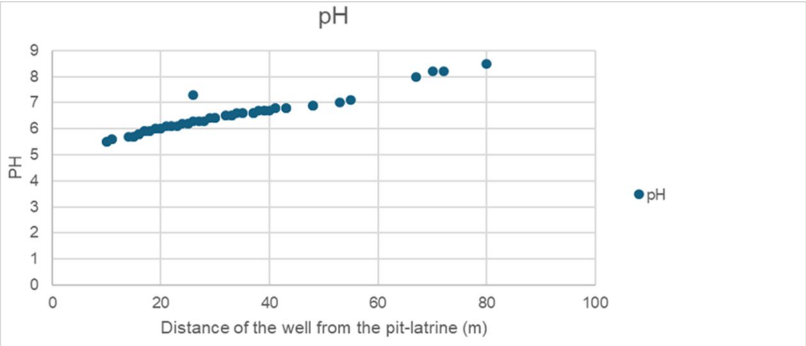

Figure 9: *The relationship between Total dissolved solids and distance of the well from a pit latrine*

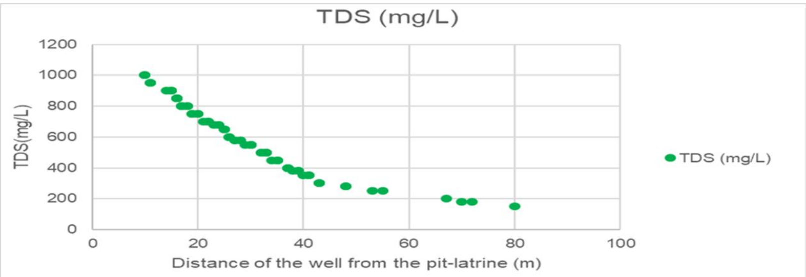

Figure 10: *the relationship between turbidity and distance of well from a pit latrine*

water. Wells 30 to 50 meters away had moderate nitrite levels, while those more than 50 meters away had the lowest levels, generally below 0.1 mg/L, meeting WHO standards. This indicates that greater distance from pit latrines reduces nitrite levels. (Figure 6)

Closer distances to the pit latrine (10-20 meters) showed lower pH values, indicating more acidic conditions while those that has a distance between 30m-50 m shows neutral pH values and those whose well distance from the pit latrine had higher pH values upto 8.5 which is within the recommended WHO standard.(WHO, 2021) of 6.5-8.5. The relationship between pH and distance of well from pit latrine is shown in figure 7.

Studies in Kenya have shown that water pH can be significantly influenced by proximity to pit latrines. Close proximity often results in more acidic conditions due to the leaching of organic matter and nitrates from the latrines. A study by (Kaponda, 2019)observed that pH values tended to decrease with decreasing distance to pit latrines, potentially due to increased contamination levels. This pattern was consistent with findings in a rural Kenyan study, where pH values were slightly lower in wells closer to latrines, suggesting higher levels of organic and microbial contamination (Ngatia, 2022)

Electrical conductivity and the distance of the well from pit – the latrine

High Electrical conductivity values at closer distances, with 1500 µS/cm at 10 meters, decreasing steadily with distance. Distances between 30m- 50 m have values ranging between 750 - 450 µS/cm. By 80 meters, Electrical conductivity drops to 150 µS/cm. This trend indicates that the concentration of dissolved ions is significantly higher near the pit latrine. This relationship is shown in Figure 8.

As the distance increases, the impact of these contaminants lessens, resulting in lower EC values. This decline in EC with distance highlights the effectiveness of greater separation in mitigating ionized contaminants from pit latrines, thus ensuring safer water quality for drinking and agricultural purposes. Research by Gokçeku et al. (2020) indicated a clear increase in EC values in wells closer to pit latrines, which is attributed to the seepage of salts and minerals from human waste. This trend is supported by studies that found significantly higher EC levels in groundwater samples near pit latrines

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.994[a]	.987	.987	1.80510

a. Predictors: (Constant), Turbidity, EC, pH, TDS

Table 1: *Model Fitness for Well Distance and Microbial Contamination*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.853[a]	.728	.714	8.33789

a. Predictors: (Constant), E Coli, Total Coliform, Faecal Coliform

Table 2: *Model Fitness for Well Distance and Physical Parameters*

compared to those further away, reflecting the influence of latrine leachate on groundwater quality (Kisi et al., 2022)

Total dissolved solids and the distance of the well from the pit–latrine

Higher TDS levels are seen near the pit latrine, with values around 1000 mg/L at 10 meters, decreasing to 150 mg/L at 80 meters. The closer the well is to the pit larine the higher the dissolved solids while those wells whose distances were far away from the pit latrine had low numbers of dissolved solids. This is shown in Figure 9.

High Total Dissolved Solids (TDS) levels near pit latrines indicate significant leaching of soluble compounds like nitrates, phosphates, and organic matter into groundwater. TDS levels decrease with increasing distance from pit latrines, reflecting the dilution of contaminants. A study by Lutterodt et al. (2023) found that TDS levels were notably higher in wells within 20 meters of pit latrines, confirming substantial contamination. This is consistent with global findings linking proximity to sanitation facilities with elevated TDS levels in groundwater (Cui et al., 2022

Turbidity and the distance of the well from the pit–latrine

Turbidity is highest near the pit latrine, with values around 40 NTU at 10 meters, and decreases to 7 NTU at 80 meters. As the distance from the latrine increases, the turbidity decreases significantly while turbidity is high in wells that are closer to the pit –latrine. This is evident in Figure 10.

Maintaining lower turbidity is crucial for ensuring safe drinking water, as high turbidity can harbor harmful microorganisms and interfere with disinfection processes. Studies in Kenya have shown that wells closer to pit latrines often exhibit higher turbidity levels. For instance, research (Ochiba, 2020) found that turbidity increased significantly in wells within 15 meters of pit latrines, suggesting the presence of suspended solids and microbial contamination from latrine effluent. This is consistent with findings from other studies indicating that proximity to pit latrines is a significant predictor of increased turbidity in groundwater (Kanouo et al., 2023).

Table 1: Model Fitness for Well Distance and Microbial Contamination

The results for R = 0.853 imply that the model is a good measure of the relationship between well distance and level of microbial contamination. The R squared (0.728) implies that well distance can explain 72.8% of the level of microbial contamination

Table 2: Model Fitness for Well Distance and Physical Parameters

The results for R = 0.994 imply that the model is a good measure of the relationship between well distance and level of physical contamination. The R squared (0.987) implies the well distance can explain 98.7% of the level of contamination.

Conclusion

This study consistently demonstrates high concentrations of E. coli, fecal coliforms, and total coliforms in shallow well waters, exceeding permissible limits set by regulatory authorities such as the World Health Organization (WHO). This indicates widespread fecal contamination of groundwater, likely due to the inadequate distance of the pit latrine from the well. There is a clear association between the proximity of shallow wells to pit latrines and the levels of microbial contamination. Wells located near pit latrines consistently exhibit higher concentrations as compared to wells with higher distance separation. Agricultural practices and inadequate sanitation infrastructure, such as the proximity of wells to pit latrines, are the major contributors to groundwater contamination. This study consistently demonstrates a strong correlation between the proximity of shallow wells to pit latrines and the levels of contamination. Wells situated within proximity to pit latrines exhibit higher concentrations of ammonia, nitrates, and nitrites, indicating the influence of improper waste disposal on groundwater quality.

Recommendations

Efforts should focus on ensuring adequate separation between pit latrines and groundwater sources to prevent fecal contamination. A distance of 50m separation of the pit latrine from the well is recommended. Community-based education should be implemented to educate residents about the importance of water quality, and the risks associated with consuming contaminated water. Implementing best agricultural practices, such as controlled fertilizer application and the establishment of buffer zones between agricultural fields and water sources, can help reduce the introduction of nitrates and other pollutants into groundwater.

References

Abanyie, S. K., Apea, O. B., Abagale, S. A., Amuah, E. E. Y., & Sunkari, E. D. (2023). Sources and factors influencing groundwater quality and associated health implications: A review. Emerging Contaminants, 9(2), 100207.

Aju, C. D., Achu, A. L., Mohammed, M. P., Raicy, M. C., Gopinath, G., & Reghunath, R. (2024). Groundwater quality prediction and risk assessment in Kerala, India: A machine-learning approach. Journal of Environmental Management, 370, 122616.

Chaokromthong, K., & Sintao, N. (2021). Sample size estimation using Yamane and Cochran and Krejcie and Morgan and green formulas and Cohen statistical power analysis by G* Power and comparisions. Apheit international journal of interdisciplinary social sciences and technology, 10(2), 76-86.

Cui, X., He, H., Zhu, F., Liu, X., Ma, Y., Xie, W., ... & Zhang, L. (2022). Community structure and co-occurrence network analysis of bacteria and fungi in wheat fields vs fruit orchards. Archives of Microbiology, 204(8), 453.

Gokçeku , H., Kassem, Y., Yunusa, N., Musa, M. K., John, S. O., Usman, S., ... & Ahmad, S. M. (2020). Study on pit latrine minimum design requirement and considerations in Northern Nigeria. International Journal of Scientific & Technology Research, ISSN, 2277-8616.

Kanouo, B. M. D., Assatse, W. T., Njeudjang, K., Aretouyap, Z., & Biringamine, G. N. (2023). Assessment of the Impact of Pit Latrines on Groundwater in the Melen Slum, Cameroon. J Agric Forest Meteorol Res, 6(3), 548-560.

Kaponda, P. (2019). Drinking Water Quality and Human Dimensions: a case study of the 2017-2018 cholera outbreak in Karonga, Malawi (Doctoral dissertation, Mzuzu University).

Kisi, O., Mirboluki, A., Naganna, S. R., Malik, A., Kuriqi, A., & Mehraein, M. (2022). Comparative evaluation of deep learning and machine learning in modelling pan evaporation using limited inputs. Hydrological Sciences Journal, 67(9), 1309-1327.

KNBS. (2019). Volume I: Population by county and sub-county - kenya https://www.knbs.or.ke/wp-content/uploads/2023/09/2019-Kenya-population-and-Housing-Census-Volume-1-Population-By-County-And-Sub-County.pdf

Li, P., Karunanidhi, D., Subramani, T., & Srinivasamoorthy, K. (2021). Sources and consequences of groundwater contamination. Archives of environmental contamination and toxicology, 80, 1-10.

Lutterodt, G., Gibrilla, A., Andorful, F., Ganyaglo, S., & Oduro-Kwarteng, S. (2023). Influence of on-site sanitation on groundwater quality from large diameter wells. Groundwater for Sustainable Development, 20, 100862.

Ngatia, M. W. (2022). Effects of Anthropogenic Activities on Water Quality of Ngong River, Nairobi County, Kenya (Doctoral dissertation, University of Nairobi).

Ochiba, N. K. (2020). Assessment Of Levels Of Selected Heavy Metals In Borehole Water In Ongata Rongai, Kajiado County, Kenya (Doctoral dissertation, University Of Nairobi).

Onyango, D. O. (2023). Assessment of Water Quality From Shallow Wells in Informal Settlements in Kenya: a Case of Nyalenda Estates, Kisumu County, Kenya (Doctoral dissertation, University of Nairobi).

Osiemo, M. M., Ogendi, G. M., & M'Erimba, C. (2019). Microbial quality of drinking water and prevalence of water-related diseases in Marigat Urban Centre, Kenya. Environmental health insights, 13, 1178630219836988.

WHO. (2021). Guidelines for drinking-water quality. 38(4), 104-108.

World Health Organization, & United Nations Children's Fund. (2021). Progress on household drinking water, sanitation and hygiene 2000-2020: five years into the SDGs. World Health Organization.

World Health Organization. (2022). Water and sanitation.