

**ORIGINAL RESEARCH ARTICLE****Factors Associated with Bacterial Contamination of Shallow Well Water Sources. Case Study of Juja hostels Kiambu County****Purity Kirori¹, Viviene Matiru¹, Joseph Mutai²**¹*Jomo Kenyatta University of Agriculture and Technology, College of Health Sciences, Nairobi, Kenya.*²*Kenya Medical Research Institute (KEMRI)*Corresponding email address purity.kirori@gmail.com**ABSTRACT**

The use of water from polluted water sources poses numerous public health challenges in developing countries. The ultimate purpose of any solid and liquid waste management plan is to mitigate environmental pollution; these goals become unachievable in the absence of a participatory approach to integrated waste management. This study sought to determine the extent of underground pollution of groundwater sources in Juja Town. Sanitary inspection and water quality analysis are complementary and valuable tools for characterizing and protecting water safety. The quality of the shallow wells is of great importance because it is used for consumption in Juja hostels. A two-stage cluster sampling strategy was adopted to obtain a representative sample size. Data collection involved the administration of questionnaires and field observation checklists, and *E. coli* levels present in the water were determined by the number of positive tubes in the table of computation of most probable number (MPN). Results showed that the predominant types of waste disposal practices observed in Juja were septic tank systems (77%) for liquid waste and private collection (87.3%) for solid waste methods. Sixty-eight per cent of the water samples were found to be positive (they exceeded the WHO (2004) maximum permissible load of 0.01/100 ml for drinking water. Three sanitary risk factors had a statistically significant effect on the dependent variable: the distance of the septic tank from the well on the level of water contamination (0.016), the liquid waste management plan (0.039), and the fitness of the water well cover on the level of water contamination (0.024). Shallow well water sources are unsuitable for use in food processing and drinking due to the presence of *E. coli* bacteria. The consequences of consuming contaminated water can be expensive to treat. Water from wells in Juja is contaminated with *E. coli* levels ranging from <3 - >1000 MPN/g, indicating fecal contamination in the area's underground water sources.

1.0 Introduction

Water is a basic requirement that humankind needs to survive, though for it to be sustainably used, its quality should be ascertained (Maestu, 2015). Water-borne illnesses are one of the key public health hitches in evolving countries. It is estimated that contaminated water has caused more than 20 million deaths, of which more than 80% were among children under age five (Thani et al., 2016). The rapid urbanization in African countries has resulted in the rapid production and accumulation of municipal waste due to overstretched social amenities and

limited economic opportunities. Currently, poor waste management has led to a high frequency of sanitation-related illnesses such as cholera, typhoid, and intestinal worms (Yoda et al., 2014). In sub-Saharan Africa, 42% of individuals need to get a basic water supply, defined as an improved water source accessible (Kelly et al., 2021). The dangers posed by poor waste disposal are evident within the low and middle-income countries which are the greatest consumers of industrial materials as well as obsolete technological products (Rotaru and Răileanu, 2008). In Kenya, approximately 19,500 residents, including 17,100 children under 5 years, die each year from diarrhea nearly 90% of which is directly attributed to poor Water Sanitation and Hygiene (WASH) (Wangui, 2016). Juja is one of the fast-growing towns in Kiambu County, which has been encountering a fast rise in the populace. The rapid increase in student enrollment at Jomo Kenyatta University has resulted in increased demand for housing, which has several negative effects on neighborhood development such as congestion, unplanned growth, and environmental degradation, forcing residents to rely more on groundwater to supplement their water sources (Boit and Kipkoeh, 2012). Among the risk components influencing water quality are a wide variety of anthropogenic activities and natural influences: agriculture, uncontrolled human waste disposal, population development, urbanization, and climate change, which all influence groundwater resources. Urbanization has put pressure on water sources, while climate change has led to reduced quantities of surface water supply. Juja residents have been encountering water shortages, with some areas lacking reliable clean water supply for several months. This has led to the population taking shallow well water as a substitute source, which is coincidentally located adjacent to septic tanks, resulting in compromised permeation of water between these two systems. Currently, Juja lacks a sewer line system and this has resulted in septic tanks and latrines in the area. These conditions pose a threat to groundwater quality. However, individuals have continued to consume this water without testing, primarily due to ignorance or lack of awareness of all these dangers encompassing the resource. Furthermore, there are no policies or strategies to guide the management of groundwater resources (WRMA). Fecal coliform bacteria exist in the intestines of humans and warm-blooded animals and are found naturally in soil and animal droppings. The presence of fecal coliforms in water indicates that contaminants are present and may show that the water is unsuitable for consumption (Auta et al., 2017).

2.0 Materials and methods

This study was conducted in selected hostels in Juja, Kiambu County, Kenya. A two-stage cluster sampling strategy was adopted to obtain a representative sample size (100). Data collection involved the administration of questionnaires and field observation checklists. 79 water samples taken from various wells were run using the most probable number (MPN) technique to estimate the concentration of *E. coli*. This was done according to the standard method for the examination of water and wastewater (APHA et al., 2005). The presence of microorganisms was determined in three stages, which were presumptive, confirmed, and completed the test.

2.1 Data analysis

The data was analyzed using STATA version 14. Descriptive statistics included respondents' demographic characteristics and descriptive frequencies presented in the form of tables, charts, graphs, and percentages. The laboratory analysis was done according to the standard

method of examination of water and wastewater (APHA, et al.,2005). The presence of microorganisms was determined in three stages, which are presumptive, confirmed, and completed tests. The most probable number (MPN) of coliforms present in the water was determined by the number of positive tubes using the table of computation of MPN. Additionally, factors independently associated with the dependent variable were assessed using a logistic regression model.

3.0 Results

3.1 Waste disposal practices

Both solid and liquid waste disposal practices adopted in targeted hostels were accessed and the findings are as shown below.

3.1.1 Solid waste

A few hostels (12%) had their waste separated into two categories (food waste and other waste (harmful, recyclable, e-waste, and non-recyclable waste). However, (88%) of the hostels did not have their waste separated (Table 1).

Table 1. Separation methods

| Variable | Frequency (n) | Percent |
|---|---------------|---------|
| Two categories (Food waste and other waste (harmful, recyclable, e-waste and non-recyclable waste) | 9 | 12 |
| Two categories (Recyclable waste and other waste (food, harmful, non-recyclable waste and e-waste) | 0 | 0 |
| Three categories (Food waste, recyclable waste and other waste (harmful, non-recyclable waste, e-waste) | 0 | 0 |
| Four categories (Food waste, recyclable waste, harmful waste and other waste (non-recyclable and e-waste) | 0 | 0 |

The study indicated that the most preferable solid waste disposal practice is through private garbage collectors (87.3%). It was also evident that some hostels still conduct open-air burning (12.7%) Table 2.

Table 2. Types of solid waste disposal practices

| Variable | Frequency (n) | Percent (%) |
|--------------------|---------------|-------------|
| Open air burning | 10 | 12.7 |
| Private collectors | 69 | 87.3 |
| Open dumping | 0 | 0 |
| Landfilling | 0 | 0 |
| Composting | 0 | 0 |
| Burying | 0 | 0 |

The study determined various methods of solid waste storage and collection of waste in Juja. Solid waste collection intervals ranged between daily 3.8%, weekly 78.5%, twice a week 10.1%, while 7.6% indicated that waste was collected at irregular intervals but mostly after one week (Fig.1).

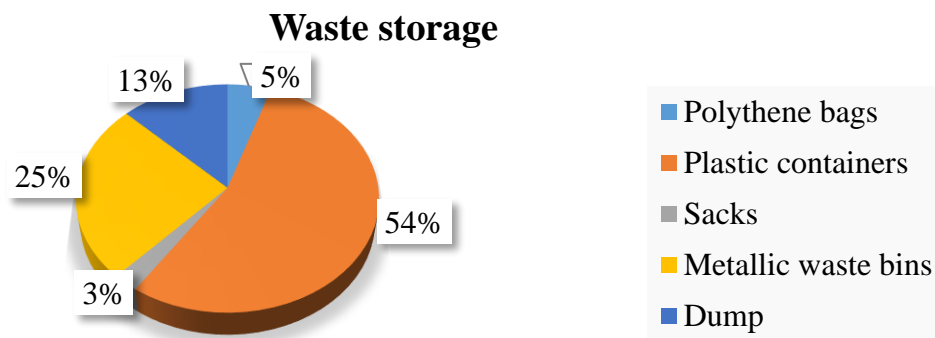


Figure 1. Waste storage methods

3.1.2 Liquid waste

The predominant type of liquid waste disposal practice observed in Juja was septic tank systems.

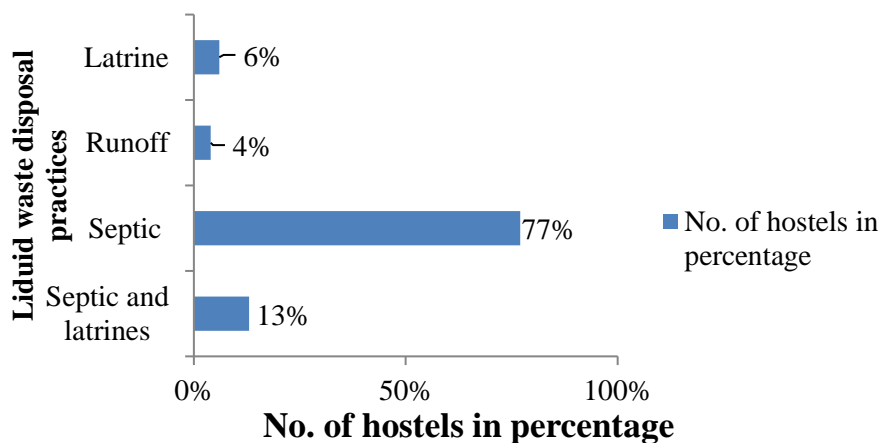


Figure 2 Liquid waste disposal practices

3.1.3 Problems related to liquid waste disposal methods

The majority of households experienced challenges with liquid waste management practices. Table 3 indicates that the dominant challenge was linked to wastewater backing up from the septic (63.3%). Other challenges were liquid waste overflows (5.1%), wet areas at the top of the septic (20.3%), and unpleasant odors (11.4%).

Table 1. Problems related to liquid waste disposal practices

| Variable | Frequency (n) | Percent |
|---|---------------|---------|
| Liquid waste overflows | 4 | 5.1 |
| Wet areas are seen at the top of the septic | 16 | 20.3 |
| Unpleasant smell | 9 | 11.4 |
| Waste water backing up | 50 | 63.3 |

3.2 Microbiological characteristics of shallow well

Samples from the various water well sources were tested to determine *E. coli* concentration according to the standard method for the examination of water and wastewater (Apha *et al.*, 2005). Based on the number of fecal coliforms obtained (MPN/100ml), the water sources studied were categorized into WHO health risk categories ranging from conformity to drinking water standards to very high risk. Of 79 samples, 53 (67%) had detectable *E. coli* in a 100ml sample. The sources were classified into different categories: conformity 26 (33%), low risk 6(7%), intermediate risk 14(18%), high risk 4 (5%), and very high-risk 29(37%). The categories chosen represented a progressive increase in the risk of infection by pathogenic bacteria following the consumption of water from various wells.

3.3 Sanitary risk factors associated with shallow well water quality

Logistic regression revealed a significant association between *E. coli* (presence/absence) and several sanitary risk factors. The distance of the well from the nearest septic tank or latrine ($p = 0.016$), liquid waste disposal system ($p = 0.039$), and fitness of well cover ($p = 0.024$) were significantly associated with *E. coli* presence at the 95% confidence level. (Table 4)

Table 2. Logistic regression results

| Bacteria presence | P> z | [95% Conf. Interval] | |
|-------------------|-------|----------------------|-----------|
| Distance | 0.016 | -7.61737 | -.7742961 |
| disposal system | 0.039 | .0942538 | 3.565232 |
| Well Cover | 0.024 | -5.345124 | -.3735231 |

The regression equation is therefore as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \epsilon \dots \dots \dots$$

$$\text{Logit}(Y) = -0.595 - 4.196(X_1) + 1.83(X_2) - 2.86(X_3) + 1.98$$

Where:

β_0 = Constant



Y= Bacterial presence

X1= Distance of Well from nearest Septic Tank

X2 = Liquid waste disposal system

X3= Fitness of Well Cover

B1- B3 = Coefficients of determination

4.0 Discussion

This study investigated the relationship between factors associated with bacterial water quality. Groundwater sources are ordinarily contaminated because of physical processes, the geochemistry of the environment, and anthropogenic activities. Therefore, users of such waters are unprotected from a series of health risks. Water pollution events are frequently caused by discharges from wastewater treatment facilities, overflowing sanitary sewer systems, waste materials from domestic and industrial sewage, and runoff from animal feces during severe storms (Auta et al., 2017). Although the most practiced method of solid waste disposal was appropriate (87.3% used private collection) under various agreements, 12.7% practiced open-air burning. This leads to harmful vaporous outflows within the atmosphere, polluting the air and depleting the ozone layer and its protective properties, subsequently increasing the hazard to health. This is inclusive of certain types of cancers (Yoda et al., 2014). Indiscriminate open dumping of municipal waste poses a great threat to human well-being and the environment in the event it is not stored, collected, and disposed of properly. Household waste from various sources is mixed and co-disposed in Juja (88%) without any form of segregation. This is a replication of what transpires in most African cities. The source separation of kitchen waste is conducive to municipal solid waste disposal and may lead to a critical environmental impact in due time. In contrast, no noteworthy benefit can be picked up from residual waste since high-valuable recyclable waste is mostly collected and sold to recyclers. Safety should be given priority in terms of waste management (Chen et al., 2017). Household waste separation decreases the levels of waste in landfills (Yoda et al., 2014). Separation and sorting of waste at the source permits removal of hazardous waste, complementing composting and recycling options (Muiruri et al., 2020). The best practice for storing waste is in covered plastic containers. Of those, 54% and 25% employed plastic bins and metallic bins, respectively. A good solid waste management plan recommends that the storage containers be intact and have covers to hinder access by insects, pests, and birds. Inappropriate solid waste collection and disposal practices may cause serious urban, sanitary, and environmental problems such as unpleasant odors, insect proliferation, or groundwater contamination (Joshi & Ahmed, 2016). Plastic storage is still being done, and this has negative implications for disposal since plastics are non-biodegradable products. Liquid waste disposal is mainly done by septic tanks, which are dug around the same areas as the wells. Bacteria can be found in the air, water, earth, animal intestines, and rotting vegetation. Positive results of the *E. coli* in the sample water were a good indicator that the water had been contaminated with fecal matter. The high fecal pollution levels in various wells identified by the study suggest that the well water is not suitable for drinking without treatment. Human and animal waste are the primary sources of bacteria in water (Mohsin and Sahib, 2013). Transmission of these pathogens occurs through fecal contamination of water in heavily used and unprotected water sources (Cheluget K, 2011). Any consumable water may be

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microbiologically polluted due to deficient sanitation and unhygienic practices.

The study revealed that the proper location of shallow wells, septic tanks, latrines, and fitness of the good covers were revealed by the study to be the most important factors responsible for good vulnerability to contamination. Heaping up on effluent can raise the level of groundwater increment and the threat of contamination by septic tank effluent. Well characteristics, comprising construction and site management, are important to water quality. Due to rapid financial and social development, Juja is presently confronted with the issue of an increasing amount of liquid waste. In densely populated areas with many pit latrines, the risk of groundwater contamination is high, especially when the latrines are situated at a higher altitude than the wells (Odiwuor et al., 2018). Overcrowding in study sites left inhabitants with a limited distance between wells and sanitary structures. An unfittingly capped well is further susceptible to contamination and presents a safety hazard. Movement of typhoid-causing microscopic organisms through at least 3 to 4 feet of sand and 210 feet of immersed soil and downward development of leachate can be up to 30m down, where precipitation desorbs microbial pathogens, counting infections and carries them down in still reasonable states (Mbugua, 2016). Groundwater protection obliges all wells to be fitted with protected covers to inhibit direct and unintended access of contaminants by people or animals into the well (Schmoll, 2013). Appropriate counteractive actions such as constructing standard good infrastructure, restructuring the wells, positioning latrines and septic tanks at a prescribed distance (>10 m) from wells, and eliminating ponding around the wells should be conducted to protect the well water. Enlightening and instructive campaigns ought to be combined with the execution of expressive pilot ventures to advance the potential health and well-being of peri-urban communities (Mushi et al., 2012).

5.0 Conclusions

Septic systems are the main effluent disposal methods that significantly contribute to groundwater contamination. Water from wells in Juja is contaminated with E. coli levels ranging from <3 - >1000 MPN/g, an indication of fecal contamination among underground sources of water in the area. The proximity threshold between the septic system and the well is the major predisposing factor to poor water quality.

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6.2 Analysis and Research

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6.3 Presentation of the study, findings, and a portion of the work

These preliminary findings were presented in seminar progress presentations at the KEMRI graduate school.



6.4 Declaration of interest

There are no known conflicts of interests associated with this publication. All co-authors agree with the contents of the manuscript and there is no financial interest to report.

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