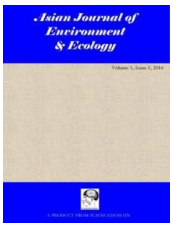

Asian Journal of Environment & Ecology

3(3): 1-11, 2017; Article no.AJEE.34699
ISSN: 2456-690X

Potential Health Risks Associated with Consumption of Shallow Well Waters in Informal Settlements in Dar es Salaam, Tanzania

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Authors' contributions

This work was carried out in collaboration between all authors. Authors MV and SY designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SY and MJ managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEE/2017/34699
Editor(s):
(1) Daniele De Wrachien, Professor of Agricultural Hydraulics at the Department of Agricultural and Environmental Sciences, State University of Milan, Italy.
Reviewers:
(1) S. O. Adesogan, University of Ibadan, Nigeria.
(2) Thant Zin, Myanmar Medical Association (MMA) and Preventive and Social Medicine Society, Myanmar.
(3) Chadetrik Rout, Maharishi Markandeshwar University, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/20032

Original Research Article

Received 6th June 2017
Accepted 1st July 2017
Published 14th July 2017

ABSTRACT

This paper explores the risks associated with the usage of private water supply from shallow wells in informal settlements in Dar es salaam, Tanzania. Studies on spatial location of water sources used by water vendors in relation to potential sources of contaminants in Tanzania are scant in literature and therefore little is documented on the potential health risks posed by such water sources. Data were collected through documents, household survey and interview with officials and local leaders at Nyambwera and Tamla Sub-wards in Dar es Salaam. It was observed that the distance between the wells and pit latrines for most of the households was less than 10 meters which is far below the acceptable standards of 30 m ($p<0.001$). Given the fact that most plots in the study areas have sizes ranging from 120 m^2 to 300 m^2 and plot coverage is beyond 90%, space for proper construction of sanitary facilities and shallow wells was extremely limited. The study recommends for close cooperation between sub ward leaders, ward officers and health officials to prevent drilling of wells in close proximity to pit latrines.

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Keywords: Water borne diseases; contamination; water vendors; latrines.

1. INTRODUCTION

The provision of potable water service in informal settlements especially to the poor households remains a critical challenge for the realization of sustainable urban development. Generally, people living in informal settlements are disadvantaged due to lack of public services such as piped water supply, high population density, and low levels of sanitation [1]. While only 30% of urban inhabitants have access to piped water, 60% of the population relies on other sources of water including shallow wells for their daily consumption [2]. Cheaper borehole drilling technology facilitates the drilling of such shallow wells [3]. Tanzania, just like many other developing countries has not adequately managed to provide safe, clean drinking water to its citizens [4]. This is inconsistent to the country's National Water Policy of 1991, which states that citizens should have access to clean and safe water within 400 metres by 2002 [5]. Rural populations in developing countries have a higher proportion of the total population without access to clean and safe water. However, the fastest growing population with no access to safe drinking water reside in urban and peri-urban areas [6]. In general, there are improvements in the number of urban populations connected with safe water but these improvements are compromised by the rapid increase in the number of urban dwellers living in informal settlements [7].

Residents in informal settlements largely depend on water which is supplied by private individuals. Such individuals obtain the water from different sources such as shallow wells, water kiosks, stand-pipes and boreholes [8]. In some African Cities, the proportion of the inhabitants served by water vendors may range from 20 – 30% [9] to as high as 90% [10]. Therefore, water vendors fill the demand of water supply gap experienced by informal settlers although they (water vendors) carry out their operations outside the legal frame work.

Water vendors use different means to supply water to households; these include door to door delivery, where they carry the water in some containers and sometimes they supply through piped water connections. However, the reliability [11], quality [12] and affordability [13] of the water supplied by these suppliers remain a subject of concern. Due to unsafe and insufficient water supply in urban areas, water borne diseases such as cholera have been prevalent. For example in 1997, 3220 cases of water borne disease and 128 deaths were reported in Ilala District in Dar es Salaam city alone [14]. In 2001, regions such as Kigoma, Arusha, Shinyanga, and Dodoma in Tanzania were also affected by cholera. Cholera in Ilala District affects people living in low-lying flat areas where the water table is high [15]. These areas depend on shallow wells as a source of domestic water. The wells especially those located in close proximity to pit latrines, are prone to contamination by human excreta [15]. It is further reported that in some parts of Dar es Salaam, Tanzania, cholera was reported for five consecutive years from 1997 to 2001 [15].

Several studies on informal water supply in urban areas have been carried out; see for example [3, 8,16]. These studies, however, have so far not done any spatial analysis of the locations between pit latrines and the water wells to explore the potential health risks associated with the consumption of such water. Studies on spatial location of water sources which are used by water vendors in relation to potential sources of contaminants in Tanzania are scant. Therefore, little is documented on the potential health risks posed by such water sources in relation to spatial location of pit latrines in the informal settlements.

Therefore this study explores the risks associated with private water supply undertakings in informal settlements in Dar es Salaam city. The exploration was done through mapping and analyzing water sources by water vendors in relation to the locations of pit latrines, exploring awareness and perception of water users and vendors on the potential health risks associated with the consumption of such waters. The study findings are intended to raise awareness on the potential risks associated with water consumption delivered by water vendors.

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried-out in Nyambwera and Tamla streets located in Tandika ward, Temeke District, Dar es Salaam. Dar Es Salaam city is located on the Eastern part of Tanzania between 6° 34` and 7°10` South along Indian Ocean coastal line (Fig. 1).

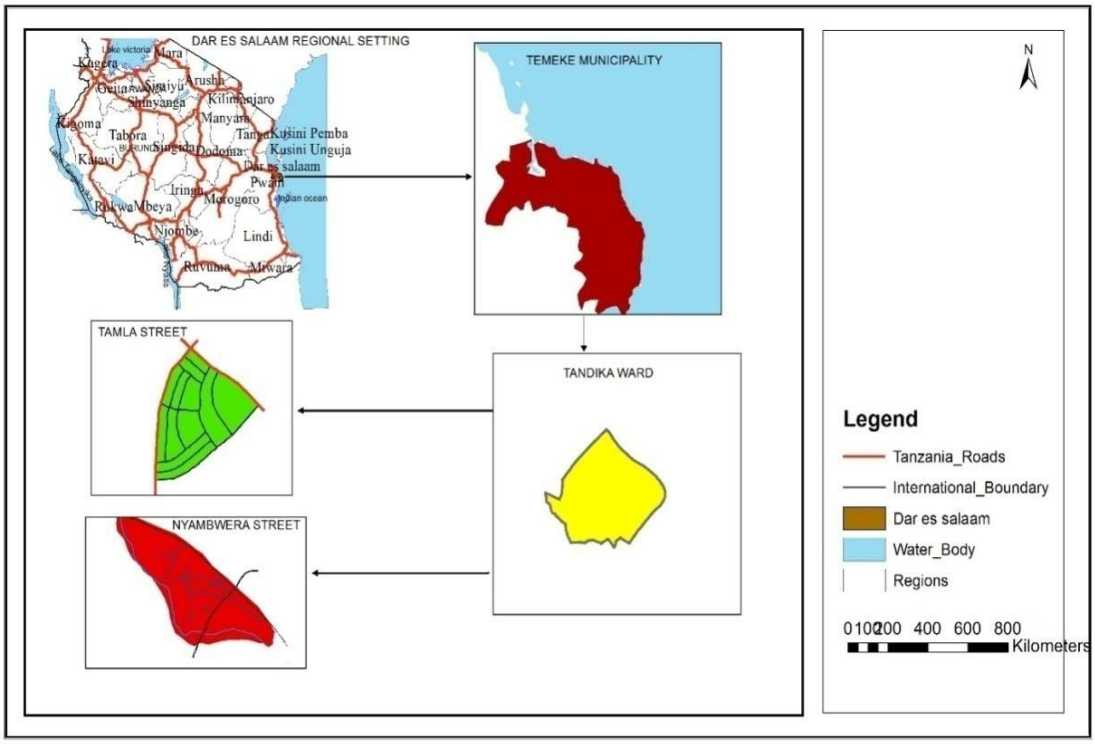

Fig. 1. Location Maps of the case study areas

The study area is boarded by the Indian Ocean on the East and Pugu on the west. According to the population census of 2012 [17], Nyambwera and Tamla had a total population of 13769; 7438 people in Nyambwera and 6331 inhabitants in Tamla. The area had a total of 3700 households, 2034 households in Nyambwera and 1666 in Tamla. Temeke District was selected because among the five municipalities in Dares Salaam, Temeke is the least serviced with piped water supply [18]. Nyambwera and Tamla sub-wards were selected as a case study area because they are comprised of informal settlements with characteristics such as lack of access to sanitation and unreliable piped water, poor roads condition and high density. Most households depend on the water from shallow wells. Pit latrines and septic tanks are used as a means of sanitation. People with high income drill shallow wells for personal use and commercial purposes.

2.2 Sampling

This study was undertaken between March 2016 and July 2016. A total of 350 household samples were obtained for this study. To map sources of water, local government leaders at sub-ward level were consulted for the purpose of identifying different sources of water used by vendors and the inhabitants. Details on the spatial locations of wells in relation to the location of pit latrines were taken using Global Positioning System (GPS) and entered on the base map after being digitized based on satellite imagery (12/13/2015) with Arch Map software.

2.3 Data Collection

Household survey was carried out to explore awareness and perception of water users and the water vendors on the health risks associated with the consumption of well waters. Questionnaires were administered to the 350 households to obtain information concerning major domestic water sources and the perception on safety of different water sources. Official questioning were carried-out to sub-ward leaders, Dar es Salaam Water Supply Company (DAWASCO) officials and health officers. Ward officers and sub-ward leaders provided information on the boundaries of Tamla and Nyambwera sub-wards, water supply systems in the area, the number of wells available, well owners, sewage system, prevalence of water borne diseases and the existing water vendors.

Water vendors and well owners were interrogated to solicit information on water safety perception in terms of water treatment before delivery and cleanliness of water storage vessels. Other types of information were collected from DAWASCO and these included the percentage of houses that have been connected with water taps and accepted standard distance between wells and pit latrines. Information collected from households' survey was analyzed using SPSS software, and information on spatial locations of shallow wells and pit latrines was analyzed using GIS software. Correlations were calculated between variables using spearman's correlation analysis (p=0.05). Furthermore, the normality of the data on the distance between pit latrines was checked using QQ plot in SPSS. Data were analyzed to ascertain if there is any significant difference in distance between pit latrines and the wells against the set standards using a z test (p=0.05).

3. RESULTS AND DISCUSSION

3.1 Socio-economic Attributes

According to sub ward and ward leaders, residents of Tandika ward engage in petty trade, selling of clothes and food vending as sources of income. There are some residents who engage in small scale industry activities and those who are employed in various government sectors such as finance, education and health. The study has revealed that 40.8% of the people were unemployed; 45.8% were employed in the informal sector; and 13.4% were employed in the formal sector. Employment status determines the level of income and often dictates the water sources a household opt to use [19]. People with stable income have access to clean water supply.

The monthly income levels in the case study areas are presented in Table 1. The greatest proportion of the respondents earns more than 100,000 TZS, per month followed by those earning between 60,000 and 80,000, and finally those earning between 20,000 and 60,000 TZS. Those earning between 80,000 and 100,000 TZS were the least in proportion. This implies that about 70% of the respondents had monthly incomes of less than 100,000 TZS. Only 30% had monthly income of higher than 100,000 TZS. 1 USD is equivalent to 2250 TZS.

From the data in Table 1, it is evident that the majority of residents live in abject poverty. Lack of water and sanitation services in the area will add more pressure on people's lives [20] and as a result increase the burden of hardships in their lives. To complicate the problem even further, water supplied by private vendors is more expensive but of poor quality than the water supplied by DAWASCO (see Section 3.4). These findings are in line with what was reported by [21] that in Morogoro, the private water vendors resold water at 4 times higher than the price of public agencies (e.g. MOROWASA) for domestic water. Households with average income of between 20,000 TZS and 80,000TZS were depending on the water directly from wells. Those earning from TZS 80,000 to TZS 100,000 depend on water vendors and wells for the supply of domestic water whereas those earning100,000 and above depended on water vendors, tap water and wells for the supply of domestic water. This shows that affluent people had multiple sources of water. Study findings reveal further that those with multiple sources of water supply used tap water, which is the safest source for cooking, drinking and washing utensils, and used water from wells largely for flushing toilets, washing clothes and gardening. These findings are consistent with those obtained in Uganda which show that affluent residents in different cities had multiple sources of domestic water supply and that they (affluent individuals) had more access to piped safe water than was the case with the poor who depend on shallow well waters [22].

Table 1. Household average income

Income levels (TZS)	Percentage
20000 - 60000	23.3
60000 - 80000	27.5
80000 - 100000	18.4
100000 +	30.8
Total	100

The Spearman's correlation analysis revealed that there is a significant relationship, (r=0.19), (p=0.034) between water sources for domestic use and employment. This signifies that employment status, which determines income levels, predetermines water sources that a household opts to use. Those who are engaged in formal employment earn more and have a stable income compared to those who are unemployed and engaged in informal employment. Although significant, the existing relationship was weak signifying that there are other factors which influence households'

choices of a particular type of water source. These results are consistent with other findings reported elsewhere [8]. It has been found that on daily basis poor households had to make decisions at to which water sources to use depending on how much money is available to purchase the water. The majority of the low income earners in peri-urban population in developing countries opted for cheaper water supply sources. If the cheaper sources happen to be unsafe as it has been observed in this study (see section 3.5), the health of the poor residents is put in jeopardy.

3.2 Infrastructure

Ward leaders revealed that Tandika has one tarmac road which connects Tandika ward with Ubungo District. All access roads are earth roads which lack side drainage systems and are poorly maintained. Lack of central sewage and drainage system provide an opportunity for storm water to flow into shallow wells. This trend contaminates the water and may lead to the outbreak of diseases [20,16]. Contamination pressure was found to be fueled by the tendency of releasing septic effluents to the flowing water by the residents in poorly serviced areas during rainy seasons. Contamination of piped water as a result of poor disposal of human excreta was especially caused by a flow of sewage in open ditches which are close to leaking water pipes [13]. The septic effluents ultimately end up entering shallow wells and sometimes in piped water systems with leaks [13]. This practice is a potential source of cholera and other water borne diseases in Dar es Salaam especially during rainy seasons. Dar es Salaam has been experiencing annual recurrence of cholera during rainy seasons. The study findings show that private water vending at Tandale ward was not organized. There are no guidelines on how they should operate. They use the same containers for delivering water to customers from different sources. For example they may use a 20 litres container to carry water from shallow wells for a customer 'A' and then the same container will be used to deliver tap, safe water to a customer 'B'. This poses a potential danger of cross contamination. In contrast with what has been observed in the present study, [23] reported that private water vending in Onisha area in Nigeria is well elaborated and well organized as a result of well-placed legislation that governs water vending operations by the private sector [24]. This shows that if authorities set standards and, recognize the private sector in the provision of water and sanitation systems, the private water vending can offer safe services. According to an interrogation with the Sub ward leaders and the DAWASCO officials, it was evident that the authorities had turned a blind eye to this informal water supply system. If this trend is left to continue, residents in informal settlements will continue getting water of questionable safety.

3.3 Sources of Water by Private Water Suppliers

Findings during the household's survey in the present study indicate that the majority of the respondents (50%) depend on water which is purchased directly from wells (Fig. 2) as the main source. Water from shallow wells has been reported to be prone to contamination rendering it unsafe for human consumption [25]. The consumption of such water may contribute to the prevalence of water borne diseases. On the other hand, 25% of the households were getting water from water vendors who sell the water from door to door, and only 7.5% of the households received water from DAWASCO.

At Tamla and Nyambwera sub-wards, most of the houses had no water pipe connections and the ones that are connected do not regularly get the service. Water vendors get the water for sales from 25 wells which were found within the site. Out of the 25 wells, one was owned by the government and the remaining 24 were privately owned. The depth of the wells at the case study area ranged from 10 m to 120 m deep. According to the ward executive officer, the number of wells increased with time due to increased demand which is aggravated by the growth of population and the shortage of piped water.

3.4 Price Charged by Water Vendors

Information from water vendors as well as household's information show that the price charged depended on different factors such as the type of water, location of water sources, the means used to deliver the water, availability of water and the cost incurred to get the water. According to water vendors, salt water, was charged for 200 TZS per 20 litres due to the fact that the water is easily available within the site and the cost of purchasing it was 150-300 TZS per 120 litres -200 litres, respectively. On the other hand, fresh water was charged for

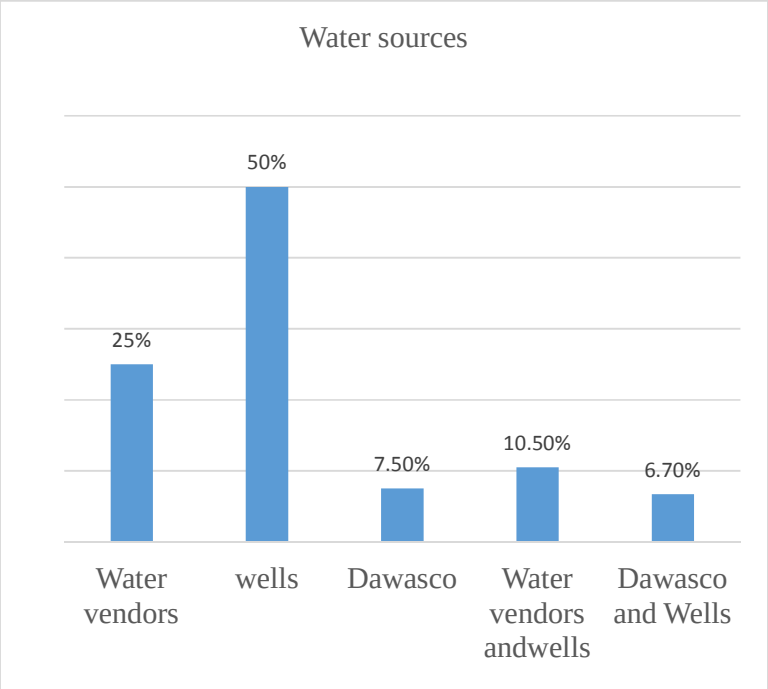

Fig. 2. Households water sources

500 TZS per 20 litres. The prices varied in accordance with distance from water sources and the cost incurred in buying such water, and the quality of water. Water vendors get fresh water far away from the site. Vendors at Nyambwera sub-ward get piped water from an area called Veterinary which is located 1 km from Nyambwera; while vendors at Tamla sub-ward get piped water at 800 m away at a cost of 100 TZS per 20 litres. Direct water vendors (wells owners) charged 50 TZS per 20 litres and100 TZS per 20 litres. For the houses which were connected with water pipes from the wells, a fixed cost of 5000 TZS was charged monthly (Table 2).

Table 2. Water price in Nyambwera and Tamla street

Water sources	Price (TZS)
Pushcart water vendor	200 – 500 per 20 litres
Neighbor connection from well	5000 TZS per 1000 litres tank
Water kiosk	50 – 100 TZS per 20 litres

Households who purchased water from water vendors in general pay 4 -10 times more than those who purchase directly from water sources. This puts more pressure on the urban poor because of the hiked water costs. In line with the findings of the present study, [26] reported that dwellers who obtain water from water vendors pay from 10 to 40 times more than those who have own connections depending on condition of supply and location of consumers. [8] reported that fresh water which is bought directly from DAWASCO was much cheaper than salty water. He contended that vendors get more troubles to get salt water than securing fresh, good quality water and therefore the difficulties encountered in getting the water dictated the price of water rather than the quality. Dar es Salaam residents who get water supply from private agents end up paying more than those getting water from formal water supply companies [16].

3.5 Distance between Pit Latrines and Wells

Nyambwera and Tamla sub-wards depend on wells as the main source of water. It was observed that the distance between the wells and the pit latrines for most of the wells (24 out of 25) is less than 10 meters (Table 3).

Table 3. Distance between wells and pit latrines

Distance (Meter)	Number of wells	Accepted distance (Meter)
1-3	2	30
4-6	12	30
7-9	10	30
10-12	0	30
13-15	0	30
15+	1	30

Most plots in the study area are small. Plot coverage is almost over 90% due to high population density. Therefore, the amenities including pit latrines and the wells must occupy the small available space and consequently these two amenities are placed in close proximity (Fig. 3). The QQ plot carried-out revealed that the data on the distance between pit latrines and the wells are normally distributed. The z test carried-out showed that the pit latrines and the wells are in close proximity ($p<0.001$). This implies that the well operators have grossly violated the set sanitation standards and thereby pose the health threat to the neighboring population.

These findings are in line with the findings of [26] who revealed that most of the households in Kenya were depending on water from wells that are in close proximity to pit latrines. About 38% of the wells were placed at a distance between less than 15 m (The commonly used guideline requires a distance of at least 15 m) in Kenya. Most (about 59%) of the wells were estimated to be within the distance of between 15 and 30 m from pit latrines. [27] further reported that the analysis of coliforms in waters collected from shallow wells and deep wells showed that the water was highly contaminated with fecal matter while samples from taps, the coliforms were not detected. The results showed that well water is associated with high risks of contamination. However, this work did not determine the number of coliforms in wells and this requires further research.

Since the distance between the pit latrines and the wells is less than the accepted standard of 30 m (Table 4; Fig. 3a; Fig. 3b), there is a high risk [28] that the water can be contaminated by feacal matters [29] because the soils in the site are sandy in texture. Fig. 3a and 3b show the extent of spatial proximity between pit latrines and shallow wells.

Sandy soil which is dominant in the case study areas is permeable and allows rapid movement of liquids. The risks of contamination corroborate very well with the presence of water borne diseases such as Typhoid and Diarrhea in the area as explained by ward executive officers and the household respondents. Similarly, [16] reported concerns of possible contamination of shallow well waters in Yombo Dovya and Tungi informal settlements in Dar es Salaam, Tanzania. The author observed further that further densification of the informal settlements is likely to increase the risks of contamination.

The prevalence of water borne diseases, which in principle could be easily controlled, put a lot of pressure on the costs of living to the urban poor. In South Africa, social and health costs of diarrhea accounts for about 1% of the GDP [30]. The closer to the contamination sources (such as Pit latrines) the wells are, the higher the risks of contamination. The number of bacterial counts (coliforms) in water wells was significantly negatively correlated with the distance between wells and pit latrines [31]. This testifies that the farther away from the pit latrines the wells are, the safer the wells and vice versa.

The study revealed that all the respondents who depended on water from wells reported to have suffered from water borne diseases. From 2013 to 2015, the total number of patients who suffered from water borne diseases in the study area was 2,266. This elucidates that the improvement in water and sanitation is of paramount importance in improving the quality of life of human beings [32]. Water from shallow wells is prone to contamination from different

Table 4. Distance between wells and pit latrines

Well code	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y
Distance (m)	21	5	5	6	4	3	7	6	7	4	9	5	9	8	8	8	8	3	8	6	6	7	5	5	5
Accepted standard (m)	30																								

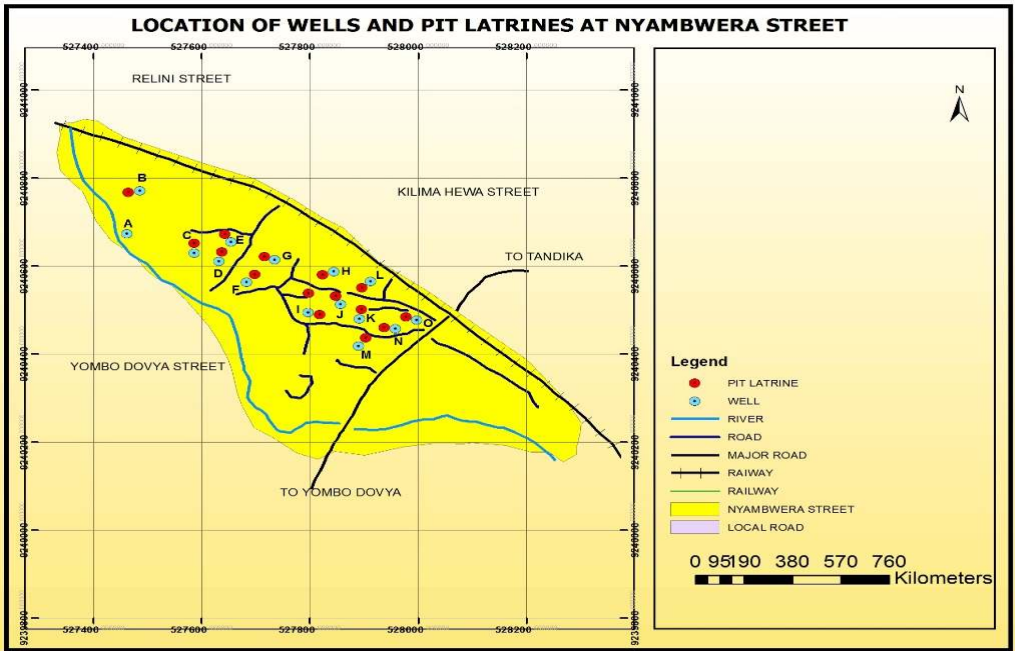

Fig. 3a. Distance between well and pit latrines at Nyambwera Sub-ward

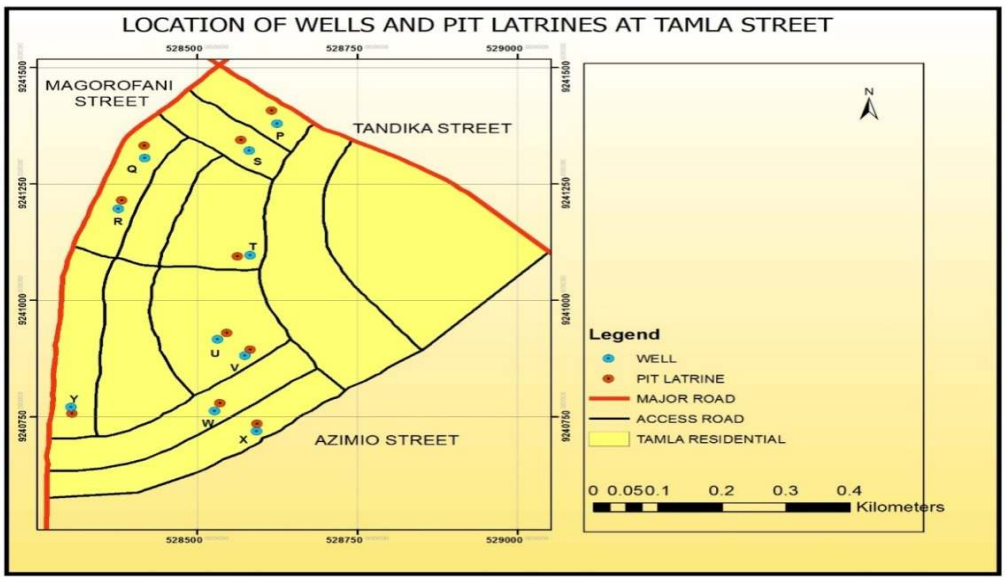

Fig. 3b. Distance between well and pit latrines at Tamla Sub-ward

kinds of pollutants. For example, [33] reported elevated levels of coliforms, aluminum, copper, iron and manganese in shallow wells compared to deep wells in Ndola, Zambia. The concentrations of these pollutants exceeded the WHO acceptable levels. The authors concluded that shallow water wells in Ndola, Zambia were associated with high health risks.

3.6 Perception of Residents on the Safety of Well Water

From the data collected, the majority of households (92.5%) were not treating the water before drinking it despite the high risk of water borne diseases such as diarrhea and typhoid witnessed in the community (Table 5).

Table 5. Top five disease in Nyambwera and Tamla Sub-wards

Diseases	Reported cases		
	2012	2013	2014
Malaria	400	320	200
Diarrhea	200	250	360
Urinary track infection	109	312	400
Typhoid	400	544	512

The residents had the perception that water from the wells was safe and therefore it did not need any treatments prior to consumption. Diarrhea was among the top five diseases that people were suffering from. Others include malaria, acute respiratory infection, pneumonia, urinary tract infection, anemia and typhoid. Only 7.5% of the households were boiling the water before drinking. [27] reported that despite the short distance estimated between the pit latrines and the wells, only 42% of those reported using wells boiled the water for drinking. Those who were boiling drinking water cited contamination as a possible source of waterborne diseases. Water contamination agents in the wells in the area included children dipping dirty objects into the wells, drawing water from the sources with dirty containers, domestic animals defecating around water sources and people washing clothes near the wells. No respondent who use well waters mentioned closeness of the wells to the pit latrines as a possible source of contamination. This implies that residents may continue digging wells in close proximity to pit latrines due to low awareness on the potential danger of contamination.

Spearman's correlation analysis showed that there was a significant relationship between perception of safety and the treatment of water ($p=0.001$).This shows that those who were aware of the quality of water and its relationship with water borne diseases, treated water while those who were not aware of the possible sources of contamination did not treat the water. This finding should be used as a wakeup call by health officials on the need to intensify awareness campaigns so that the community is educated on the different ways of preventing water borne diseases. It was revealed that 92.5% of the house hold respondents were not treating water in any way. This explains the persistence of water borne diseases in the area. Households failed to treat the water because they were not aware of the possible sources of contamination as explained above. Furthermore, when asked as to why they did not treat water, they pointed out that they cannot afford the costs of charcoal and other sources of energy. In line with the findings of the present study, [34] reported a relationship between treatment of drinking water and the average monthly income of the respondents. This shows that it is easy for the high income earners to afford the cost of chlorinating drinking water as opposed to low income earners.

4. CONCLUSION AND RECOMMENDA-TIONS

Majority of the respondents do not treat drinking water due to the fact that they are not aware of the potential dangers of contamination of the water they use. This shows that households are unaware of health risks associated with consuming water from wells which are located in close proximity to pit latrines. High population density in the informal settlement as witnessed in the case study areas at Nyambwera and Tamla Sub-wards, limited space for erecting sanitary facilities at the plot yards including water wells and pit latrines pose a potential health risks to the inhabitants.

The study recommends for close cooperation between sub-ward leaders, ward officer and health officials to prevent drilling of wells in close proximity to pit latrines. Health officials should provide education to households concerning health risks associated with consuming such water. Those who own the wells should be provided with education on treating water before selling it to consumers. DAWASCO should provide Water Kiosks in areas which have no piped water.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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