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# Risk assessment of Sanitation and water Infrastructure in informal settlements of Kisumu: Implications for Hygiene and Public Health

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## Abstract

Risk assessment encompasses assessment and reporting of the potential harm, danger and health concerns arising from the use or contact with potentially harmful materials or substance. In the context of urban sanitation and water, risk assessment may involve the assessment of the likely harm arising from the use of unprotected or unimproved water and sanitation facilities and likelihood of injuries that such facilities may exert on the community. Urban informal settlements, which remain the face of urban vulnerability in most developing countries, are dominated by unprotected sanitation facilities and water sources which have subsequently exacerbated the urban social and health vulnerabilities and risks. This article assessed risks from sanitation and water infrastructure in urban informal settlements and their implications on community hygiene and public health using the case study from Kisumu City, Kenya. The article is based on data collected using a modified WASHFIT risk assessment tool developed by the WHO. One hundred and fourteen water sources and 460 sanitation facilities were covered by the study. Findings from the study revealed that 87% of water sources studied were shared by multiple households, while 65% and were unprotected. Some improvements had been undertaken in only less than 20% of sanitation facilities, with large proportion accounting for the ventilated improved pit latrine type. The remaining more than one fifth or 80% of the facilities were poorly constructed traditional pit latrines. Water quality findings revealed that nitrate and thermotolerant coliform levels were higher across most water sources and beyond the minimum recommended thresholds by WHO drinking water standards. On the risk assessment scale, 67% of water sources and 70% sanitation facilities were categorised as “risky” respectively. Considering the findings, this article concludes that the sanitation and water facilities in the study fails to meet the mean risk threshold desirable for an improved facility and thus falling short of the aspirations of the global sustainable development goals. The study recommends an inclusive forward planning to address the risks in the context of possible future climate change threats.

**Keywords:** S*anitation facilities; risk, traditional pits; water supply infrastructure*

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## Introduction

Informal settlements are residential areas where the residents lack security of both the land tenure and housing (Were *et al*, 2022). In law the occupancy and the settlements are illegal. Lack of basic services and infrastructure is a widespread phenomenon in the informal settlement neighbourhoods. This sustains informality that research has over the years identified as a source of environmental hazards to the residents (Odote & Olale, 2021). Urban informal settlements or slums is one of the main causes of poverty that also catalyzes vulnerability to urban social vices and crime. Veriah (2018) points out that poor access to basic facilities, under-provision or absolute lack of sanitation and water are some of the indicators of the vulnerability. Findings from a recent study show a proportion of 19% of people globally had no access to safe drinking water, 33% lack safe sanitation while a 13% of them relied on on-site sanitation (WHO, 2021). These indicators are lower in the urban informal settlements which typically register weak indicators of the livelihood parameters in cities, thereby recording equally weak performances city indices globally (Were *et al,* 2022).

Owing to rapid growth in urban informal settlements, urban informal dwellers are made to use health-wise risky, unprotected rudimentary sanitation facilities dominated by poorly built pit latrines commonly referred as traditional pit latrines (TPL), and water supply systems like open shallow wells (Williams *et al.,* 2018). Besides poorly built facilities, the facilities especially latrines are built close to the shallow wells that also provide water to many households without access to municipal water supplies. Poor siting together with the fact that most facilities lack protection continues to amplify risk of contamination of water. Again, unprotected facilities may present physical risks to members of the community especially children and the vulnerable i.e. risk of falling and drowning.

Risks for instance drowning is a grievous key health risk in the urban informal settlement, a problem that is likely to be compounded by factors such as lack of protection and congestion which is characteristic of urban informal settlements. It is reported (Meddings *et al.*, 2021) that drowning remains the third leading cause of unintentional injury death, accounting for a significant number of all injury-related deaths statement across the world and affecting the most vulnerable like children, males, and individuals with increased access to water (Taonameso *et al.*, 2018). While data on drowning remains scanty for urban informal settlements, the WHO estimated that in 2014 alone, 236,000 people died from drowning with the greatest burden reported in the developing countries (WHO, 2019).

More importantly, the compounding factor of climate change on risks associated with unprotected sanitation facilities cannot be overstated. The uncertain anticipated climate risks and extremes such as extreme precipitation and floods may exacerbate the present hazards leading to more injury, losses of lives, and drawbacks on development gains (IPCC, 2014).

The present study assessed risks of sanitation and water infrastructure in poor urban settlements and the implications on hygiene and public health. The paper recognizes that provision of safe and secure sanitation and water remains a key focus of the SDGs with the sixth, ninth, eleventh and thirteenth SDGs seeking to ensure availability and sustainable management of sanitation and water for all, and making human settlements safe, resilient, and sustainable as well as taking targeted actions to combat the impacts of climate change (Othoo *et al*., 2020). The study aims to provide insights into the risks arising from unprotected urban informal settlements' sanitation and water facilities while exploring forward planning in addressing present urban challenges and future threats posed by future climate risks.

### *Vulnerability and Risks of Urban Sanitation Facilities*

That Urban informal settlements in developing countries possess unique vulnerabilities and multiple hazards and risks, cannot be overstated (Zerbo, *et al.,* 2020; Satterthwaite *et al.,* 2020). Many of these settlements exist in high-risk areas such as low-lying plains and on riparian areas, a situation exacerbated by poverty, and the lack of adequate planned housing settlements to meet the growing demands of urban populations (Wagah & Mwehe, 2019). By the nature of their spatial existence in fragile ecosystems, most residents in the urban informal settlements cannot afford to construct permanent housing structures that are durable owing to continued growth of the informal housing structures that lack sanitation facilities and water supply. Additionally, presence of weak social, economic and physical infrastructure support has enhanced susceptibility that undermined capacity to cope with adverse outcomes of climate extremes, especially floods (Fatemi *et al.,* 2020; Ochola *et al*., 2010; Okaka & Odhiambo, 2019; Huang *et al.,* 2012). This latter reality has in turn led to increased risks from unprotected sanitation and water facilities in the urban informal settlements.

Okaka & Odhiambo (2019), UNISDR (2017), Sakijege *et al.* (2014) have suggested that informal settlements are themselves disastrous hotspots where residents are continuously exposed to risky livelihoods. Such risk manifests themselves in the form of continuous exposure to precarious facilities and infrastructure such as open manholes of sewer lines, shallow wells and open pit latrines that are not covered. Moreover, underground water may percolate to dampen the earthen floors, creating conducive conditions for water borne diseases to thrive.

Sanitation facilities and water sources are generally classified based on the extent of improvements or protection, which to a large extent define their vulnerability (Simiyu *et al.,* 2016). Other factors which may define the vulnerability of water and sanitation facilities include the nature and type of facility and the technologies used to build them. Generally, water sources are categorised as either improved/protected or non-improved (WHO, 2015). An improved water source is defined as one that, by nature of its construction, is protected from entry of physical, chemical, and biological contamination. Protected water sources are often covered by stonework, concrete or other materials that prevent the entry of contaminants, while unprotected sources are those with no barrier to protect the water from contamination (De Risi *et al.,* 2013**).**

Sanitation facilities on the other hand, are classified based on different systems and types into the following three categories, namely: (a) context of use i.e., shared, or household owned facilities, (b) earth/dry and water-based types; and (c) types and stability of the structures for instance mobile and permanent facilities (Othoo et al., 2021). Examples of common sanitation facilities in urban informal settlements may include the traditional pit toilet (TPL), the San-plat pit latrine, and the ventilated improved pit toilet (VIP) - the widely promoted type among low-cost settlements (Tilley *et al.,* 2014). For pit latrines, the number of risks faced is dependent on the type of latrine/facility, nature of superstructure and roofing, and the available mechanisms for building stability against flooding such as raising above height of water table as well as existence of mitigation measures toward flood risks (Othoo *et al.*, 2021).

## Materials and Methods

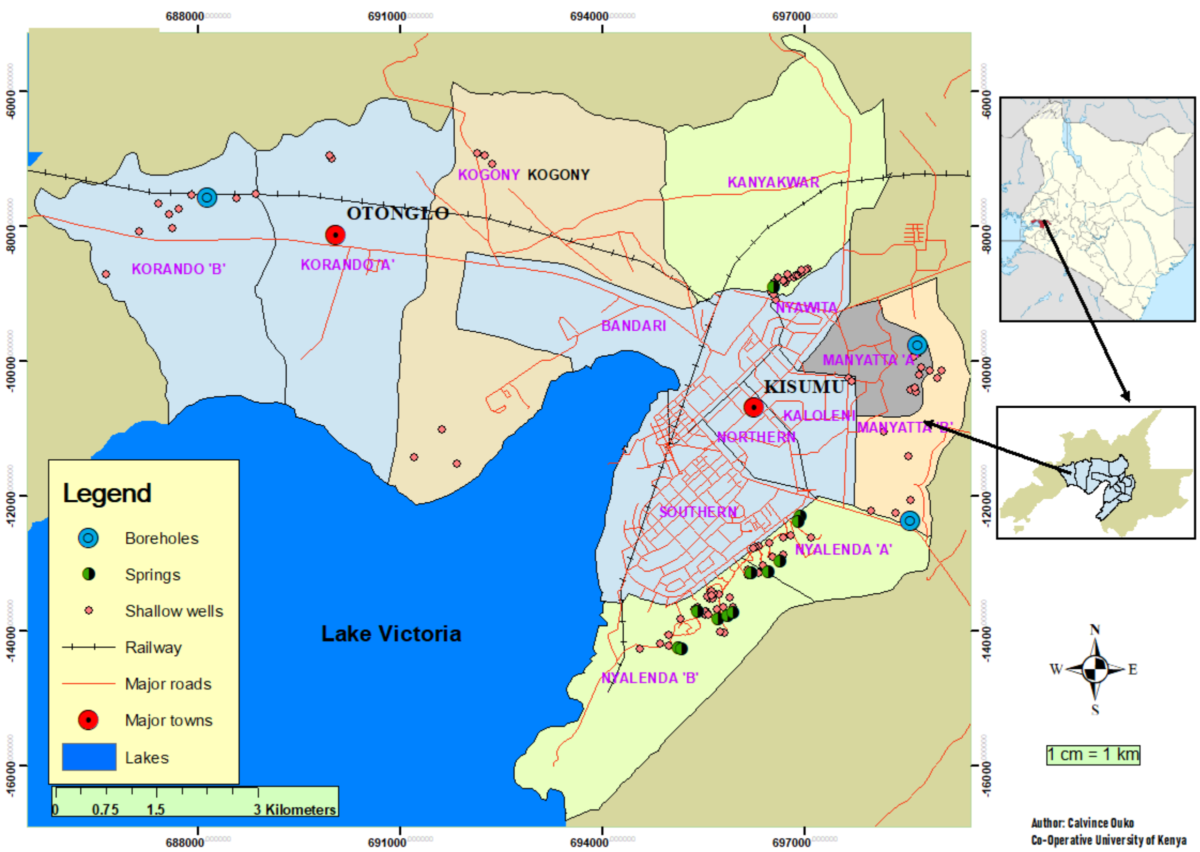
### *Description of Study area*

Data for this article was collected from five sample informal settlements, namely, Nyalenda, Manyatta, Obunga, Kogony and Korando within Kisumu City – the latter two being peri-urban informal settlements. Kisumu city is the commercial capital of the Western Kenya region. The city is situated on the shores of Lake Victoria at longitudes 34°20′E and 34°70′E, latitudes 0°20′South and 0°25′South (Otieno *et al.*, 2021) and lies at an altitude of about 1160 m above sea level. The city has an annual precipitation between 1111 and 1407 mm received in two major rainy seasons; March, April and May (467- 477 mm) and October, November and December (370 mm) and a subdued rainfall peak in August (150 mm) (Othoo *et al*., 2021). Temperature varies seasonally with a maximum annual temperature range from 25ºC to 30ºC while the mean annual temperature ranges from 18ºC to 20ºC.

The choice of the study areas was informed by the fact that the five informal settlements experience similar challenges of water and sanitation while also sharing common socioeconomic conditions. Studies by Simiyu *et al*. (2020) and Wagah & Mwehe (2019) confirm that poverty, social deprivation, and health related challenges arising from poor hygiene is rampant in these urban and peri-urban informal settlements. Traditional pit latrines have been found to dominate both the urban and peri-urban areas of Kisumu (Othoo *et al.*, 2020; Davies *et al.*,2018). The recent Kisumu County Integrated Development Plan (CIDP) highlighted diarrheal diseases as the third leading cause of morbidity among the under-fives in Kisumu County which point to substandard water and sanitation condition mostly reported the informal settlement areas (Simiyu *et al.*, 2020).

**Figure 1**

*Study Area showing urban and peri urban informal settlements*




Kisumu city is surrounded by hilly escarpment on the north, wetlands in the south and two plain belts on the south-east and in the mid-north (Wagah & Mwehe, 2019). The soils of the plains are often flooded, and the water table is generally high. In the informal settlements of Manyatta and Nyalenda, the water table often can rise to depths of 3 m (Wright *et al.*, 2013). The main water sources within Kisumu's informal settlements include Lake Victoria, shallow wells, unprotected springs, water pans, dams, boreholes, and roof catchment systems. However, with the rising population in the city and environs, pressure is mounting on existing amenities and infrastructure installations leading to more vulnerability and uncertain future (Simiyu *et al.*, 2020).

Kisumu City performs below the national average on most socio-economic indicators. The city scores a 0.49 (bellow 0.56 national average) on the Human Development Index (HDI) according to the statistics from the Kenya National Bureau of Statistics (KNBS) (KNBS, 2022). The city currently experiences the highest average urban "poverty" levels at 48% against a national average of 29%. Available statistics indicate that Kisumu, has the highest number of urban informal dwelling population among the five major Kenyan cities. This is also true when compared to the city's peer urban centres around the lake in Uganda and Tanzania. Urban poverty in Kisumu manifests itself in reduced living standards, continued access to unclean water and sanitation services, increasing number of social ills and crime, especially in the low-income settlements.

***Ground surveys for Water Sources and Sanitation Facilities***

To identify the sanitation facilities and water sources of interest, a random sampling criterion was used to identify the initial water source/point. Once the initial water point was identified, sanitation facilities within 50 metre radii were identified with the help of a community guide, neighbouring water sources were further identified and assessed using a snowball technique. A total of 460 sanitation facilities and 114 water sources were surveyed; the water sources comprised 100 shallow wells (88%), 11 springs (1%) and 3 boreholes (0.02%). Of the water sources, about 83.4% water sources were from the urban informal settlements (Nyalenda, Manyatta and Obunga) while the rest (16.4%) were from the peri-urban informal settlements of Otonglo and Kogony. The choice of the sample design was informed by the vastness of the study area, high number of pit latrines, and on the presence of high number of shallow water sources. Information relating to the number of users, nature and type of protection (indicated by the presence of the top cover), wall protection, proximity of water sources to sanitation facility, condition of the well, nature of sharing (i.e. whether used by two or more households), were all documented. The outcome of this assessment provided a basis for evaluation of various risk categories for the sanitation and water facilities.

***Water Quality Data;*** A total of 74 water samples were collected from the selected water sources **(**19 SWs and 4Sps**)** within in the study area. The necessary sampling procedures and standard analytical procedures were considered for each sample analysis in line with the ISO standards (ISO 17381:2003) which were outlined in the University of Nairobi Laboratory manual and procedures. Quality Control and Quality Assurance (QC/QA) was achieved by ensuring that samples were taken in duplicates across large sample size and by including a few control samples to eliminate background contamination. The pH, Thermotolerant Coliform bacteria (TTC) and electrical conductivity (EC), were undertaken in-situ using the portable analysis toolkit. Laboratory analysis for nitrates ($NO_3^-$) was undertaken at the Geochemistry Laboratory of the University of Nairobi using a HACH DR600TM spectrophotometer machine.

***Assessment of Risk Factors for Sanitation and Water Facilities***

Modified WASH FIT Tools, 2A and 2C, developed by WHO (WHO, 2017b) was used to assess the sanitation and water risks according to the WHO standards for drinking water. The study used an improved WASH FIT Tool 2A to conduct a comprehensive sanitation assessment of the sanitation facility using the agreed list of indicators. The investigator recorded whether each indicator meets **(+++)**, partially meets **(++),** or does not meet **(+)**, the minimum standards.

Tool 2C was used to conduct the sanitary inspection (SI) and determine the level of risk from sanitation and water sources at the facility. The risk scores are divided into four major classes namely, low risk, where the risk score is between 0 – 2 (read as 0 – 20%), and moderate risk (3 – 5), high risk (6 – 8) and very high risk (9-10) – see Table 1 and Table 2. A high-risk indicator shows that the hazard/problem very likely results in injuries, acute and/or chronic illness, or infection. A high-risk case demands immediate actions to be taken to minimize the risk.

**Table 1**

*Risk assessment criteria*

| Indicator criteria | Cumulative 'YES' score | Percent |
|---|---|---|
| Very High Risk | **9-10** | **>90%** |
| High Risk | **6-8** | **≥60 ≤90%** |
| Medium Risk | **3-5** | **≥30 ≤60%** |
| Low Risk | **0-2** | **≤20%** |

**Table 2**

Risk assessment framework

| | | Risk Assessment | |
|---|---|---|---|
| **Item** | **Indicator** | **Description/summary** | **Assessment Criteria** |
| **Water Sources** | **Nature and types** | • Compared to other sources of water, shallow wells are the least improved. They are more vulnerable to contamination.<br>• Risk was assessed based on percentage of total water sources composed of SWs | • High risk = >70% SWs<br>• Moderate risk = 30-70%<br>• Low risk = <30% |
| | **Depth** | • Depth affected protection, deeper wells were more protected than shallower wells<br>• Risk assessed based on the proportion of water sources that are below 2m, 3m - 15m, and above 15m deep | • High risk = <2m<br>• Moderate risk = 3-15m<br>• Low risk = >15m |
| | **Uses** | • Drinking is the most sensitive use of water, and demanding the highest form of purity.<br>• Risk assessed based on the percentage of the sampled SWs that were used for drinking. | • High risk = >50%<br>• Moderate risk = 20-50%<br>• Low risk = <20% |
| | **Users** | • Users define exposure to risks.<br>• Risk assessed based on the average number of users per water source. Users were considered during dry season. | • High risk = > 60users<br>• Moderate risk = 30- 60 users<br>• Low risk = <30 users |
| | **Abstraction** | • Hand drawing (HD) was observed as the basest form of water abstraction.<br>• Risk assessed based on the proportion of SWs using HD in each site. | • High risk = >60% use HD<br>• Moderate risk = 30-60% use HD<br>• Low risk = <30% use HD |
| | **Protection** | • Protection is indicated by presence of wall lining, top cover & concrete embankment.<br>• Protection safeguards against cross-contamination, and defines improvement.<br>• Risk assessed based on calculated percentage of water sources with protection in each site | • High risk = <30%<br>• Moderate risk = 30-60%<br>• Low risk = >60% |

| | | | |
|---|---|---|---|
| | **Risk to ground water** | • Assessed based on the scores in the water source scores<br>• The percentage of scores falling on the "very high risk" category | • High risk = >50% in VHR<br>• Moderate risk = 20-50% in VHR zone<br>• Low risk = <20% in VHR zone |
| **Sanitation facilities** | **Types** | • Risk assessed based on the proportion of total sanitation facilities made up of TPLs. TPL represents non-improved sanitation | • High risk = >70% TPLs<br>• Moderate risk = 30-70% TPLs<br>• Low risk = <30%TPLs |
| | **Roofing** | • Risk assessed based on percent of sanitation facilities with no roofing at all (non-roofed). Lack of roofing lowers latrine quality and increases risk to effects of weather | • High risk = >50% no roof<br>• Moderate risk = <30-50% no roof.<br>• Low risk = <30% no roof |
| | **Facility sharing** | • Assessed based on the percentage households sharing sanitation facility. Facility sharing is an unhealthy practice | • High risk = >30%<br>• Moderate risk = 10-30%.<br>• Low risk = <10% |
| | **Body structure** | • Risk assessed based on percent of TPLs possessing iron sheet superstructures/none.<br>• lack of superstructure increasers users vulnerability | • High risk = >70% iron sheet.<br>• Moderate risk = <30% - 70% iron sheet.<br>• Low risk = <30% iron sheet. |
| | **Proximity Distance** | • Assessed based on presence of more than three pit latrines within 30 m radius.<br>• Generally, density of pit latrines near water points is attributed to water quality | • High risk = >5 No.<br>• Moderate risk = 3–5 No.<br>• Low risk = <3 No. |
| | **Risk to ground water** | • Assessed based on the sanitation risk assessment scores<br>• Percentage meeting 30 - 70% of the 10 indicator-list scale (percentage of yellow zones). | • High risk = <30% meet 30-70% requirements<br>• Moderate risk = 30% - 50% meet 30-70% requirement,<br>• Low risk = >50% meet 30% - 70% |
| **Water quality** | **TTC** | • Risk assessed based on the proportion samples, from each study area, that meet/fail the WHO guidelines (0.0 CFU/100 ml).<br>• TTC is a biological pollutant | • High risk = >60% do not meet<br>• Moderate risk = 30-50% do not meet<br>• Low risk = <30% do not meet |
| | **$NO_3$** | • Risk assessed based on the proportion samples, from each study area, that meet/fail the WHO guidelines (50 mg/l) | • High risk = >60% fail<br>• Moderate risk = 30-50% fail<br>• Low risk = <30% fail |
| | **pH** | • Risk assessed based on the proportion samples, from each study area, that meet/fail the WHO guidelines (pH = 6.5 - 8.5) | • High risk = >60% fail<br>• Moderate risk = 30-50% fail<br>• Low risk = <30% fail |
| | **EC** | • Risk assessed based on the proportion samples, from each study area, that meet/fail the WHO guidelines (1500 μS/cm) | • High risk = >60% fail<br>• Moderate risk = 30-50% fail<br>• Low risk = <30% fail |
| **Aggregated Summary** | | | **Risk class**<br>**High**<br>**Moderate** |

| | |
|---|---|
| | **Low** |
| | **No risk** |

## Results

### *Water facilities*

The results showed 87% of the residents use shared water facilities (used by multiple households) and only 10% use piped water systems into their households. The shared water facilities comprised of shallow wells, springs, and municipal water connections to specific community taps or water kiosks. About 3% used vended water supplied through carts. About 32.7% of the shallow wells studied had wall linings, while 36.3% of the springs had protection (Table 3). The results also revealed that there were more shallow wells with protection in the peri-urban settlements (63.2%) as opposed to the urban informal settlements (35.2%).

**Table 3**

*Condition of shallow wells and springs*

| Settlement | Site | Number of SWs (N=100) | Protected | Concrete drainage | Outflow pipe | Seasonality (permanent ) |
|---|---|---|---|---|---|---|
| **Urban informal** | Nyalenda B | 24 | 6 (26.1%) | 3(12.5%) | Nil | 14(58.0%) |
| | Nyalenda A | 17 | 1 (6.0%) | 0(0.0%) | Nil | 8(57.0%) |
| | Manyatta B | 14 | 5 (35.7%) | 4(28.5) | Nil | 8(55.0%) |
| | Manyatta A | 7 | 6 (85.7%) | 3(43.0%) | Nil | 3(43.0%) |
| | Obunga | 22 | 5 (22.7) | 2(10.0%) | Nil | 10(45.0%) |
| **Peri-urban** | **Kogony** | 8 | 2 (37.5%) | 2 (50.0%) | Nil | 2(25.0%) |
| | Korando | 9 | 8 (88.9%) | 7 (78.9%) | Nil | 2(22.2%) |
| | | **Number of springs (N=11)** | | | | |
| **Urban informal** | Nyalenda B | 6 | 3 (50.0%) | 2(33.3%) | 2(33.3%) | 2(33.3%) |
| | Nyalenda A | 3 | 1 (33.3%) | 1(33.3%) | 1(33.3%) | 3(100.0%) |
| | Obunga | 1 | 0 (0.0%) | 1(100) | 0(0.0%) | 1(100) |
| **Peri-urban** | Korando | 1 | 0 (0.0%) | 0(0.0%) | 0(0.0%) | 0(0.0%) |

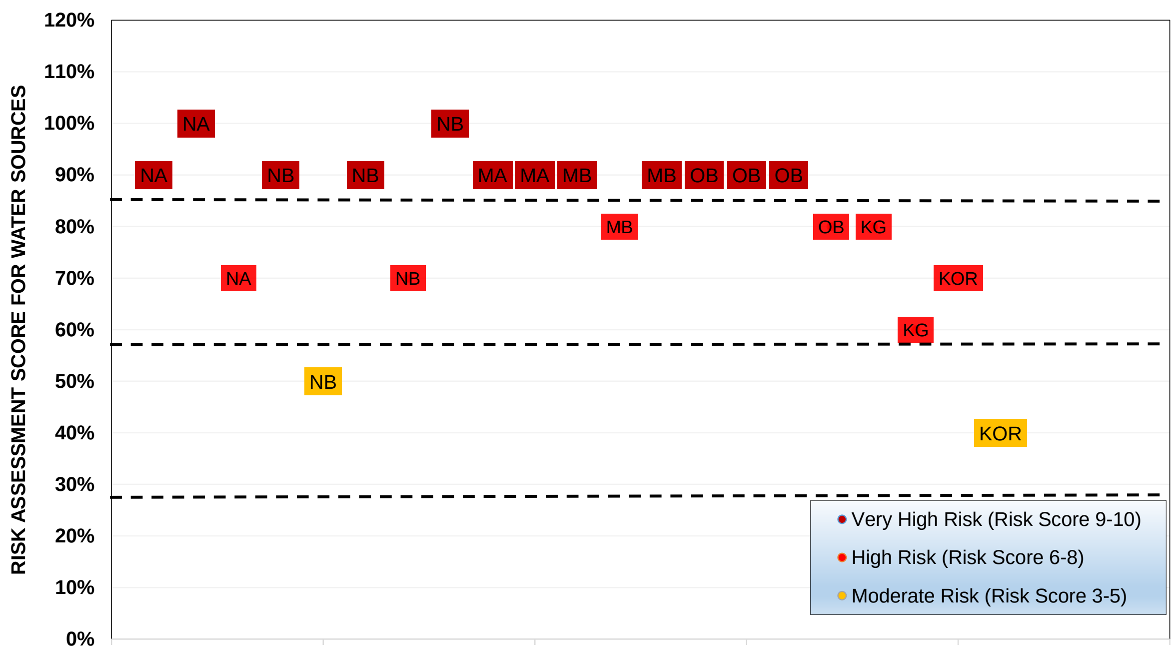
*Nil – not observed

***Risk Scores for Water facilities***

The detailed risks assessment considered factors such as risks of exposure to surface contamination, risks to ground water pollution and including hazardous exposures to residents i.e. risks of falling into pits and eventually injury and losses of life. The detailed risk assessment undertaken produced scores reported in Figure 2. The results show 57.1% of the sampled wells recorded very high-risk status, about 33% have high risk and approximately 10% recording low risk status. Observably, shallow wells from the urban informal settlements dominated the "very high-risk" category as opposed to the peri-urban informal settlement. In addition, about 65% water sources in the informal settlements were unprotected or non-improved, this means that they were open to external infiltration since they were lacking wall lining. Again, these facilities that scored high risk were mostly shared by multiple users and households. About 12% of the water sources are used by residents for cooking and drinking. This usage of unimproved water sources for such critical household needs - cooking and drinking - is evidence to the municipal water supply challenges experienced by residents in the informal settlements. It was observed that waterflow in the form of springs were emerging beneath certain houses, a phenomenon believed to be responsible for dampness and wetness which is also a risk factors for cold feet and other water borne diseases especially among children.

**Figure 2**

*Risk assessment score for shallow water sources*




***Risk from non-improved sanitation facilities***

The facilities were assigned three, two or one stars if they "met", "partially met", or "did not meet" the minimum standards, respectively. The results (Table 4) present the percentage of sanitation facilities that met the targets, expressed symbolically as <30, 30-70% or >70% of the sanitations facilities that met the criterion. Less than 30% of facilities studied met the targets across most of the indicators. The study further shows that traditional pit latrine represents 61% of all sanitation facilities, 65.2% being from the urban informal settlements while 57% being from the peri-urban informal settlements. In the urban informal settlements, sharing of facilities was common, informal settlements such as Nyalenda A, Manyatta B, Nyalenda B, and Manyatta A showed 20%, 19%, 18% and 16% respectively of shared facilities.

***Risks Associated to Water Quality***

Water quality risks was assessed for electrical conductivity (EC), pH, thermotolerant coliform bacteria (TTC) and the Nitrate ($NO_3^-$) concentration. The results showed that pH varies from 6.1 – 7.8 with the lowest values recorded in Nyalenda B, and highest in Manyatta B. The Electrical conductivity showed a slight range of 708 µS/cm and 637 µS/cm. This therefore meant that pH and electrical conductivity were both within acceptable WHO limits across all the shallow wells in the urban and peri-urban settlements. The WHO allowable pH limit is 6.5 - 8.5, while EC WHO limit is 3,000 µS/cm (WHO, 1997).

The TTC ranged between 270 to 57,200 CFU/100 ml for different shallow wells. These values are notably higher than the tolerance level recommended by the WHO (WHO, 1997) which provide zero (0.0 CFU/100 ml) as the acceptable concentration limits for TTC. In addition, the study found mean nitrate concentrations of 83.0 mg/l from water sources in the urban areas, while the peri-urban mean was 16.0 mg/l. In some informal settlements such Nyalenda A and Nyalenda B, the nitrates were in the average of 131.4 mg/l and 58.5 mg/l, respectively. These values are above recommended nitrate levels of 50 mg/l according to WHO.

**Table 4**

*Summary of indicator assessment for sanitation facilities*

| | **Indicator/Targets** | **× - Less than 30% meets the target<br>● – Approximately 30-70% meets the target<br>√ - More than 70% meets the target** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **NYA** | **NYB** | **MA** | **MB** | **OBU** | **KOG** | **KOR** |
| | **Number of toilet facilities evaluated** | **14** | **18** | **12** | **6** | **18** | **4** | **4** |
| 2.1 | Sufficient number of improved toilets or latrines available | × | × | × | ● | × | ● | √ |
| 2.2 | Toilets separated for different users, visitors | × | × | × | × | × | ● | ● |
| 2.3 | Toilets separated for male and female | × | × | × | × | × | × | × |
| 2.34 | Menstrual hygiene management | × | × | × | × | × | × | × |
| 2.5 | Toilet meeting the needs of people with reduced mobility | × | × | × | × | × | × | × |
| 2.6 | Functioning hand hygiene stations at latrines | × | ● | × | ● | × | × | ● |
| 2.7 | Cleaning records signed and visible | × | × | × | × | × | × | × |
| 2.8 | Wastewater is safely managed | × | × | × | × | × | × | × |
| 2.9 | Greywater drainage system is safely managed | ● | ● | ● | ● | × | √ | ● |
| 2.10 | Toilets and latrines are adequately lit | × | × | × | × | × | × | × |

**Discussions**

***Risks Associated with Water Facilities***

Access to quality water always, and by all, is one of the key aspirations of the sustainable development goal six (SDG 6), however, this study has shown that many facilities (about 70%) in both the urban and peri-urban informal settlements of Kisumu had failed to achieve the status of improved facilities going by the laid standards of an improved facility according to WHO (2017a). Consequently, these non-improved facilities recorded higher risk status results based on the WASHFIT tool (WHO, 2017b). By being considered risky, the facilities (both sanitation and water facilities) lack the necessary merit for safe community use and promotion of community hygiene standards. Without sufficient improvements, facilities become conduits of disease transfers and contaminant seepage into the shallow wells. According to Tilley et al. (2014), protection of water sources is promoted as a measure for safeguarding against surface and ground water mixing during high seasons of precipitation. Considering Kisumu's geographical and geological setting, with frequent flooding occasioned by high water table, waterlogged clay soils and level terrain, unprotected shallow wells without wall lining or top cover protection, are essentially vulnerable to surface intrusion by surface contaminants (Plate 1) (WHO, 2017b). The city's water facilities standard codes should consider stricter adherence to shallow wells covering and wall lining as a way of promoting water source protection and sustainable use. Top covering, besides protecting from sanitation facilities' overflows, especially during flooding, also protects against emergencies such as the risks of falling. On the other hand, wall linings may prevent entry or seepage of contaminants through the walls, and across other contaminating surfaces such as toilets. In the context of urban informal settlements, any actions towards preventing surface inflows into shallow wells is highly encouraged as a preventative measure against compromised water quality (Serrano *et al.*, 2017). Likewise, contamination arising from compromised waste management practices or illegal dumping sites and open sewer flows demands deliberate intervention. Recent research by Othoo et al. (2020) confirm that water facilities exist within very close proximity (~ <1.0 m) which maybe a precursor to the already existing vulnerabilities of water facilities in Kisumu's informal settlements.

Other observable risks from the study area relate to the presence of persistent wetness and dampness in some houses. In some houses, spring waters outflow from beneath the housing floors as shown in Plate 2. Such phenomenon could be attributed to the high-water table conditions already alluded for the study area (Othoo *et al.*, 2021; Okotto-Okotto et al., 2015) and the relatively flat topography conditions which characterizes Kisumu city, and the fact that major informal settlements are situated in flood prone areas. Dampness can cause varied health challenges including but not limited to bacterial and fungal contamination among other waterborne diseases (WHO, 2017a). This finding agrees with reports that keep Kisumu region at the top of the regions with higher national statistics of water-borne diseases annually (Okaka & Odhiambo, 2019). According to Thrasher (2016), damp indoor environments favor house dust mites and microbial growth, supports cockroach and rodent infestations, while excessive moisture may initiate chemical emissions from building materials and furnishings. One factor that may exacerbate this situation is the existence of mud floors, which being an informal settlement environment, is common. Again, wet conditions in the neighborhood could increase risks of slipping and injury, besides being an impediment to residences recreation, as there would be no more space for activities such as children playground, even this is a social risk attributable to wetness and flood related dampness rampant in the area.

**Plate 1**

*Uncovered Manhole observed within the study community members (photo by author)*

**Plate 2**

*Wet conditions caused by pring outflows beneath residential houses (photo by author)*

*Risk from non-improved sanitation facilities*

While the global community aims to ensure access to safely managed sanitation for all, the findings of this study have shown that only a few facilities (less than 30%) met the risk targets across most of the risk indicators for sanitation assessment. Kisumu's informal settlements are dominated by traditional pit latrines with the situation worsened in the urban informal settlements where they are also largely shared by multiple households. Traditional pit latrines (TPL) are often poorly constructed without due consideration to hygiene and sanitation infrastructure building codes. Often the workmanship is rudimentary and low skilled (Tilley et al., 2014). Because of the foregoing reasons, they are unable to withstand emergent shocks such as flooding and regular overflows arising from frequent flooding and bad weather. Again, the nature of superstructures cannot withstand contaminates exposure, thus they are often exposed to unhygienic conditions. The result is normally high risk of contamination for neighbouring water facilities and risk to health of community members who must contend with poor smells and possibility of communication diseases related to poor hygiene. These complex urban vulnerability mix coupled by increasing population pressure, poor housing structures and limited access to amenities which push community members to share facilities. More worrying is the fact that residents coexist in congested environments with close proximal facilities as depicted in Plate 3.

***Risks Associated to Water Quality***

While four water quality parameters were assessed (pH, nitrate, thermotolerant coliforms, conductivity), thermotolerant coliforms (TTC) and Nitrate results were the major concern for this study. All the shallow wells had higher TTC levels (range 270 - 57,200 CFU/100 ml) against WHO recommended standards of zero TTC in drinking water. Thermotolerant coliforms are indicators of faecal pollution (Hachich *et al*., 2012). In an urban informal settlement setting, where poorly sited toilet facilities and garbage dumping is common, this higher TTC is potentially indicative of contamination emanating from pit latrines. Sometimes, pathogenic contaminants infiltrate through the pervious soil layer into neighbouring water sources, especially when the pit latrines and water sources are too close. Already confirmatory studies confirm the proximity distance to be high in Kisumu (Othoo *et al.* 2020). Such a close distance between facilities may present a higher probability of contaminant seepage through the walls of unprotected of pit latrines and water sources. Proximity of pit latrines and shallow wells may also compound the contamination risk arising from surface waste dumping which may also be a source of TTC and other pollutants into shallow wells (Opisa *et al*., 2012).

**Plate 3**

*Risks posed by waste dumping and poorly sited sanitation facilities (photo by author)*

The nitrate level was higher for water sources in both the urban informal settlements (~131 mg/l) and peri-urban informal settlements (58.5 mg/l) with some showing values three times the amounts recommended by WHO (50 mg/l). High nitrate levels is a matter of public concern in drinking water (Taonameso *et al*., 2019; Thrasher, 2016). Nitrates are known to cause oxygen deprivation in the human body from a condition commonly known as methemoglobinemia where the nitrates bind with haemoglobin of the red blood cells and thus reduce the capacity of red blood cells to carry oxygen (Hachich *et al.,* 2012). In the natural environment, excess nitrates can cause eutrophication in water bodies such as ponds, wells, or dams, a process which results in algae and plant bloom, subsequently resulting in oxygen deprivation or anoxic condition. The result is aquatic life death or dead water syndrome for other living organisms that depend on the water (Serrano *et al.*, 2017). The work of Craswell (2021) highlight that nitrates activity in the environment is catalysed by the high mobility of nitrates in the environment which is attributed to high nitrate solubility in water. The elevated levels of nitrate contamination in Kisumu's informal settlements have been expressed in other studies (Wright *et al.,* 2013; Opisa *et al.,* 2012). Some studies argue that it is partly associated to proximal leaky on-site sanitation (Okotto-Okotto *et al.*, 2015) and peaking during rainfall events, indicating that enhanced leakages, and sometimes pit latrine flooding and overflow may contribute to contamination. It is noteworthy to say that higher nitrates observed in some of the shallow wells in Kisumu may have contributed to the high-risk profile reported in this study. The high-risk profile obtained in this study confirms the public health concerns in urban informal settlements and a need for regular monitoring of the state of provision of improved and affordable water and sanitation services to vulnerable urban settlements.

**Conclusion and Recommendations**

Following the above discussion, this study summarises key risks posed by risky wells and pit latrines in the study area as follows: while majority of water sources in the urban informal settlements of Kisumu are unprotected and failed to meet the guidelines for drinking water provided by WHO, there is room for improving the facilities to make them meet the necessary quality standards befitting a sustainable city. Moreover, majority of the water sources and sanitation facilities were shared between many households leading to compromised hygiene and quality, a challenge which can be overcome through awareness and sensitization household sanitation as opposed to public or shared ones. Existence of proximal pit latrines to water sources together with poorly maintained shallow wells, indiscriminate dumping of waste, and poor sanitation practices was among the factors compounding the risks of water and sanitation in the urban informal settlements of Kisumu, and which not isolated from similar problems affecting other cities in the developing world. The study recommends an inventory of all shallow wells in the informal settlements and regular monitoring of water quality, status, and enhanced efforts at providing water treatment to the residents who use shallow wells in the urban areas.

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**Conflict of Interest**

The authors have no conflicts of interest to declare.

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