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The Impacts of Septic Tanks and Pits Latrines on Soil and Water in Peri-Urban Areas of Africa

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ABSTRACT

Air, soil, and water are the major and most important components of the environment and thus should always be protected. The state of these three environmental components directly or indirectly affects life. Pit latrines and septic tanks systems are simple and affordable solutions for onsite sanitation in many underdeveloped and developing parts of the world, especially in peri-urban areas. These have also been identified as culprits for environmental pollution, releasing nitrates, phosphates, ammonia, dissolved solids, and heavy metals into the environment. This paper investigates the negative impacts of pit latrines and septic tanks on soil and water in peri-urban areas of Africa. It highlights that these systems are responsible for soil and water contamination in many areas, leading to the spread of water-borne diseases and other health risks. This paper further highlights the factors that influence the performance of pit latrines and septic tanks on the environment as well as realistic, cost-effective approaches to mitigate the negative environmental effects of septic tanks and pit latrines. The study also serves as a basis for further studies to build on for making pit latrines and septic tanks more environmentally safe.

1. INTRODUCTION

The major and most important components of the environment are air, soil, and water. The state of these three components directly or indirectly affects life. Humans cannot live without water, air, and soil, thus, the reason for sustainable living is to ensure that these environmental components are always in the best possible state. Sanitation plays an important role in keeping the environment and human beings in good health. Proper sanitation, water, and hygiene are crucial for development anywhere in the world. According to the Britannica Dictionary [1], sanitation can be defined as the process of keeping surroundings and places free from dirt, infection, and diseases by cleaning up and keeping waste away.

Mara et al. [2] define sanitation as the "safe disposal of human excreta". Indicating that there must be hygienic excretion that is safely contained or treated to avoid environmental pollution or disease outbreaks that threaten human health. Sanitation can also be defined as facilities that hygienically separate human excreta from human contact [3]. Sanitation is an important topic in our world today because inadequate sanitation leads to many environmental and health problems that limit the wellbeing of the people [4]. For instance, poor sanitation can result in the pollution of water resources which increases the spread of water-borne diseases such as typhoid fever, diarrhea, cholera, dysentery, etc. In Addis Ababa, Diarrhea is the second most common cause of death, with a serious outbreak in 2016 and the major culprit is the contact of feces with public water sources such as rivers that are used for domestic purposes by many people [5]. It is estimated that 2.3 billion people do not have access to basic sanitation systems [4], as at year 2015, these people still lacked access to a decent toilet in their homes [6]. According to WHO reports, in 2020, 20% of the global population (1.6 billion people) used toilets or latrines where excreta was safely disposed of in situ, while 78% of the world's population (6.1 billion people) used at least a basic sanitation service. In many underdeveloped and developing countries, the most common types of on-site sanitation are pit latrines (PLs) and septic tanks (STs) [7]. PLs and STs are essentially effective in achieving adequate and affordable sanitation in many parts of the world, but they come with disadvantages.

The objective of this study was to determine the common impacts of septic tanks and pit latrines on soil and water. This is required to understand the side effects of these technologies, to improve sanitation in most African developing and under-developed nations. Although there have been previous studies that addressed the effects of septic tanks and pit latrines on soil and water, this study provides a recent update on this topic and is focused on peri-urban areas. The focus is on peri-urban areas because most developing and underdeveloped countries are experiencing a rise in the development/spring-up of peri-urban areas. According to Thornton [8], peri-urban areas are a physical interface where complex rural-urban interactions take place. A peri-urban area is typically not spatially zoned, can be near a city center, and is occupied by poor households and the socially excluded [9]. Therefore, the findings of this study will be relevant in guiding decisions by urban and regional planners as well as public health practitioners regarding the potential health risks associated with STs and PLs if not well managed. This study also provides possible cost-effective solutions to overcome the negative impacts of STs and PLs on soil and water and the overall environmental well-being.

Industrialization and the rising population have resulted in the development of peri-urban areas around industrial areas where people can get more job opportunities. In the presence or absence of adequate town planning, septic tanks, and pit latrines can serve as a cost-effective, easily maintained, and user-friendly mode of onsite sanitation for many people. However, questions arise concerning the effects of STs and PLs on the surrounding soil and water. On their own, STs and PLs are not a threat to soil and water, but several factors such as maintenance, construction standards, usage, monitoring, site suitability, and number of users determine the effects of STs and PLs on soil and water. Since there are no adequate town planning and municipal services in most peri-urban areas, these factors are usually of poor quality, therefore, the STs and PLs result in increasing pollution levels in the soil and water of peri-urban areas.

2. METHODOLOGY

This review paper aims to provide information concerning septic tanks and pit latrines including their construction, maintenance, factors affecting their performance as well as the possible management and mitigation strategies for the negative effects of these systems. The narrative review will help provide a general overview of the topic of septic tanks and pit latrines and their effects on soil and water. Therefore, a narrative approach was employed for the literature search and analysis to ensure that it captures specific studies focusing on the negative impacts of septic tanks and pit latrines on soil and water in the peri-urban areas of Africa. Articles concerning the use and construction of pit latrines and septic tanks, the environmental effects of pit latrines and septic tanks, and the solution to the negative effects of these systems were selected for this review study. Google Scholar and Scopus were the selected databases from which related articles were downloaded. The following keywords were used while searching for articles: "pit latrines", "septic tanks", "negative effects of septic tanks and pit latrines", "effects of pit latrines and septic tanks on soil", "effects of pit latrines and septic tanks on water", "factors that affect the functioning of septic tanks and pit latrines", "how to mitigate the effects of septic tanks and pit latrines". All articles retrieved from the database search were checked for relevance to the study, by checking the title of the study. Only the studies whose titles depicted relevance to the study aim were included in the next stage, while nonrelevant ones were excluded. Afterward, the abstracts of the selected articles were read and checked closely for relevance, and only those that were conducted in Africa were selected for the study.

3. THE USE OF PIT LATRINES (PLS) AND SEPTIC TANKS (STS) AS ONSITE SANITATION SOLUTIONS

3.1 PLs

Pit latrines are a type of toilet that collects feces and urine through a drop-hole on the floor. The top may be fitted with a toilet seat or a squatting pan. Pit latrines are usually used in most rural and disadvantaged parts of the world because they are easy to maintain, affordable, and can function with/without water. Another advantage of PLs is the fact that they reduce open defecation, thereby curbing the negative effects of this act on people and the environment. A pit latrine usually consists of a slab or floor with a hole in the ground. A major disadvantage of pit latrines is that they must be emptied from time to time or new ones have to be constructed when one gets full.

3.2 Septic tanks (STs)

STs are storage systems designed to contain raw domestic effluents including fecal matter. Typically, the denser materials settle at the bottom of the septic tank, while the liquid components are dispersed into the ground (absorbed by the surrounding soil). Septic tanks harbor a lot of pathogens that are associated with human wastes such as bacteria and other parasites that pose serious health risks to human beings when in contact [10]. A major risk associated with the septic tank system is the extensive installment of septic tanks in some areas, which end up saturating or overloading the soil, which prevents an effective natural effluent purification by the soil [11, 12], thus leading to contamination. In areas where sewerage systems are not in place, septic tanks are the most used alternatives for onsite sewage disposal and management [13]. Septic tanks are used in many parts of the world, especially in areas with no access to drainage facilities like peri-urban areas [7, 8], usually, a family of five will need their tank pumped out every 8-10 years on average.

Although STs and PLs are very important sanitation infrastructures due to their low cost and their potential to help meet global sanitation targets [3, 4], there are many environmental risks associated with these sanitation infrastructures. These risks revolve around the discharge of chemical and microbial contaminants from the ST and PL systems into surface water, groundwater, and soil, which may negatively affect human health [3]. Considering Sustainable Development Goal Six (SDG 6), whose target is to have safely managed sanitation, a clean environment, and clean water, it is therefore important to understand the effects of septic tanks and pit latrines on soil and water with a specific focus on peri-urban areas. While soil and water are affected adversely by pollution from pit latrines and septic tanks, there is a lack of information on the factors that promote pollution and the extent of pollution including the related health and environmental problems.

4. NEGATIVE IMPACTS OF SEPTIC TANKS AND PIT LATRINES ON SOIL AND WATER

Proper sanitation, water, and hygiene are important for development anywhere in the world. According to Kookana et al. [12], in most emerging economies (within and outside Africa), up to 90% of the peri-urban population relies on septic tanks. In developed countries such as the UK, only about 4% of the population still use small, private treatment works or septic tanks, although in Ireland, over one-third of the houses still use onsite sanitation like PLs and STs, about 13% of the Australian population, while approximately 25% of houses in the US still rely on STs [13]. Ideally, PLs, are designed to collect and store fecal sludge onsite, and are meant to be covered over when full to allow the waste to decompose, but in some communities, they are used for other purposes (such as general waste disposal) that prevent proper decomposition. Likewise, the misuse of STs can result to clogging, giving rise to soil and water pollution. Table 1 provides some details of studies concerning soil and water pollution because of the impacts of STs and PLs. According to Debela et al. [5], communal pit latrines that are shared between several households are widespread in most peri-urban areas of Ethiopia. Most of these do not safely contain waste, causing the waste to end up in the environment where they pose health risks to the inhabitants. The unsafe waste containment could be because of poorly designed and poorly managed systems. This majorly happens because there is no available advice, support, or standards on the design and construction of latrines and other types of sanitation facilities [5].

Table 1. The negative impacts of pit latrines and septic tanks on soil and water in peri-urban areas of Africa

Study	Contaminants/Parameters	Region	Findings
		PLs	
[14]	Nitrates, electrical conductivity, chlorides, ammonia, and thermotolerant coliforms	Harare, Zimbabwe	Groundwater at the lowest end of the settlement had the poorest water quality. High contents of thermotolerant coliform indicated fecal material
[15]	Coliforms	Ibadan, Nigeria	Surrounding pit latrines impact groundwater, leading to biological contaminants that exceed the recommendation of WHO drinking water quality
[16]	Ammonium, nitrates, coliforms	Marondera, Zimbabwe	Prevalence of diarrhea was recorded, due to the interaction of the latrines with the water table (up to 25 m from the latrines) and structural failure of the latrines. Total and fecal coliforms exceeded WHO guidelines
[17]	E. *coli*	Matlerekeng, South Africa	Samples from domestic boreholes showed high E. *coli*
[18]	Physico-chemical parameters	Lagos, Nigeria	Boreholes and wells contained non-permissible levels of pH, hardness, total dissolved solids, and chloride. The heavy metal analysis revealed non-permissible levels of lead and nickel in all of the water samples, total bacteria and coliforms were above the permissible limits in all of the water samples
[19]	Enteric pathogens	Maputo, Mozambique	Soil samples from shared latrine entrances contained enteric pathogens as a result of fecal contamination
[20]	Coliforms	Zanzibar, Tanzania	In the squatter settlements, fecal coliform counts increased in the wells, with decreasing distance from pit latrines
[9]	Nitrates and phosphates	Kampala, Uganda	Nearby pit latrines are responsible for very high levels of NO_3, NH_4, and PO_4 in shallow aquifers
[21]		Sissala, Ghana	Contamination of groundwater which is attributable to the siting of pit latrines with a depth above 2 m and within a 50 m radius downstream of the pit latrines
[22]	Nitrates, phosphates, and fecal coliforms	Langas, Kenya	Most wells were contaminated as a result of their proximity to pit latrines. Therefore, a safe well-pit latrine separation distance of 48 m is recommended to avoid contamination
[23]	Enteric bacteria	Cape Coast, Ghana	98% of water samples from domestic wells (within 25 m) to septic tanks contained high enteric bacteria
		STs	
[24]	Coliforms and salt content	Cotonou, Benin	Septic and sewerage contamination and seawater intrusion
[25]	Fungi	Rivers, Nigeria	Two fungal species were detected in septic tank-impacted soil
[26]	Coliforms	Oyo, Nigeria	Septic tank-impacted groundwater around schools showed microbial parameters that are above the WHO recommended limit of zero
[27]	Physicochemical parameters	Kajiado, Kenya	Total dissolved solids (TDS), conductivity, and sulfates in borehole water did not show any seasonal variation, unlike the other parameters. On the other hand, boreholes at least 70 m away from septic tanks had parameters within the World Health Organization (WHO) standards
[28]	Overall water quality	Kenitra, Morocco	There is no respect for the distance between septic tanks and wells, this affects the overall water quality in the study area
[29]	Coliforms	Delta, Nigeria	Hand-dug wells contained fecal coliform as a result of proximity to septic tanks
[30]	Sulfate, chloride and Streptococcus	Ain Soltane, Algieria	Sulfates, chloride, and bacteria are present in borehole water as a result of septic tank proximity
[31]	Coliform	Gulu, Uganda	The density of septic tanks around spring wells ultimately affects coliform counts and nitrate concentrations
[32]	E. *coli* and physicochemical parameters	Abeokuta, Nigeria	Infiltration of sewage into groundwater was indicated by high BOD, NO_3^-, and E. *coli* concentrations
[33]	Total and fecal Coliforms	Lusaka, Zambia	Bacterial contamination of borehole water as a result of infiltration from nearby septic tanks. Total coliform count of more than 10 per 100 ml was observed

Richards et al. [34] also point out that domestic wastewater may contain materials that are likely to pollute soil and water if not contained. Dissolved nutrient loads around STs and PLs result in heightened levels of heavy metals, pathogens (such as E. *coli*), nutrients (such as nitrates, phosphorus, ammonia, organic matter, suspended solids), pharmaceuticals, and other chemicals are all associated with STs and PLs and they determine the quality of water resources. All these find their way through the household chemicals and substances that are used and washed into the septic tanks such as (detergents, personal hygiene products, and food processing) or through substances consumed by human beings. For example, antibiotics are found in human urine and feces [34, 35]. Some studies have connected phosphorus pollution to septic tanks [36, 37]. In a study by Nyenje et al. [9], it was discovered that significant pollution to groundwater originated from the pit latrine site with nutrient loads increasing by factors of 1.7 for NO_3, 10.5 for NH_4, and 49 for PO_4 [9]. Wright et al. [10] report chemical and biological contamination of groundwater in two peri-urban areas of Kenya where pit latrines are widely used. The groundwater quality parameters exceeded the WHO standards/guidelines.

Due to inadequate pipe-borne water supply in Nigeria, most households have wells as sources of potable water. The wells are prone to contamination because most households also use septic tanks for sewage containment. Adetunji and Odetokun [38], confirm that the wells in the Agbowo community were on average, 15.24 m from septic tanks and had high TABC (4.76±1.41 log CFU/mL) and TCC (2.29±0.67 log CFU/mL) counts which exceeded the international standards based on the assessment of 40 wells in. They also noted that the TABC increased with a decrease in distance from the septic tanks. The proliferation of septic tanks has drastically increased the levels of nitrogen as an environmental pollutant in Chesapeake [39]. Once contaminated, it is difficult to decontaminate affected wells as evident in the study of Mester et al. [40] who found that after five years of dismantling a septic tank (pollution source), the nearby well still showed high pollutant levels although slightly positive changes were noticed.

Septic tanks and pit latrines can attract pests like mosquitoes, rodents, and cockroaches, which may spread diseases. Research by Burke et al. [41] showed that in southeastern Puerto Rico, areas with septic tanks had high numbers of both adult and immature Aedes aegypti mosquitoes, especially where septic tanks were cracked or large. Additionally, septic tanks and pit latrines without proper bases can leak wastewater into nearby water bodies, harming aquatic life and promoting the growth of parasites [42].

5. FACTORS THAT INFLUENCE THE EFFECTS OF PIT LATRINES AND SEPTIC TANKS IN THE ENVIRONMENT

Several factors such as age, structural design, soil type, number of users, and system management all determine the effects of STs and PLs on the environment [43]. Each factor is discussed in this section.

5.1 Age

As pit latrines and septic tanks get older, they become saturated with wastes and, therefore, may fail to contain the wastes adequately especially in situations where the pits are used for holding domestic wastes as well. Although the feces dry up with time, the other components as well as structural incompetence may lead to collapse or leakage in the ST or PL systems. As time passes, feces get dehydrated, thus reducing weight and volume by up to 72% within 4 months. Also, with age, water activities reduce, although energy and nutrients are not reduced and biodegradation is not promoted. All in all, aging improves the drying and mechanical handling of feces and sludge in PLs and STs [43]. With time, poor maintenance may also result in the failure of the PL and ST structures.

5.2 The structural design

Ideally, the density of constructed PLs and STs should follow a range of lot sizes that are sure to protect groundwater. According to Perkins [44], the reasonable lot sizes that are sure to protect groundwater quality are from 0.2 to 0.4 ha. Although in most peri-urban settlements that lack proper planning, these lot sizes are not taken into consideration and there may be clusters of septic tanks in a particular area and they are likely to pollute groundwater. Generally, most PLs do not have physical barriers like concrete, therefore, the stored feces easily come in contact with the underlying soil, thus polluting soil and groundwater [3]. Also, poorly structured PLs are potential risks to the immediate environment [45]. A structurally poor ST or PL can collapse at any time causing harm to the users and their environment.

5.3 Soil type

The underlying soil type matters and sometimes determines how STs and PLs affect the immediate environment, especially soil and water. Alluvial sands are good materials that prevent groundwater pollution. Nyenje et al. [9], found that depending on the geochemical and hydrochemical conditions of underlying alluvial aquifers, they can provide reducing conditions that are effective for removing pollutant nutrients. Also, fine sandy soil is an effective filter medium for pit latrines and septic tanks by preventing the passage of bacteria and pollutant nutrients from entering the soil and water bodies. This was indicated by the study of Still and Nash [46], based on a study conducted in Maputaland, an area in KwaZulu-Natal, with many pit latrines and shallow wells. Highly permeable subsoils encourage the passage of pollutants to water bodies [47]. According to Appling et al. [48], clay soils also prove to be effective subsoils for PLs and STs because the clay materials adsorb and absorb pollutants [49], thus preventing the passage of pollutants into groundwater. Karst landscapes are prone to collapse thus releasing the contained wastes in STs and PLs to the soil, ground, and surface waters.

5.4 Number of users

The number of users of a facility will also affect how fast they become full and how diseases can be spread because more people are in contact with the facility. According to a study in Kampala Slum in Uganda, the number of users of a particular PL affects the sludge accumulation rates [50]. The higher the number of users, the lower the sludge accumulation rate, thereby posing a risk to soil and water resources. Also, more microorganisms and faster fill-up rates are expected as the number of users increases [50]. Mohamed [51] explains that there are many households in the United Kingdom with poorly managed Septic tanks. This could be a result of multiple households sharing one ST and no one wants to be responsible for the maintenance of the STs, negatively affecting public health quality.

5.5 Management of the system

System management such as monitoring, cleaning, and maintenance also plays a huge role in how pit latrines and septic tanks affect the environment. For example, as a result of manual emptying of pit latrines in Kwazulu-Natal, South Africa, E. *coli* and Staphylococcus spp. were found on the skin, personal protective equipment, the municipal vehicle, and on various surfaces in households before and after emptying of the latrines [52]. Contact with the polluted surfaces poses a huge health risk to the community.

5.6 Other environmental factors

Environmental factors affect the performance of STs and PLs. Water is the major environmental component that negatively affects PLs and STs. For example, when the water table is high, there may be easy infiltration of pollutants into groundwater. Also, in flood-prone areas, the flood waters cause an overflow of the STs and PLs, thus resulting in the infiltration of contaminants into soil, groundwater, and nearby surface waters. A major reason for the fecal contamination of water resources is as a result of poor sanitation infrastructure [53, 54]. For instance, after the Cyclone Idai flooding in the year 2019, multiple pit latrines were flooded, resulting in pollution of the water table and boreholes in certain areas of Malawi, making their water supplies unsafe [54, 55]. According to Debela et al. [5], there is frequent contamination of shallow wells, ground and surface waters, and soil in some areas of Addis Ababa (Ethiopia) as a result of using PLs as a method of onsite sanitation. The most common contaminants are nutrients and A. *lumbricoides*, indicating the influence of human feces.

6. SUSTAINABLE MANAGEMENT OF PIT LATRINES AND SEPTIC TANKS

Septic tanks and pit latrines have served as excellent technology for onsite sanitation in many middle- and low-income parts of the world. However, these technologies have also resulted in huge pollution issues, especially soil, surface, and groundwater pollution. In this section, solutions for mitigating and managing the problems associated with PLs and STs are presented.

6.1 The application of adsorbents for purification

Adsorbents are materials that trap or capture contaminants and prevent them from moving to other compartments. The most common examples are clay minerals and biochar [55, 56]. These adsorbent materials can be applied as liners on the surface and/or bottom of PLs and STs for the adsorption of organic and inorganic pollutants [57]. According to Mamera et al. [58], when applied to soil, biochar can serve as a cost-effective material that holds heavy metals, and organic and inorganic pollutants in pit latrines and thus reduces contamination of soil and water [55]. While the biochar-amended sludge can also be an economically beneficial by-product [58]. Some other studies have successfully applied adsorbents such as fly ash, rice husk, sand particles, dry cow dung (as carbon source), etc. for the treatment of STs and PLs sludge to prevent water resource pollution [59-61].

According to Mittal et al. [54], low-cost by-product wastes such as fly ash and rice husk, have proven to be effective for the removal of NO_3^- and PO_4^{3-} from pit-toilet leachate. A mixture of air-dried cattle manure, sand, and gravel was used to reduce the chemical oxygen demand (COD) concentration in pit toilet sewage by 85% and ammonium by 77% [59]. Fly ash was applied as an additive in a synthetic pit toilet sludge, the additive reduced fecal coliform concentration by 98.9% after 28 days, but can cause environmental contamination with phosphate [60]. Therefore, pilot studies and adequate tests should be conducted before the final application of adsorbents for treatment. Sludge from ST was treated with rice husk and outer shell of dried Bael (Aegle marmelos) [61]. The results revealed that COD and BOD concentrations were significantly reduced.

6.2 Improved adequate guidelines from respective governing bodies

According to Beukes and Schmidt [52], most STs in peri-urban areas are not professionally designed, likewise PLs. Therefore, there is a huge tendency for environmental pollution from these systems. Most of the guidelines and regulations available concerning STs and PLs are mainly focused on physical parameters. The government should implement guidelines on every aspect of PLs and STs, with details on the construction, maintenance, emptying, usage, number of users, density, cleaning, etc. For instance, the United States Agency for International Development (USAID) recommends that the pits should not be completely emptied. A small amount of digesting sludge should be left at the bottom to encourage the growth of microbes that will promote the decomposition of fresh sludge. Pits should be emptied when sludge is 0.5 meters from the top, and the bottom of the pit and tank should at least be about 1.5 meters above the highest seasonal groundwater level [62]. Incentives and sanctions should also be developed around the maintenance of PLs and STs through the available government policies [49]. Beukes and Schmidt [52] emphasized that when household sanitation is seen as a household responsibility, it is difficult to get commitment from relevant agencies and local authorities. Governments should work to improve sanitation services. In Burkina Faso, a partnership between the municipality and the water utility resulted in improved maintenance of latrines [51].

6.3 Manual emptying should be avoided

In many areas, there is either no space to dig another pit, or it is cheaper for the owner to empty the pit than to build a new one. As a result, emptying fecal sludge from pits is necessary. Research suggests that manual pit emptying with buckets and shovels should be avoided [63]. In a peri-urban community (KwaZulu-Natal, South Africa) before and after manual emptying of ventilated improved pit latrines. There was a high detection frequency for bacteria on household surfaces and on municipal workers' hands (which were frequently contaminated before pit emptying). This even increased after the pits were emptied, indicating that manual pit emptying might pose a potential health risk to workers and community members [51, 52]. Manual emptying also encourages disposal close to water sources or residential areas, posing health and environmental risks [47]. Jenkins et al. [64] encourage the use of vacuum tankers as a hygienic mode of emptying PLs and STs.

6.4 Frequent monitoring of surrounding water and soil

Frequent characterization of environmental parameters (especially soil and water) is very important because they can help to easily detect the impacts of STs and PLs in an area at any given time [39]. In Malawi, important water quality parameters have been documented against standards and used to discern contamination from PLs [53]. Another way by which the impact of PLs and STs can be adequately monitored is to involve community members in the monitoring exercise. These programs can positively influence the responses of communities towards environmental sanitation and result in positive environmental changes in the local ecosystems [16].

6.5 Upgrading systems

There have been some improved advancements in the design of STs and PLs. These improvements include a minimum depth of about 1.5 m, a foundation, a cover slab, and a framework with a vent pipe and a fly screen for the PLs [51, 65] The ventilated improved pit (VIP) latrine, can greatly improve sanitation in low- and middle-income communities. These VIPs have multiple windows and insect screens for better airflow and prevention of flies [66]. Of the South African households with access to sanitation facilities, approximately 17.2% use ventilated improved pit latrines (VIPs), and 13.4% use non-ventilated pit latrines [67]. Despite advancements, large parts of Africa are still predicted to use poorly designed PLs. It was predicted that Nigeria would increase the usage of unimproved pit latrines and open-pit latrines, while a general increase in PLs usage was noted for countries like Ghana, the Democratic Republic of Congo, and Burundi between 2017 to 2019 [68]. In China, biogas septic tanks have been introduced in small households for the direct treatment of waste and the production of energy [69]. This prevents contaminants from being released into the environment and also has economic value for waste.

6.6 Awareness of the dangers or threats of STs and PLs on groundwater

There are many benefits to improving the understanding of the related environmental risks of STs and PLs because many people really do not know and thus require some education on the issue. Governments and non-governmental organizations should prioritize awareness, by developing educational programs in communities to train households of the environmental and health risks associated with poorly maintained ST and PL systems and how to maintain these systems on their own. Martínez-Peña et al. [68], interviewed some women in the Yucatán peninsula of Mexico concerning water sources and the risk cleaning products pose to health and sewage. They found that the women were not aware of the city’s water management system, this being the case in many other countries. They found a positive and statistically significant association between risk perception and environmental awareness, education level, and employment status. Therefore, education and awareness concerning the environmental and health risks associated with poorly managed PLs and STs should be promoted. Outreach programs should also be promoted to ensure that adequate information and assistance reaches the concerned communities. Many people lack awareness of well, ST, and PL maintenance guidelines. Communication materials should be distributed. Also, many people believe that sensory evaluation is enough to know the basic quality of water. Such beliefs should be eradicated with adequate information and education [65]. Post signs and posters around STs and PLs should be promoted to stop users from dumping other waste materials in the PLs and to distribute the users evenly between all facilities [62].

6.7 Adoption of smart technologies

The use of advanced technologies for monitoring PLs and STs should be encouraged. This allows for timeous knowledge and responses to any associated risks. Oduah and Ogunye [70], developed a remote sensing device for the detection and monitoring of sewage levels in underground STs. This prevents the overflow of STs and minimizes the associated environmental risks, especially water pollution. According to Tyagi et al. [71], two-dimensional (2D)-material-based sensors are highly efficient and compatible with modern fabrication technology, to yield data that can be effectively applied for health and environmental monitoring. Winata and Haryono [72] used MQ-4 sensor and JSN-SR04T distance sensor to detect the volume of sludge and gas in STs to prevent damage to the environment and human health.

7. CONCLUSIONS

Septic tanks and pit latrines are good technologies for onsite sanitation especially in low- to middle-class settings. It is noted that these systems are also responsible for many environmental pollution issues and the spread of diseases, especially waterborne diseases. The studies reviewed in this work show that soil and water (surface and groundwater) resources are susceptible to contamination by pit latrines and septic tanks. The key parameters of pollution are nitrates, phosphates, ammonia, dissolved solids, bacteria, fungi, and heavy metals. However, the negative environmental effects of these onsite sanitation systems can be mitigated through several measures such as adequate and realistic government policies around the construction and maintenance of pit latrines and septic tanks; frequent environmental monitoring; the use of natural amendments for onsite treatment; avoidance of manual emptying; upgrading the systems; adequate education concerning the environmental risks associated with pit latrines and septic tanks; frequent monitoring; and adoption of smart technologies. However, the limitation of this study arises from the fact that no standardized guidelines for the literature search and analysis.

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