Access to improved sanitation technologies in sub-Saharan Africa (SSA) is very low. Despite the importance of improved sanitation technologies in sanitation monitoring, little attention has been given towards the types and distributions of improved sanitation technologies used in SSA. This paper presents an analysis of the distribution of improved sanitation technologies in SSA, with particular emphasis on factors influencing their distribution. Study data were derived from demographic health surveys, multiple indicator cluster surveys and World Bank Development Indicators. Results showed that the pit latrine with slab was the most prevalent technology (21%), while the composting toilet had the least coverage (0.6%). Multiple regression analysis results showed positive significant relationships between the following: income and flush toilets connected to sewer ($p = 0.000$), urban population and flush toilets connected to septic tanks ($p = 0.000$), development assistance and pit latrine with slab ($p = 0.035$) and a negative relationship between population and flush toilets connected to pit latrines ($p = 0.030$). The paper concluded that selection of sanitation technologies is influenced by different factors. In addition, prevailing socio-economic conditions can result in selection of inappropriate technologies. Technology selection, however, should strive to strike a balance between the economic, environmental, human health and socio-cultural sustainability aspects of sanitation.

**Key words** | coverage, improved sanitation technology, sanitation technology, sub-Saharan Africa, technology selection

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It seems that the composting toilet has not been widely accepted in SSA despite the attached economic and environmental benefits such as high potential for nutrient and energy recovery and reductions in water use and wastewater treatment costs (Hill & Baldwin 2012; Anand & Apul 2014). One reason for the low adoption of the composting toilet is that traditionally people in SSA do not use human faeces as a soil conditioner in agriculture (Dellstro & Rosenquist 2005; WSP 2005), unlike in other regions such as Asia where countries like China have been using human excreta as a soil conditioner for a long time (Winblad & Simpson-Hebert 2004; Dellstro & Rosenquist 2005). The uptake of composting toilets, especially in urban areas in SSA, may also be hampered by a lack of awareness, and by policies and regulations and a lack of

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knowledge and skills in designing and operating the toilets (Anand & Apul 2014).

In contrast, the pit latrine with slab is the most prevalent sanitation technology in SSA (Katukiza et al. 2012; Nakagiri et al. 2016). This could be attributed to the technology’s low capital and operation and maintenance (O&M) costs, ease of O&M, simplicity and non-use of water (WHO/UNICEF 2000; Flores et al. 2009; Nakagiri et al. 2016). The pit latrine with slab, however, can pose risks of groundwater contamination and disease transmission and can have problems of flies and odour (Dzwairo et al. 2006; Nakagiri et al. 2016).

On the other hand, the flush/pour-flush toilet is more expensive and more advanced than the other improved sanitation technologies and requires water to operate (WHO/UNICEF 2000; Murray et al. 2009), which could explain its low coverage in SSA (Nakagiri et al. 2016). However, despite its high costs, several authors have reported that the flush toilet has higher health benefits compared to other improved sanitation technologies (Morella et al. 2008; Günther & Fink 2010, 2011). Research has also shown that flush toilets can greatly reduce the probability of children under-5 suffering from diarrhoeal diseases and that they can reduce child mortality compared to improved pit latrines (Günther & Fink 2010, 2011). This, however, does not mean that the flush toilet is the best sanitation option, as it may fail to provide public health protection in other sections of the sanitation service chain, e.g. transportation or treatment of wastewater. Several authors have reported that most of the wastewater in SSA is discharged untreated into the environment thus posing a serious public health risk (Baum et al. 2013; Sato et al. 2013). In contrast, onsite sanitation technologies like the VIP latrine and septic tanks, which can be more affordable compared to sewered flush toilets (Dodane et al. 2012), can provide better public health protection when properly maintained (Morella et al. 2008; Günther & Fink 2010). However, faecal sludge collected from onsite technologies in urban areas of SSA is largely discharged untreated into the environment, thereby compromising public health (Peal et al. 2014; Strande et al. 2014).

In monitoring access to sanitation, the Joint Monitoring Programme for Water Supply and Sanitation (JMP) of the World Health Organization and the United Nations Children’s Fund (UNICEF) assesses usage of improved sanitation technologies. The format used by JMP to report global and country sanitation coverage shows statistics disaggregated into improved, shared, other unimproved sanitation facilities and open defaecation. However, the improved sanitation technologies which contribute towards the improved sanitation access are not shown in the JMP reports. Thus, this makes it difficult to understand the impact of technology choice on sanitation coverage and, by extension, sanitation success.

In order to improve the understanding of the relationship between improved sanitation technologies and sanitation success within a given SSA country, the distributions of the improved sanitation technologies must be known. This information seems to be currently lacking. Earlier work by Morella et al. (2008) failed to capture the distributions of the different technologies. For example, pit latrine with slab and VIP latrines were grouped as improved latrines, making it impossible to decipher the separate coverage of the two technologies. Furthermore, in a more recent study by Nakagiri et al. (2016), statistics for the pit latrine with slab, VIP latrines and pour-flush toilets for the national coverage were also grouped together although they were presented separately for urban areas. Similar to the study by Morella et al. (2008), Nakagiri et al. (2016) did not show the coverage for the separate flush toilet connections.

In addition, there seems to be a lack of information on the factors influencing the distribution of sanitation technologies in SSA. Previous studies by Morella et al. (2008) attempted to analyse the factors which influence access to different sanitation technologies in SSA. Some of the suggested factors were income and population densities. However, the study was rather qualitative and failed to bring out the actual relationships between sanitation technologies and the suggested factors. Other studies have also suggested a number of factors that influence technology selection (Mara et al. 2007; Murphy et al. 2009; Malekpour et al. 2013). In these studies, the factors cited can be classified as economic, environmental, health, institutional, socio-cultural and technical. The current study builds on and improves on the previous studies on improved sanitation technologies in SSA. The objectives of the present study were: (i) to assess the distributions of the improved sanitation technologies used in SSA countries; and (ii) to
investigate the factors which affect technology distribution/selection in SSA.

METHODS

Description of the study area

SSA comprises 52 African countries and island states and excludes the northern African countries: Algeria, Egypt, Libya, Morocco, Tunisia and Western Sahara (UN 2013; PRB 2014). The population of SSA is approximately 1 billion (UN 2015). The majority of the population of SSA lives in rural areas (63%) while only 37% live in urban areas (PRB 2014). Annual population growth rate averages 2.7%, which is higher than the average growth rate for Africa of 2.5% (UN 2015).

The economies of SSA countries have been growing strongly since the mid-1990s (IMF 2015) with some of the world’s fastest growing economies (on the basis of gross domestic product, GDP) found in the region. The economic growth of the region, however, slowed down in 2015, largely because of the falling prices of oil and other commodities (World Bank 2015). The decline in economic growth coupled with the large number of low-income countries, could have a bearing on the selection of sanitation technologies (Morella et al. 2008; Murphy et al. 2009).

Selection of variables

The independent variables were chosen based on their likely influence on technology selection as informed by previous studies. Previously studied factors include: population, population density, urban population, water use and water availability, social acceptance of the technology, policy, land requirements, experience and knowledge, protection of human health and environment, investment costs, technology resilience, soil type in settlement area and recycling of nutrients (Mara et al. 2007; Mels et al. 2007; Murphy et al. 2009; Malekpour et al. 2015). In the current study, six independent variables were identified and used: population, population density, urban population, renewable freshwater availability, GDP and development assistance (Table 1). Other variables such as religion, culture, policy and soil type were not included in the analysis either because of lack of data or the complexity of using them in such an analysis.

Data and data sources

Data on the types and distributions of improved sanitation technologies within the 48 SSA countries analysed were derived from the most recent surveys on the demographic and health surveys (DHS) database (USAID 2015), multiple indicator cluster survey (MICS) database (UNICEF 2015) and the JMP country files (WHO/UNICEF 2016). The data used were from the year 2008 to 2014. The selection of countries for analysis was guided by the availability of data for the variables used in the regressions. Data on independent variables were taken mainly from World Development Indicators (World Bank 2016) and from the Food and Agriculture Organization of the United Nations (FAO)’s AQUASTAT main database (FAO 2016). The DHS and MICS are nationally representative household surveys which collect information on household characteristics, including access to sanitation. The JMP country files report processed data from different DHS and MICS surveys.

It is worth noting that countries sometimes have different definitions for improved sanitation facilities (UN-Water 2012), with some countries regarding a portion of their traditional pit latrines as improved latrines, as reflected in the respective JMP country files. Other countries such as Angola include shared facilities in their definition of improved sanitation facilities (UN-Water 2012). However, in this study, all traditional latrines and shared facilities were treated as unimproved. This was done to avoid the overestimation of sanitation technologies and to improve the comparability between countries. In cases where a distinction was not made for shared technologies, all the sanitation technologies were assumed to be private.

Statistical analysis

The data were analysed in two separate stages. Firstly, in order to get the distributions of the various sanitation
 technologies, the frequencies of each named sanitation technology in the individual SSA countries were calculated using a program constructed in Python software (version 2.6). The sanitation technology data were first weighted using household sampling weights in accordance with the DHS method (Rutstein & Rojas 2006). Weighting was done to produce proper representation of the sample by adjusting for differences in the probability of sample selection and interview cases introduced either by sample design to expand the number of available cases or by chance. Descriptive statistics for each country were generated in Statistical Package for Social Scientists (SPSS) version 20 using cross tabulation. Secondly, to establish factors which affect technology selection, a step-wise multiple regression analysis was performed in SPSS. The analysis was done in six separate equations, equivalent to the six dependent variables used: composting toilet, pit latrines with slab, VIP latrine, flush/pour flush toilet connected to pit latrine, flush/pour flush toilet connected to septic tank and flush/pour flush toilet connected to piped sewer. The variables were entered and removed from the models based on p-values of 0.05. The multiple regression equation used is:

\[
DV = \beta_0 + \beta_1X_{1i} + \beta_2X_{2i} + \cdots + \beta_jX_{ji} + \text{Constant} \quad (1)
\]

where \(DV\) is the dependent variable of interest, representing the different sanitation technologies, \(\beta_0\) is the

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Units</th>
<th>Justification</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>numbers</td>
<td>Population increases can pose capacity challenges on selection of sanitation technologies. Thus, countries might be forced to select technologies which might not be appropriate (Murphy et al. 2009).</td>
<td>UN (2015)</td>
</tr>
<tr>
<td>Population density</td>
<td>people per km(^2) of land area</td>
<td>Research shows that land availability may influence technology selection (Nelson &amp; Murray 2008; Flores et al. 2009). Where land is not a problem, such as in low-density areas, on-site sanitation options (e.g. septic tanks and VIP latrines) may be selected. However, in high density areas, off-site sanitation technologies (e.g. flush toilets connected to sewer) may be considered appropriate (Morella et al. 2008).</td>
<td>UN (2015)</td>
</tr>
<tr>
<td>Urban population</td>
<td>% of total population</td>
<td>Urbanization generates economies of scale, which reduces units costs of sewerage systems (Arimah 2005; Krause 2008) thereby positively influencing their selection. Urbanization can also negatively impact on technology selection, because of capacity and resource constraints resulting in the selection of inappropriate technologies (Murphy et al. 2009).</td>
<td>UN (2014)</td>
</tr>
<tr>
<td>GDP</td>
<td>US$ per capita</td>
<td>Research shows that affordable sanitation technologies are most appropriate and most likely to be selected (Mara et al. 2007; Murphy et al. 2009). GDP, which measures the level of economic development of a country, is an indication of a country’s capacity to invest in a particular technology. It is expected that countries with high economic growth will select more advanced, expensive sanitation technologies and vice versa (Rudra 2011; Frone &amp; Frone 2014).</td>
<td>World Bank (2016)</td>
</tr>
<tr>
<td>Development assistance</td>
<td>US$</td>
<td>Development assistance is an important source of external financing for sanitation infrastructure in many countries (Sachs 2005; UN-Water 2014). It reflects the country’s capacity to invest in a specific technology. However, it can be argued that aid conditions and use of aid can also influence technology selection.</td>
<td>World Bank (2016)</td>
</tr>
<tr>
<td>Renewable freshwater availability</td>
<td>m(^3) per capita per year</td>
<td>The type of sanitation technology selected can be greatly influenced by its water usage and water availability (Mels et al. 2007; Flores et al. 2009). Where water supply is limited, it is expected that dry technologies will be the technology of choice, while wet technologies could be preferred in countries with no water supply challenges.</td>
<td>FAO (2016)</td>
</tr>
</tbody>
</table>
intercept; $\beta_1$ to $\beta_j$ are the regression coefficients for the independent variables $X_1$ to $X_j$ and $i$ represents the individual countries.

RESULTS

Variation of improved sanitation technologies used in SSA and technology selection variables

Table 2 shows the descriptive statistics of the variables used in the analysis. Results showed that there is a wide variation in the distribution of improved sanitation technologies in SSA. The minimum for all technologies is 0%. The pit latrine with slab was shown to be the most prevalent technology with a mean coverage of 21%. It was followed by the flush/pour flush toilet connected to septic tank whose coverage was 14%. The composting toilet seems to be the least used sanitation technology with a mean coverage of 0.6%. Huge differences were also observed for other variables. For example, renewable freshwater availability ranged from a minimum of 103 m$^3$ per capita per year to a maximum of 98,000 m$^3$ per capita per year with an average of 9,000 m$^3$ per capita per year. The GDP ranged from US$175 per capita to US$9,400 per capita with a mean of US$1,500 per capita while the average population was 14,933,000 (range 84,400–135,789,000).

Distribution of improved sanitation technologies according to type

Composting toilet

The composting toilet is not widely used in SSA as evidenced by more than half of SSA countries (54%) which do not use the technology. Among the countries which use this sanitation technology, the highest coverage was found in Ethiopia (8%), followed by Chad (5%) and Lesotho (4%).

Pit latrine with slab

The highest pit latrine with slab coverage was found in Burkina Faso (83%), Rwanda (61%) and The Gambia (56%) while the lowest coverage was observed in Seychelles (0.7%) (Figure 1). It is also worth noting that some countries such as Cape Verde, Equatorial-Guinea, Eritrea, Guinea-Bissau, Mauritius, Sao Tome and Principe, and Reunion seem not to use the pit latrine with slab.

VIP latrine

The highest VIP latrine coverage was found in Botswana (32%), Nigeria (51%) and Zimbabwe (50%) (Figure 2). It is instructive to note that the island states of Cape Verde, Mauritius, Seychelles and Reunion do not use the VIP latrine.

Table 2  Descriptive statistics for sanitation technologies and technology selection variables (N = 46)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Units</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean ± std deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composting toilet</td>
<td>%</td>
<td>0</td>
<td>8</td>
<td>1 ± 2</td>
</tr>
<tr>
<td>Pit latrine with slab</td>
<td>%</td>
<td>0</td>
<td>83</td>
<td>21 ± 18</td>
</tr>
<tr>
<td>VIP latrine</td>
<td>%</td>
<td>0</td>
<td>32</td>
<td>7 ± 9</td>
</tr>
<tr>
<td>Flush/pour flush toilet connected to pit latrine</td>
<td>%</td>
<td>0</td>
<td>66</td>
<td>5 ± 12</td>
</tr>
<tr>
<td>Flush/pour flush toilet connected to septic tank</td>
<td>%</td>
<td>0</td>
<td>85</td>
<td>14 ± 18</td>
</tr>
<tr>
<td>Flush/pour flush toilet connected to piped sewer</td>
<td>%</td>
<td>0</td>
<td>73</td>
<td>11 ± 16</td>
</tr>
<tr>
<td>Population</td>
<td>numbers</td>
<td>84,400</td>
<td>135,789,000</td>
<td>14,933,000 ± 23,702,000</td>
</tr>
<tr>
<td>Population density</td>
<td>people per km$^2$ of land area</td>
<td>2</td>
<td>608</td>
<td>84 ± 113</td>
</tr>
<tr>
<td>Urban population</td>
<td>%</td>
<td>9</td>
<td>84</td>
<td>38 ± 17</td>
</tr>
<tr>
<td>GDP</td>
<td>US$ per capita</td>
<td>175</td>
<td>9,400</td>
<td>1,500 ± 2,100</td>
</tr>
<tr>
<td>Development assistance</td>
<td>US$</td>
<td>378,000</td>
<td>125,113,000</td>
<td>27,582,000 ± 29,700,000</td>
</tr>
<tr>
<td>Renewable freshwater availability</td>
<td>m$^3$ per capita per year</td>
<td>105</td>
<td>98,000</td>
<td>9,000 ± 18,000</td>
</tr>
</tbody>
</table>
Figure 1 | Distribution of pit latrines with slab in SSA.

Figure 2 | Distribution of VIP latrines in SSA.
Flush/pour flush toilet connected to pit latrine

The usage of flush/pour flush toilets connected to pit latrine in SSA is very low (5%). However, a total of seven countries had coverage which was above the SSA average while nine countries seem not to use this sanitation technology. The highest usage of the technology was found in Mauritius (66%) and Sao Tome and Principe (39%) (Figure 3).

Flush/pour flush toilet connected to septic tank

Liberia and the island states of Reunion, Seychelles and Cape Verde had the highest coverage of flush/pour flush toilets connected to septic tanks. Reunion had 85% while Seychelles and Cape Verde had 52% coverage each. The lowest coverage for the same technology was found in Central African Republic (0.1%) and South Sudan (0.2%) (Figure 4). In countries such as Gabon, Mozambique and Uganda, flush/pour flush toilets connected to septic tanks are almost non-existent.

Flush/pour flush toilet connected to piped sewer

The highest coverage of flush/pour flush toilets connected to piped sewer in SSA was found in Namibia (73%), South Africa (66%) and Gabon (55%) (Figure 5). In other countries such as Mozambique, Sao Tome and Principe, and Rwanda, the flush/pour flush toilets connected to piped sewer are virtually non-existent.

Factors affecting distribution of improved sanitation technologies in SSA

Table 3 presents the results of the step-wise regression analysis performed to establish the factors which affect the distribution of sanitation technologies.

The analysis produced four regression models which were statistically significant (all p-values ≤ 0.035) whose coefficients of determination, R², varied from 0.3 to 0.6. The significant models were the pit latrine with slab, flush/pour flush toilet connected to pit latrine, flush/pour flush toilet connected to septic tank and flush/pour flush toilet connected to piped sewer. The VIP latrine and composting toilet models were not significant.

The pit latrine with slab model showed the pit latrine with slab to be significantly associated with development assistance (p = 0.035). In addition, a significant negative relationship was found between flush/pour flush toilet connected to pit latrine and population (p = 0.030). For the
flush/pour flush toilet connected to septic tank model, urban population \( (p = 0.000) \) and population density \( (0.004) \) had a positive significant relationship with flush/pour flush toilet connected to septic tanks. In the flush/pour flush toilet connected to piped sewer model, GDP showed a positive significant relationship with flush/pour flush toilet connected to piped sewer \( (p = 0.000) \).

**DISCUSSION**

**Distribution of improved sanitation technologies**

This study demonstrates that in SSA, the improved sanitation technology with the highest coverage was the pit latrine with slab while the composting toilet had the lowest coverage. This observation is supported by earlier studies, which attributed the high usage of the pit latrine with slab to low capital and O&M costs, simplicity and non-water usage \( (\text{Flores et al. 2009; Nakagiri et al. 2016}) \) relative to other technologies, which tend to be more expensive (e.g. VIP and flush toilets) and require water for operation (e.g. flush toilets). On the other hand, the low usage of composting toilet could be influenced by the faecophobic culture prevalent in most parts of SSA \( (\text{Dellstro \\& Rosenquist 2005}) \).

The distribution of improved sanitation technologies for SSA, however, mask the variations across countries. For example, it was shown that some countries had pit latrine with slab coverage as high as 83\% whereas other countries had coverage as low as 0.7\% for the same technology. These results are a reflection of the variability in the socio-economic
and environmental conditions of SSA countries which tend to influence technology selection and use.

Factors affecting distribution of improved sanitation technologies

Results of multiple regression analysis performed to investigate the factors which affect the distribution of improved sanitation technologies in SSA showed a positive significant relationship between pit latrine with slab and development assistance, suggesting that countries which received higher aid tend to install the pit latrine with slab over other technologies. While reasons for such choices might not be clear, it is assumed that when the aid is disbursed, it will have conditions on how it is supposed to be used, including installation of the cheapest technology in order to rapidly increase coverage. Alternatively, it could be the aid recipients themselves who may target a particular technology over other sanitation technologies.

On the other hand, the present study found a negative association between flush/pour flush toilet connected to pit latrine and population, suggesting that countries with high populations were most unlikely to select the flush/pour flush toilet connected to pit latrine. This is probably because when the population increases, population density will also likely increase, making it infeasible to install this type of technology as it will be difficult to empty, close the pit or dig another one because of space constraints (Satterthwaite et al. 2015).

The distribution of the flush/pour flush toilet connected to septic tank was found to be positively associated with urban population and population density. The association of the flush/pour flush connected to septic tank and urban population suggests that countries tend to select this technology when urban population increases. The positive association between urban population and flush/pour flush toilet connected to septic tank could be attributed to the capacity challenges faced by...
local authorities to extend sewerage connections to the unserved populations (McGranahan 2015), as sewerage is a technology of choice for most urban areas (Paterson et al. 2011). The sewerage network capacity challenges then force households to provide their own sanitation services, which results in the proliferation of septic tanks installed by households.

A positive association, which was found between population density and flush/pour flush toilet connected to septic tank, was not consistent with expectations. It would have been expected that local authorities would take advantage of economies of scale to install technologies such as the flush/pour flush toilet connected to piped sewer, where unit costs decrease with population (Krause 2008). Nonetheless, sometimes because of population growth in urban areas, the authorities fail to provide services, as explained above, leading to households installing septic tanks even in high density areas where the stand sizes might be below the minimum standard sizes required to install septic tanks (Ngwenya 2013).

The study also found a positive relationship between flush/pour flush toilet connected to piped sewer and GDP. This association suggests that countries with higher income have higher coverage of the flush/pour flush toilet connected to piped sewer technology, which is more advanced and more expensive compared to other sanitation technologies. These results are consistent with earlier studies which found a relationship between high economic development and the presence of advanced sanitation technology (Rudra 2011; Frone & Frone 2014).

The lack of association between VIP and composting toilet with any of the independent variables suggests that the other factors which were not investigated could have influenced the selection of these technologies in countries where they have high coverage. Factors such as policy, culture, protection of health, and recycling and reuse of nutrients could have

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**Table 3** Results of multiple regression analysis to determine factors affecting distribution of sanitation technologies in SSA

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Units</th>
<th>Pit latrine with slab</th>
<th>Flush/pour flush toilet connected to pit latrine</th>
<th>Flush/pour flush toilet connected to septic tank</th>
<th>Flush/pour flush toilet connected to piped sewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>numbers</td>
<td>***</td>
<td>−0.331 (−2.249) 0.030</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Population density</td>
<td>people per km² of land area</td>
<td>***</td>
<td>***</td>
<td>0.393 (3.068) 0.004</td>
<td>***</td>
</tr>
<tr>
<td>Urban population</td>
<td>% of total population</td>
<td>***</td>
<td>***</td>
<td>0.570 (4.446) 0.000</td>
<td>***</td>
</tr>
<tr>
<td>GDP</td>
<td>US$ per capita</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>0.584 (4.771) 0.000</td>
</tr>
<tr>
<td>Development assistance</td>
<td>US$ per capita</td>
<td>0.312 (2.180) 0.055</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

The figures in cells are: regression coefficient (b); t-statistic; p-value (p < 0.05); *** indicates non-significant relationships (p > 0.05).

N = sample size; F = F-statistic; R² = coefficient of determination.
played a major role in the selection of sanitation technologies (Mara et al. 2007; Malekpour et al. 2013).

CONCLUSIONS AND RECOMMENDATIONS

The study analysed the types and distributions of improved sanitation technologies used in SSA and the factors influencing their distribution. The need to understand the distribution of improved sanitation technologies is based on the realization that such information is currently not readily available yet it could help to explain the differences in sanitation success observed in the SSA region.

The study demonstrated that the distribution of improved sanitation technologies varies widely within and across SSA countries. While some countries had coverage of all the improved sanitation technologies specified in the sanitation ladder, in other countries some technologies were almost non-existent. From this study, it was concluded that the technologies used in SSA were influenced by certain criteria. The factors influencing distribution of technologies included income, population, population density, urban population and development assistance. It is imperative to note that sometimes countries select inappropriate sanitation technologies because of unfavourable socio-economic conditions.

Due to data limitations, the study, however, could not investigate the influence of other factors which have previously been suggested to influence technology selection. These factors include: policies, culture, technology resilience, knowledge, skills and experience, and the recycling and reuse of nutrients. In order to improve the understanding of factors affecting technology selection in SSA, there is a need to carry out further investigations on the influence of these factors. While technology selection in SSA was shown to be influenced by a number of factors, it is important to strike a balance between the economic, environmental, human health and socio-cultural sustainability aspects of sanitation.

REFERENCES


IMF International Monetary Fund 2013 Regional Economic Outlook: Sub-Saharan Africa. Keeping the pace. International Monetary Fund, Washington, DC.


Rudra, N. 2011 Openness and politics of potable water. Comparative Political Studies 44 (6), 771–803.


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