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Compliance of private ventilated improved pit latrines to odour and fly control guidelines: A technical audit in selected regions of Ghana

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ABSTRACT

The ventilated improved pit (VIP) latrine offers a promising route to safely managed sanitation to many households in developing countries. However, some technical guidelines must be followed in order to realise the technology's advantage of odour and fly nuisance control. This study sought to audit private VIP latrines in selected regions of Ghana to assess their compliance to conventional technical guidelines and to understand the major factors that influence the latrine designs. An inspection checklist was developed to assess 296 private VIP latrines in the Central, Ashanti and Northern Regions of Ghana while semi-structured interviews were conducted among the latrine owners to enquire the factors that influenced the designs of their latrines. The results show that provision of a window in the superstructure (86 %), and the avoidance of an insect screen in the window(s) (77 %) were the most complied guidelines. The use of 150 mm diameter vent pipe was the least satisfied guideline (5 %). On the average, a latrine satisfied about half (3.6) of the technical guidelines that were assessed. The decision or advice of local artisans is the most influential factor in the design of the latrines. Cost was the least mentioned factor cited by the latrine owners. There is the need to establish information desks at the various Metropolitan, Municipal and District Assemblies (MMDAs) to guide prospective owners on the proper design and construction of the VIP latrine. In addition, toilet construction should be incorporated in the curriculum for the basic training of building and construction students in Technical and Vocational Education and Training (TVET) institutions in Ghana. Further research is required to ascertain the basis of the decisions of local artisans and the potential impact of the use of accessories that are 'borrowed' from the WC toilet on odour and fly control in the latrine.

1. Introduction

Access to safe sanitation is a global challenge. The problem is worse in Sub-Saharan Africa which has only 35 % of the population

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having access to at least basic sanitation [1]. This is attributed in part to the absence of sewerage systems in most countries in the sub-region where only 4 % of the population are connected to safely managed sewer systems [1]. The absence of sewerage systems means that households have to self-invest in non-sewered sanitation systems. This explains why on-site sanitation is predominant in the sub-region, with 63 % of urban and 32 % of rural population using this service [1]. In Ghana for example, over 95 % of households with access to sanitation use various forms of on-site sanitation systems [2].

Flush toilets (wet on-site sanitation systems) are the preferred sanitation system for majority of households in Africa [3]. It is believed that in cities and peri urban settings where sludge treatment exists, people may possibly adopt an improved wet sanitation facility for excreta management. The water closet toilet (WC) is perceived as the standard and many prospective latrine owners aspire to use this technology. Nevertheless, certain socio-economic obstacles impede the use of wet sanitation systems among households. The challenges include unreliability of water supply, limited cesspit emptying services and lack of access for cesspit emptying trucks to reach residential facilities [4,5]. Consequently, some households are unable to use wet sanitation systems despite having the financial means to afford them.

Furthermore, in cities where no wastewater treatment facilities exist, the use of the coveted flush toilet or some other technologies previously classified under the Millennium Development Goals (MDGs) as 'improved sanitation' still leads to what has been labelled as 'postponed open defecation' [6]. That is the situation in which untreated faecal sludge dislodged from septic tanks and other on-site storage facilities is eventually disposed of in open fields and other 'unengineered' sites. The sanitation target under the Sustainable Development Goals (SDGs), i.e. 'safely managed sanitation', goes beyond the in-house toilet facility (capture and storage stages of the sanitation chain) to encompass environmental safety along the entire sanitation chain. Considering the current coverage of wastewater treatment plants in Sub-Saharan Africa, the pursuit of safely managed sanitation through wet on-site sanitation technologies places a huge responsibility on national and municipal governments. Governments must provide infrastructure for the treatment and safe disposal of faecal sludge dislodged from wet on-site sanitation systems before the use of such systems can be classified as safely managed. This may explain why, out of the 46 % of the population in Sub-Saharan Africa that use on-site sanitation technologies, only 21 % are classified as safely managed [1].

In view of the above, the use of dry sanitation systems which are designed to ensure the on-site decomposition of faecal sludge while ensuring the prevention of groundwater pollution offers the most practical approach to safely managed sanitation in developing countries. Nevertheless, the challenge of odour and fly nuisance associated with dry sanitation systems tend to discourage many prospective toilet owners from considering such systems. The ventilated improved pit (VIP) latrine is designed to overcome these challenges and is said to be capable of affording its users most of the health benefits and convenience of water-borne sanitation [7].

Nevertheless, the VIP latrine has a mechanism for controlling odour and fly nuisance which are quite technical and can be easily disrupted unless one follows a set of design and construction guidelines that have been developed through a series of field investigations. Poorly designed or constructed versions of the VIP latrine are likely to function like ordinary simple pit latrines and create odour and fly nuisances. Such latrines become obstacles to the promotion of the technology to new owners as a viable route to safely managed sanitation. Poor designs may arise from ignorance on the part of latrine builders. They may also result from self-motivated choices or modifications demanded by some owners that may interfere with the VIP latrine's odour and fly control mechanisms. It has been noted that, some owners of the VIP latrine, especially those for whom cost is not the main motivation for opting for the technology, try to mimic the features of the WC toilet in their VIP latrines in their quest for more aesthetically pleasing toilets [8]. In the process, some emerging modifications or innovations may inadvertently interfere with some conventional technical guidelines for odour and fly control.

The choices of design and construction of VIP latrines are not necessarily based on technical considerations only; sometimes socio-cultural and economic factors play a role. In Zimbabwe, Kanda et al. [9], reports that though the BVIP latrine is resilient to climate change, its costly nature drives households to create substandard and low-quality designs, affecting odour and fly control which are obstacles to continued latrine use. In addition, local culture is critical in latrine design/construction decisions. Through the Risks, Attitudes, Norms, Abilities and Self-regulations (RANAS) model of behaviour change, Nunbogu et al. [10] explained that cultural and social relations are influential factors to latrine construction decisions. Behaviours among physical neighbours and other social contacts may instil peer effects on household's latrine choices [11]. Many of these non-technical factors may be context specific whereas others may be general. Understanding these factors as important drivers for household owners' design choices for their latrines, would enable technical experts to create a good balance between technical requirements and user preferences and aspirations.

Currently, the level of compliance of existing VIP latrines to conventional technical guidelines has not been adequately studied. Furthermore, there is a lack of understanding of the major factors that are influencing the design and construction of existing VIP latrines which may create barriers to the adoption of the conventional guidelines. Such understanding is needed to guide the design of training and educational materials as well as policy and institutional interventions to support the sections of the populace for whom the technology might be the most appropriate option to safely managed sanitation. It would also form the basis for further research to inform innovations in the technology to meet the aesthetic demands of prospective users without necessarily compromising its odour and fly control functions. This study, therefore, sought to audit existing VIP latrines in selected regions of Ghana to assess the level of compliance to conventional technical guidelines on odour and fly control and to understand the major factors that influence the design choices and construction of the sanitation technology.

2. Theoretical framework for odour and fly control in VIP latrines

Fig. 1 illustrates the conventional design of the VIP latrine and the mechanisms by which it controls odour and fly nuisances. According to classical works such as Kalbermatten et al. [12], Ryan and Mara [13] and Mara [7], odour is controlled in the VIP latrine by ‘forcing’ malodorous air in the pit through the vent pipe into the atmosphere rather than leaving it to return to the latrine cubicle through the squat hole. Similarly, flies produced in the pit are ‘encouraged’ or attracted to bright light at the top of the vent pipe rather than moving into the cubicle. An insect screen fixed at the top of the vent pipe prevents the flies from escaping into the surrounding. After several unsuccessful attempts at escaping through the screen, the flies become dehydrated and fall into the pit and eventually die. The factors which enhance the effectiveness of these two processes underpin the VIP latrine design guidelines. For further explanation of these processes and the factors involved, the reader is directed to the above classical works as well as the review paper by Obeng et al. [8]. However, the salient factors involved are explained below.

The movement of air from the pit through the vent pipe is primarily determined by the pressure difference between the ends of the pipe [15,16]. The pressure difference is also controlled by two phenomena: the stack or chimney effect and the Bernoulli’s principle. The stack or chimney effect is the pressure difference occasioned by temperature difference between fresh air from the surroundings and warm air in the pit. Cold air entering the pit through the cubicle displaces the warm, malodorous air in the pit by virtue of its (cold air’s) higher density and pushes the malodorous air up the vent pipe into the atmosphere. This aspect of the movement of air is also referred to as buoyancy-driven ventilation [16]. This phenomenon is enhanced by: (i) a higher wind speed in the neighbourhood which compels more air to enter the cubicle in a given time; (ii) provision of a window in the superstructure to allow entry of air into the cubicle; (iii) making the window or opening face the windward direction to directly receive the air; (iv) allowing no other windows or openings in other sides of the superstructure through which the air can escape from the cubicle instead of being pushed down into the pit; (v) avoiding the use of insect screens in the window to prevent the loss of air pressure (or slowing down the air) as it moves across the screen; (vi) ensuring that the squat hole or seat is left uncovered to allow the movement of air from the cubicle into the pit [7,12,13].

Alongside the chimney effect is the Bernoulli’s principle, which may also be regarded as the suction effect of air at the top of the vent pipe. As air moves across the top of the vent pipe at a high speed, its high kinetic energy leads to a drop in its pressure, thereby creating a pressure gradient between the bottom and the top of the vent pipe. This makes the vent pipe act as when a suction tube is used to draw a fluid from a vessel as in the case of a straw used to suck a drink from a bottle. The effectiveness of this phenomenon is dependent on the speed of air at the top of the vent pipe. It also depends on the size of the vent pipe, which determines the area over which the action of wind takes place. The two phenomena are required to establish adequate pressure difference to generate a recommended ventilation rate of 20 m^3/h in order to guarantee odourless conditions in the VIP latrine [7]. It should be noted, however, that poor maintenance could also create odour nuisances aside the design of the latrine.

For the effective control of flies in the VIP latrine, the vent pipe and superstructure should be designed to ensure that: (i) the bright light of the skies is unobstructed; (ii) the vent pipe is vertically straight to allow flies to see the sky; (iii) the cubicle is kept dark, else light from the cubicle would divert the attention of flies from the top of the vent pipe [7,12,13,17–20].

The above theoretical underpinnings inform the various technical guidelines that govern the design and construction of the VIP latrine.

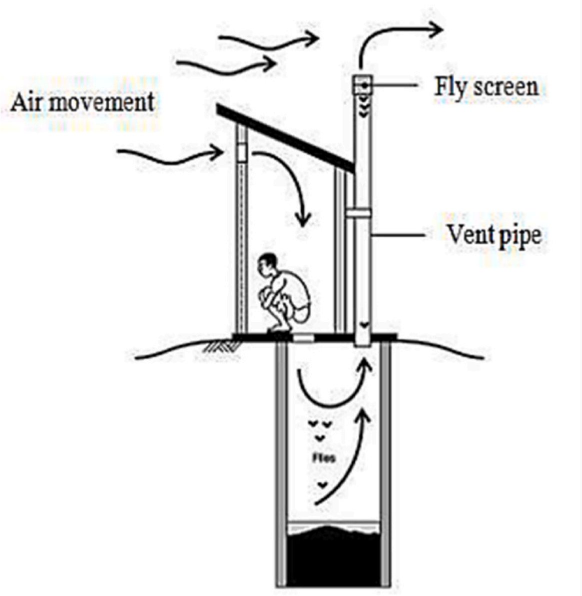

Fig. 1. An illustration of the VIP latrine design concept (*Source:* Harvey et al. [14]).

3. Methodology

3.1. Description of study area

The study was conducted in three (3) administrative regions in Ghana, namely Central, Ashanti, and Northern Regions. These regions, respectively, represent the coastal (southern), forest (middle), and savannah (northern) belts of Ghana which have some distinct socio-cultural and economic characteristics that influence their sanitation practices. In terms of socio-economic development, the savannah belt is less developed, as compared to the other two, and dominated by the Islamic religion [21,22]. On the other hand, communities in the coastal belt may be distinguished from those in the forest belt by their history of defecation at the airy beaches [23–25] which may influence the way they build their toilets. Due to the low coverage of sanitation facilities and the VIP latrine in particular, the choice of regions and communities within the belts was purposeful rather than probabilistic and informed by the guidance of local informants. Where there were no special considerations of scientific significance, the cost of transportation and other resource implications were considered in the selection of study communities. The communities were mostly within 20 km from the regional capital. The administrative capitals of the Central, Ashanti and Northern Regions are Cape Coast, Kumasi, and Tamale, respectively. The three selected regions constitute a little over one-third of the total population of Ghana. The Ashanti Region represents 17.6 % of Ghana's population while the Central and Northern Regions represent 9.3 % and 7.5 % respectively [26]. The main economic activities across the regions are agriculture, forestry and fishing, but the administrative capitals are dominated by trading (wholesale and retail) and manufacturing [27]. Christianity is the prevailing religion in both Central and Ashanti Regions, but Islamic religion dominates in the Northern Region.

Data from the 2021 Ghana Population and Housing Census indicates that access to improved household toilet facilities is quite high in the Central and Ashanti Regions but low in the Northern Region. The proportion of household toilet facilities that are improved stands at 64 % for Central Region, 62.4 % for Ashanti Region and 24.2 % for Northern Region. The proportion is higher in the Urban areas. VIP/KVIP latrine technology constitute 19.3 % of household toilet facilities in the Central Region, 12.5 % in the Ashanti Region and 10.1 % in the Northern Region. The proportion is, however, higher for the urban areas (50 % higher in the Central and Ashanti Regions and 200 % higher in the Northern Region) [28].

3.2. Study design

The study adopted a cross-sectional approach using a combination of qualitative and quantitative methods to evaluate the compliance of private VIP latrines to conventional design guidelines for fly and odour control and the factors influencing design choices. The evaluation focused on the design and positioning of the vent pipe, design and construction of the superstructure (including placement of windows/openings) and the design of the user interface (squat hole/seat with or without cover). Table 1 summarises the specific design and construction criteria for odour and fly control that were assessed in this study and the relevant guidelines that were used to evaluate them.

In addition, latrine owners were engaged to understand the factors that influenced the design and construction choices of their latrines. The assessment exclusively included VIP latrines from the targeted communities. A VIP latrine is described as a pit with a cover slab, a superstructure featuring a roof to ensure privacy for latrine users, and a vent pipe.

3.3. Sample size and sampling approach

The study was conducted in peri-urban communities around the administrative capitals (Cape Coast, Kumasi and Tamale). One

Table 1
Design and construction criteria used to assess the latrines.

Design Criterion	Recommend Technical Guidelines for Odour and Fly Control	Key Reference
Size of vent pipe	Minimum of 150 mm diameter for polyvinyl chloride (PVC) or asbestos pipe but can be reduced to 100 mm where average wind speed exceeds 3 m/s; 230 mm square for brickwork	Mara [7], Kalbermatten et al. [12], Ryan and Mara [13]
Height of vent pipe	Above the apex of a conical roof and minimum of 500 mm above the highest point of a slanted roof.	Mara [7], Ryan and Mara [13]
Fixing an insect screen on vent pipe	Strongly recommended to prevent escape of flies into the surroundings	Mara [7], Kalbermatten et al. [12], Ryan and Mara [13]
Top of vent pipe	There should be no obstruction to the action of external wind and free exit of air from the pipe	Mara [7], Ryan and Mara [13]
Covering of squat hole or seat	Strongly prohibited to allow entry of air into the pit	Mara [7], Ryan and Mara [13]
Provision of window or other opening[a]	Strongly recommended in the windward side only	Mara [7], Ryan and Mara [13]
Provision of insect screen in windows/openings	Prohibited to prevent loss of air pressure across the screen	[7,13], Obeng et al. [20]

[a] Note: Wind direction could not be scientifically determined at each latrine site. Hence, only the provision of a window was assessed but whether or not windows were in the windward side of the latrine was not assessed.

hundred latrines were targeted to be selected from six communities in each of the regions. However, data collection in the Northern Region was extended to the seventh community due to the relatively lower coverage of VIP latrines. In the Central Region, the communities selected were Sewin, Kakumdo, Nkanfoa, Amosima, Adukrom, and Ebukonko. Communities selected in the Ashanti Region comprised Atwima-Koforidua, Mpasatia, Twedie, Mankranso, Atwima-Manhyia, and Atwima-Maakro. The Northern Region focused on Sagnerigu, Zagyuri, Gumbihini, Dabokpa, Lamashegu, Gumani and Sakasaka communities. Due to the low coverage of VIP latrines in the study areas, a non-probabilistic sampling approach was used to identify and select the latrines that are used by single households or privately shared by two or more households.

Using the non-probabilistic sampling method, 100 households from each of the regions were identified. However, two latrines each from Central and Ashanti Regions were omitted and their data not included in the analysis because they had some key components missing. Therefore, a total of 296 households with private VIP latrines took part in the study. These latrines were literally searched from the communities with the assistance of local residents. Prior to the commencement of the study, unwritten consent was obtained from individuals who owned or used the latrines, as well as from the heads of households. The survey included only individuals who provided their consent to participate.

3.4. Data collection methods

3.4.1. Structured observation of latrines

A latrine inspection guide was prepared based on the conventional VIP latrine design and construction guidelines for odour and fly control. A comprehensive visual inspection of the selected VIP latrines was performed by trained research assistants using the inspection guide. The latrine assessment was primarily designed to examine general construction practices, with emphasis on features that could impact the odour and fly control function of the latrine.

3.4.2. Interviews with latrine owners

A semi-structured interview guide was developed to collect data from latrine owners on the factors that influenced the design and construction choices of their latrines. The interviews also helped to collect data on the age, user population and sharing status of the latrines. The choice of semi-structured interview, which included some open-ended questions, was to allow the respondents the opportunity to reveal local factors that inform the design and construction of VIP latrines other than those previously reported in literature. The interviews were conducted in the language of preference to the respondents and the responses recorded in English. Twi was the predominant language used in the Ashanti Region, Fante/Twi in the Central Region, and Dagbani was used in the Northern Region.

3.5. Quality control

The selected households were not given advance notification regarding the timing of the survey. This measure was adopted to prevent modifications to the latrines and their surroundings prior to the survey. Latrine assessment and latrine owners' interviews were conducted concurrently by trained research assistants and supervised by the lead researcher. The research assistants were people who had received formal education on the VIP latrine design and construction principles.

3.6. Data analysis

The data was analysed using descriptive and inferential statistics with Microsoft Excel 2016 and SPSS Statistical Software version 23. All data were tested for normality with the Shapiro-Wilk test at a 95 % significance level. Categorical data was summarized using frequencies and proportions, and the findings were presented in both narrative and tabular formats. A non-parametric test (Kruskal-

Table 2
Latrine superstructure design and construction features.

Design/construction feature	Central Region (N = 98)	Ashanti Region (N = 98)	Northern Region (N = 100)	All Regions (N = 296)
Superstructure wall material				
Sandcrete block	96 (98.0 %)	92 (93.9 %)	92 (92.0 %)	280 (94.6 %)
Mud/brick	1 (1.0 %)	4 (4.1 %)	4 (4.0 %)	9 (3.0 %)
Others (wood, steel, etc.)	1 (1.0 %)	2 (2.0 %)	4 (4.0 %)	7 (2.4 %)
Provision of window(s) in superstructure				
Provided in one side	68 (69.4 %)	38 (38.8 %)	74 (74.0 %)	180 (60.8 %)
Provided in multiple sides	16 (16.3 %)	40 (40.8 %)	18 (18.0 %)	74 (25.0 %)
None provided	14 (14.3 %)	20 (20.4 %)	8 (8.0 %)	42 (14.2 %)
Use of screens in windows				
Screens provided	13 (13.3 %)	4 (4.1 %)	8 (8.0 %)	25 (8.4 %)
No screens in windows	71 (72.4 %)	74 (75.5 %)	84 (84.0 %)	229 (77.4 %)
Not applicable (no windows or openings provided at all)	14 (14.3 %)	20 (20.4 %)	8 (8.0 %)	42 (14.2 %)

Wallis) was used for comparison of medians of non-normal data. Post-hoc analysis was performed using the Dunn-Bonferroni test. Responses to open-ended questions which sought to understand latrine owners' design choices were subjected to content analysis to identify the major factors and themes under which their responses were classified. The frequencies of the major factors or themes were determined and represented in bar charts.

4. Results and discussion

4.1. Description of odour and fly control features of the latrines

The design criteria relating to odour and fly control were assessed in relation to the superstructure design, provision of windows in the superstructure, use of insect screens in windows, vent pipe material and size, type of user interface and covering of the latrine seat or squat hole.

4.1.1. Superstructure design and construction

Table 2 presents the results on the design and construction of the superstructure of the latrines.

The predominant material for constructing the superstructure wall is sandcrete block. This accounts for over 90 % across the regions. Only a small fraction (less than 6 %) of the latrines is constructed with mud/bricks or other materials (wood, roofing sheets, etc.). Fig. 2 shows sample superstructure wall materials found in the study areas.

A household's choice of latrine material is influenced, among others, by local availability, culture and local architecture, as well as the influence of latrine artisans [29]. The predominant use of sandcrete blocks is consistent with the choice of wall materials for the construction of dwellings in the regions but too high in the case of the Northern Region where the use of mud is relatively higher. The

Fig. 2. Types of superstructure wall materials (*Source: Author's fieldwork*) (Note: (a) Sandcrete blocks (plastered and painted); (b) Sandcrete blocks (unplastered); (c) Bricks; (d) Iron sheets).

2021 Ghana PHC reports that over 85 % of walls of dwellings in the Ashanti and Central Regions and 64 % in the Northern Region were constructed with sandcrete blocks [2]. The findings in the Northern Region differ from those of Delaire et al. [29] who assessed latrines in rural areas of Bole and Sawla-Tuna-Kalba districts in Northern Ghana and found that about 60 % of the superstructure of latrines were constructed with mud and only 22 % from bricks and other materials. This difference may be attributed to the fact that most of the communities covered in this study were within or close to the Tamale Metropolis and were, therefore, urban or peri-urban. The extensive use of sandcrete blocks for construction of latrine superstructure may account for the durability or age of the latrines.

Some 14 % of latrines had no windows at all as seen in Fig. 2 (a)–(c). This is most prevalent in the Ashanti Region (20 %). The absence of windows or openings on the superstructure will lead to no or limited entry of air for odour control as explained above. In addition, such latrines could be uncomfortable to use due to potentially high levels of heat and darkness in the cubicle. High levels of heat and darkness in the cubicle could discourage people, especially children, from using such latrines. There is high probability that such latrines would be associated with odour nuisance.

Provision of windows or openings in multiple sides of the superstructure, which was observed in 25 % of all latrines, is known to reduce the ventilation rate in the vent pipe and, hence, the odour control potential of the latrine. Consequently, existing technical guidelines discourage this practice and recommend a single window on the windward side of the superstructure [7]. Furthermore, the provision of windows on multiple sides of the superstructure may increase the intensity of light in the cubicle and, therefore, encourage fly entry from the pit into the cubicle. Nevertheless, the provision of multiple windows has been linked to providing user comfort by allowing entry of more fresh air and minimizing heat in the cubicle [23].

Most of the latrines (92 %) had no insect screens in their windows as required by existing technical guidelines. It is not clear whether the high level of compliance was accidental or due to artisans' awareness of the conventional design guideline of the VIP

Fig. 3. Types of vent pipe materials and designs (*Source: Author's fieldwork*) (Note: (a) PVC pipe (75 mm diameter, below roof level); (b) PVC pipe (bent at the base and the roof level); (c) PVC pipe (installed straight and well above the roof); (d) Brickwork ventilation).

latrine. However, provision of screens in windows may serve a practical purpose of warding off rodents and reptiles which are not friendly to users, especially to children [30]. But their use may result in loss of air pressure across the screen [31] and found to result in 7 % reduction in the ventilation rate through the vent pipe if all other factors are held constant [32].

4.1.2. Vent pipe design and construction

Fig. 3 shows some vent pipe materials and designs observed during the study.

The prevalence of the types of vent pipe materials, sizes and other features are summarized in Table 3. The use of polyvinyl chloride (PVC) vent pipes dominates in all the regions (98 %).

All latrines in the Central and Ashanti Regions and 95 % of those in the Northern Region were fitted with PVC vent pipes. A small proportion of latrines (one in twenty) assessed in the Northern Region had vent pipe made with bricks. The internal surface of such vent pipes is anticipated to be very rough due to the nature of the material and constructional practice. However, PVC pipes have a smooth internal surface for the passage of air. The headloss in vent pipes made of bricks is expected to be higher compared to that in PVC vent pipes. A higher headloss in a vent pipe would lead to reduced ventilation rate through the vent pipe. This explains why a bigger (3 times) cross-sectional area is required from a vent pipe made from brickwork (230 mm × 230 mm) as compared to that made from PVC pipe (150 mm diameter).

The 100 mm diameter PVC pipe dominates in all the regions (93 %) instead of the recommended 150 mm as reported in earlier studies [19,20,33]. Some 6 % of latrines in the Ashanti Region were fitted with as small as 75 mm diameter vent pipes as shown in Fig. 3 (a). Few latrines in the Ashanti (3 %) and Northern (6 %) Regions were fitted with the recommended 150 mm PVC pipes. The results suggest that 95 % of the latrines in all regions do not comply with the recommended vent pipe size of 150 mm for PVC pipes. However, it should be noted that the use of the 100 mm diameter PVC vent pipe is not strictly forbidden. It is noted as the minimum size required to generate a satisfactory air flow rate of 10 m^3/h, which is associated with the attainment of odourless conditions [13]. This suggests that the 100 mm diameter PVC vent pipes widely used in Ghana may not necessarily be delivering inadequate ventilation in the VIP latrines provided other design criteria are satisfied. Nevertheless, the 75 mm diameter PVC pipes used in some latrines in the Ashanti Region are likely to generate inadequate air flow and will cause odour nuisance in those latrines.

The 150 mm diameter pipe is recommended to generate air flow rate of 20 m^3/h which guarantees an adequate factor of safety against odour generation. This is particularly emphasised for latrines that are intended to be used permanently, sited close to dwelling places as in the case of urban centres and where cost is not an overriding factor [13]. Considering the fact that most of the toilets were selected from urbanised communities where they are sited close to dwellings, one would have expected them to be fitted with 150 mm diameter vent pipes. However, the cost of the 150 mm diameter pipe seems to justify the use of the 100 mm diameter pipes. Obeng et al. [19] observed that the use of the 150 mm diameter PVC pipe in Cape Coast was problematic for many households due to the cost and availability. The cost of the 150 mm diameter pipe in Cape Coast was found to be about thrice that of the 100 mm diameter pipe. In real economic terms, the difference in price was said to be equivalent to a little more than a week's earning based on Ghana's minimum wage at the time of their study. Besides, they noted that the 150 mm diameter pipe is not readily available in small neighbourhood plumbing shops. Therefore, one had to commute to large plumbing shops in city centres to purchase one and bear the extra cost of transporting it back to the latrine construction site.

About one-third of the latrines were fitted with vent caps that are likely to obstruct the free flow of air out of the vent pipe as can be seen in Fig. 3 (b). These vent caps may be suitable for septic tanks but would compromise the ventilation mechanism in a VIP latrine. However, like other emerging practices, the magnitude of its effect on the ventilation rate has not been established and needs to be

Table 3
Vent pipe design and construction.

Design/construction feature	Central Region (N = 98)	Ashanti Region (N = 98)	Northern Region (N = 100)	All Regions (N = 296)
Vent pipe material				
PVC pipe	98 (100 %)	98 (100 %)	95 (95 %)	291 (98.3 %)
Brick work	–	–	5 (5 %)	5 (1.7 %)
Vent pipe size				
75 mm diameter	–	6 (6.1 %)	–	6 (2.0 %)
100 mm diameter	98 (100 %)	89 (90.8 %)	89 (89.0 %)	276 (93.2 %)
150 mm diameter	–	3 (3.1 %)	6 (6.0 %)	9 (3.0 %)
≥250 mm sq (brickwork)	–	–	5 (5.0 %)	5 (1.7 %)
Height of vent pipe				
Below roof	17 (17.3 %)	11 (11.2 %)	7 (7.0 %)	35 (11.8 %)
Above roof but below recommended height	51 (52.0 %)	35 (35.7 %)	65 (65.0 %)	151 (51.0 %)
≥500 mm above roof	30 (30.6 %)	52 (53.1 %)	28 (28.0 %)	110 (37.2 %)
Type of vent cap				
No vent cap	25 (25.5 %)	35 (35.7 %)	49 (49.0 %)	109 (36.8 %)
Open-top vent cap	22 (22.4 %)	51 (52.0 %)	7 (7.0 %)	80 (27.0 %)
Closed-top vent cap	46 (46.9 %)	12 (12.2 %)	44 (44.0 %)	102 (34.5 %)
Other vent cap[a]	5 (5.1 %)	–	–	5 (1.7 %)
Insect screen on vent pipe				
Visible	15 (15.3 %)	34 (34.7 %)	11 (11.0 %)	61 (20.6 %)
Not visible	83 (84.7 %)	68 (65.3 %)	89 (89 %)	235 (79.4 %)

[a] Examples are sac, empty plastic container, and metal container.

investigated. Even though it is expected that the vent pipes should be fitted with insect screens to prevent flies from escaping from the pit into the neighbourhood, only about 20 % of the latrines had insect screens visibly fitted to the top of the vent pipes. Aiyuk and Tsepa [34] observed a similar trend among VIP latrines studied in Lesotho. Such latrines fail to fulfil the crucial function of raising a barrier against oral-faecal transmission of diseases since flies will have unhindered access into and out of the pit.

A vent pipe construction error that was frequently encountered is the bending of the pipe as shown in Fig. 3 (b). This practice is fundamentally caused by failure to ensure an offset between the pit and the superstructure to allow the vent pipe to be installed perpendicularly to the cover slab as shown in Fig. 3 (a). A bent vent pipe may increase the loss of energy in the movement of air out of the vent pipe and decrease the ventilation rate. Perhaps, more importantly, a straight vent pipe is needed to direct flies inside the pit to the bright sky and, hence, divert their attention from the cubicle. This is the main fly control mechanism of the VIP latrine but becomes defeated when the vent pipe is bent.

4.1.3. User interface design

Fig. 4 show types of user interfaces that were observed among the VIP latrines.

A summary of the frequency of the different types of user interface designs is presented in Table 4. The study reveals a fair balance between preference for seats (51 %) and squatting (49 %) nationally. However, there is a sharp disparity between the two preferences when the data is disaggregated between the Central and Ashanti Regions, on one hand, and the Northern Region on the other hand. While there is a high preference for seats in the Central and Ashanti Regions, users in the Northern Region predominantly prefer

Fig. 4. Types of user interface designs (*Source: Author's fieldwork*) (Note: (a) No seat (squat hole design); (b) In-situ masonry seat; (c) Prefabricated ceramic seat; (d) Wooden seat).

Table 4
User interface design.

Design/construction feature	Central Region	Ashanti Region	Northern Region	All Regions
Type of user interface				
No seat (squatting)	17 (17.3 %)	35 (35.7 %)	93 (93.0 %)	145 (49.0 %)
In-situ masonry seat	43 (43.9 %)	32 (32.7 %)	4 (4.0 %)	79 (26.7 %)
Prefabricated ceramic seat	37 (37.8 %)	31 (31.6 %)	3 (3.0 %)	71 (24.0 %)
Wooden seat	1 (1.0 %)	–	–	1 (0.3 %)
Covering of seat/squat hole				
No cover	44 (44.9 %)	67 (68.4 %)	85 (85.0 %)	196 (66.2 %)
Solid/full cover	54 (55.1 %)	31 (31.6 %)	15 (15.0 %)	100 (33.8 %)
Covering of toilets with squat holes (without seats)	3 (17.7 %)	3 (8.6 %)	11 (11.8 %)	17 (11.7 %)
Covering of toilets with seats	28 (44.4 %)	51 (63.0)	4 (57.1 %)	83 (55.0 %)

squatting. The preference for squatting in the Northern Region may be attributed to their religious practice. People in the Northern part of Ghana are predominantly Muslims who prefer to use water as an anal cleanser after using the toilet [35]. It may be the case that anal cleansing with water on a squat hole is easier or more convenient than in a latrine with a seat installed [35]. This is further buttressed by Bahrainwala [36] that squatting toilets are common in Muslim homes or places of worship. The foreseeable challenge with squatting is poor anal targeting of the squat hole leading to soiling of the slab with faeces especially by children. On the other hand, seats solve practical problems for those with restricted mobility who may find it difficult to squat such as pregnant women, the elderly and the sick.

In-situ masonry seats are slightly more predominant than prefabricated ceramic seats probably because of their lower cost and long history of use in pit latrines until more recently when prefabricated ceramic seats emerged on the market. Nonetheless, prefabricated ceramic seats are becoming popular among those who prefer seats. Even though they may be more expensive than masonry seats, their aesthetics, comfortability in use and ease of cleaning could account for their increasing popularity. In principle, seats with covers could obstruct the flow of air into the pit and undermine the odour control function of the latrine. However, seats with wide 'mouths' such as the prefabricated ceramic seats could allow more air to be drawn into the pit.

Closely associated with the use of seats is the tendency to provide them with a cover as seen in Fig. 4 (b)–(d). Conventional guidelines prohibit the covering of the latrine seat or squat hole since it prevents entry of air into the pit to facilitate the odour control mechanism. Among toilets with seats, 55 % were fitted with a cover as compared to 12 % of squat holes that were covered. Thus, the odds ratio of a toilet with seat being covered to that of one with a squat hole being covered is 9.19 (CI: 5.05–16.73). Kanda et al. [9] found 15 % of VIP latrines in rural villages of Mbire District in northern Zimbabwe to have squat hole cover. In Upper West Region (part of the Northern belt) of Ghana, Dumpert et al. [33] found 90 % of the VIP latrines assessed to have some form of cover.

The increasing adoption of prefabricated ceramic seats reflects latrine owners' demand for aesthetics to mimic the water closet toilet. This gives rise to the question of how to satisfy users' preference for such seats with covers without compromising the odour control mechanism of the VIP latrine. A potential solution is seat covers partially lined with insect screens that would allow entry of air into the pit.

4.2. Compliance to key technical guidelines

4.2.1. Levels of compliance per design criterion

The latrines were assessed for their compliance with seven (7) key design criteria for odour and fly control. Table 5 presents the results on the latrines' compliance to the selected technical guidelines.

Provision of widow(s) or other openings in the superstructure was the criterion with the highest level of compliance (85.8 %). It is not clear and may require further enquiry from the latrine artisans whether this is a deliberate compliance to the VIP latrine guideline, per se, or in conformity with a normal, 'common-sense' practice in the construction of all human dwellings, especially in a tropical weather. Considering the crucial role the entry of air into the cubicle plays in the chimney effect, it is encouraging that many of the

Table 5
Compliance of VIP latrines to key technical guidelines.

Design Criterion/Technical Guideline	% of Latrines Satisfying the Guideline			
	Central Region (N = 98)	Ashanti Region (N = 98)	Northern Region (N = 100)	All Regions (N = 296)
Using a vent pipe of at least 150 mm diameter	0.0	3.1	11.0	4.7
Installing vent pipe to at least 500 mm above highest point of roof	30.6	53.1	28.0	37.2
Fixing an insect screen on vent pipe	15.3	34 0.7	11.0	20.6
Vent pipe exit unobstructed by vent cap	48.0	87.8	56.0	63.9
Providing NO cover on squat hole or seat	44 0.9	68.4	85.0	66.2
Providing window(s) or other opening(s) in the superstructure	85.7	79.6	92.0	85.8

latrines comply with this key requirement. It would be interesting to understand why some artisans built some latrines (14 %) without any windows or openings. Since it is a normal practice to build a room with a window, the artisans or the latrine owners may have had some special reasons for allowing no windows or openings in those toilets.

On the other hand, the guideline on the size of the vent pipe is the least complied with, with no latrine in the Central Region complying with the guideline. As noted earlier, this guideline is one that may require a rethinking since the 100 mm diameter vent pipe appears to be capable of delivering the required ventilation rate. It is imperative to note that, nearly all official project interventions involving the construction of household VIP latrines in Ghana make use of the 100 mm diameter PVC pipe. It is, therefore, unlikely to expect private individuals to adopt the use of the 150 mm diameter pipes.

A careful look at the levels of compliance to the various guidelines reveals the influence of cost or economic considerations on the design decisions as expected. For instance, it may have been easy for many of the latrines to satisfy the requirement of providing a window or some opening in the latrine superstructure because, apart from the practical purpose it serves to keep the latrine cubicle well ventilated, it does not seem to place any extra financial burden on the owner. In many cases, the window is left as a space at the top of the door as shown in Fig. 2 (d). Thus, it only requires making the door shorter than it would have otherwise been. This may explain the sharp difference between the level of compliance to the provision of windows as compared to the size of the vent pipe. These observations emphasise the importance of cost considerations in sanitation technology development in developing countries.

On the other hand, even though the provision of insect screens in windows appears to serve an equally practical purpose of preventing entry of reptiles and rodents from the toilet, this was found in only less than a quarter of the toilets. A similar trend is seen in the fixing of screens on top of the vent pipe, which was visibly observable in only about one-fifth of the latrines. It is not clear what informs the latrine artisans' and owners' decision to avoid the use of the screens.

4.2.2. Levels of compliance per latrine among the regions

Fig. 5 shows the cumulative percentage of latrines in the three regions that complied with a given number out of the seven criteria that were assessed. Only one latrine each in the Ashanti and Northern Regions passed all the seven criteria while six each from the same regions passed six criteria. No latrine in the Central Region passed up to six assessment criteria.

On the average, a latrine satisfied 3.6 of the assessment criteria. The median number of guidelines satisfied by latrines in all regions is 4 as seen in Table 6. Ashanti Region had the highest proportion of latrines (69.6 %) satisfying, at least, the median number of guidelines (4 or more), followed by the Northern Region (53 %). The Central Region recorded the lowest, with about one-third of the latrines satisfying, at least, the median number of guidelines.

It is seen from Table 6 that there are high statistically significant differences in the number of criteria satisfied by latrines from all the three regions (Kruskal Wallis $H = 35.87$, $p = 0.000$). Post-hoc pairwise comparisons (Table 7) show that the differences in the median compliance levels between all pairs of regions are statistically significant.

The emergence of the Ashanti Region as the region with the highest level of compliance is consistent with the identification of cost and economic considerations as factors influencing the levels of compliance to the technical guidelines. According to the Round 7 (latest edition) of the Ghana Living Standards Survey (GLSS 7) [37], the Ashanti Region has the highest household income among all the regions of Ghana, with 72,491 Ghana cedis per household as compared to 32,564 and 22,919 Ghana cedis for the Central and Northern Regions respectively. This suggests that households in the Ashanti Region are less likely to ignore a relevant technical guideline on economic grounds as compared to the two other regions. Between the Central and Northern Regions, even though the Northern Region has a lower household income as compared to the Central Region, the region may have performed better than the Central Region due to several sanitation interventions by non-governmental organisations (NGOs) that operate in the northern part of Ghana. Hence, some of the toilets may have been built by trained artisans or provided under some project interventions.

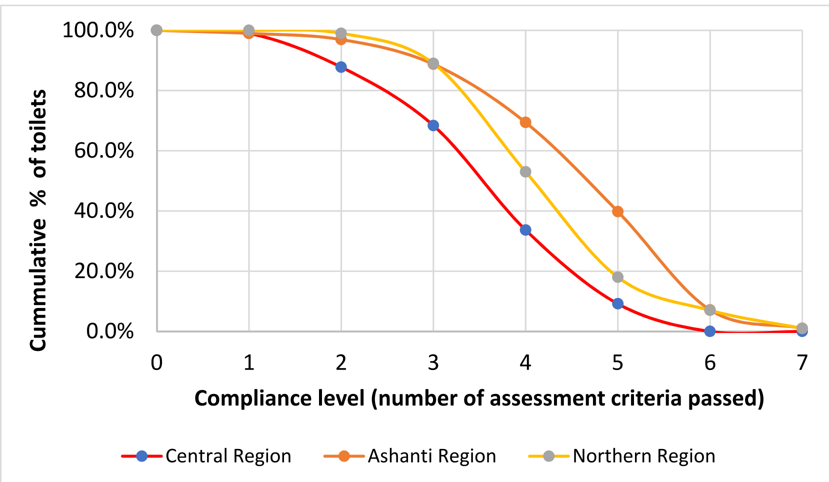

Fig. 5. Number of latrines attaining compliance levels.

Table 6
Compliance statistics.

Parameter	All Regions (N = 296)	Central Region (N = 98)	Ashanti Region (N = 98)	Northern Region (N = 100)	Kruskal Wallis H
Average number criteria passed	3.56	2.98	4.02	3.67	35.87 (p = 0.000)
Median number of criteria passed	4	3	4	4	
Number of latrines passing above median number of criteria	66 (22.3 %)	9 (9 %)	39 (39.8)	18 (18 %)	
Number of latrines passing up to median number of criteria	230 (77.8 %)	89 (91 %)	59 (61.2 %)	82 (82 %)	
Mean rank		111.1	181.7	152.6	

Table 7
Post hoc pairwise comparison.

Pair of Regions	Test statistic (Mann-Whitney U)	Adjusted p-value
Ashanti vs Northern	29.059	0.041
Ashanti vs Central	70.592	0.000
Northern vs Central	41.533	0.001

Compliance levels to the key technical guidelines assessed was quite low, especially in the Central Region. This calls for some efforts by stakeholders to educate communities and artisans on good design and construction practices for odour and fly control in VIP latrine.

4.3. *Factors influencing design choices*

The study sought to understand the major factors that influence latrine owners' design choices for their latrines. This was assessed based on six (6) design choices, namely: size of vent pipe, type of vent (pipe) cap, type of user interface, providing or avoiding a seat cover, providing or avoiding screens in windows, and providing windows in single or multiple sides of the superstructure. The responses from the semi-structured interviews were analysed using content analysis and the key factors classified under some key overarching factors. The responses provided by the latrine owners fell among one of six (6) categories. The latrine designs were found to be (i) decided or advised by the artisan (mason), (ii) based on cost considerations, (iii) demanded by the owner to satisfy some peculiar preference or interest, (iv) following popular local practice, (v) arbitrary, with no specific special reason, and (vi) one of several other miscellaneous reasons such as unintended construction errors, owner inheriting the toilet and not being sure of the rationale behind the choice. Fig. 6 presents the frequencies of the major factors behind the latrine owners' design choices.

It can be seen from Fig. 6 that all the design decisions are primarily influenced by the judgment or advice of the artisans (mostly masons) except those pertaining to the user interface, i.e., use of seat or squat hole with or without a cover. When all design decisions for all the sampled toilets are put together, the factor that was most frequently cited by the latrine owners as being responsible for the way their toilets were built is the decision or advice of the artisans, which accounted for 54 % of the decisions as shown in Fig. 7. This implies that the technical knowledge and understanding of local artisans of the relevant design guidelines is crucial for the construction of functional VIP latrines. This justifies the efforts of various stakeholders in supporting the training of local artisans. The need for training and awareness creation on the right way to build the VIP latrine is further highlighted by the fact that, some decisions (15 %) are taken with no specific or special reason, which suggests that the artisans or latrine owners who take such decisions would be open to advice.

Nevertheless, when it comes to decisions regarding the user interface, latrine owners take charge and insist on their preference. This suggests that promotion of innovations or best practices in the user interface design should go beyond the artisans to target prospective toilet owners.

Perhaps, the most interesting discovery from the feedback of the latrine owners is the fact that the least frequently cited factor which influences the designs of their toilets is the cost. This appears to be inconsistent with the earlier observation that the guidelines that were mostly violated were those that had cost implications while those that were adhered to had no significant cost implications or could even lead to cost saving. However, it could be explained that the decisions or advice of the artisans, which is largely responsible for the designs of the latrines, as well as other factors such as the popular local practices are cost-cutting. This may explain why the decisions or advice of the artisans are seemingly acceptable to the latrine owners. Unfortunately, this study could not delve into the basis of the decisions of the artisans.

5. Implications of the study

5.1. *Implications for practice and industry*

It is necessary to rethink some of the guidelines. First, the insistence on a vent pipe diameter of 150 mm is likely to remain the most ignored technical guideline due to its high cost and limited availability. With the 100 mm diameter PVC pipe proven to be capable of

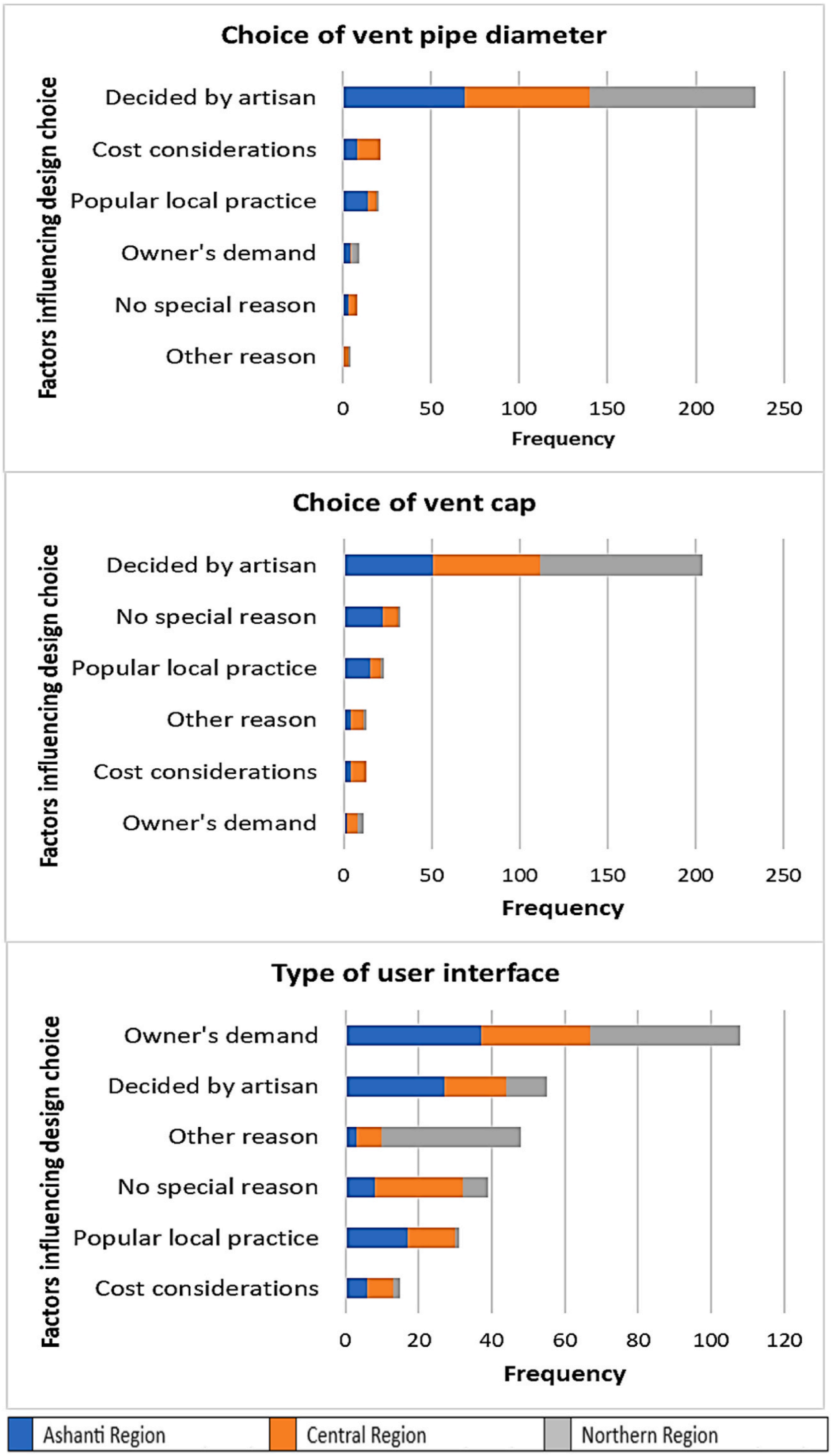

Fig. 6. Factors influencing various design choices.

yielding the recommended ventilation rate in areas where the wind speed reaches an average of 1.5 m/s [38], the threshold wind speed of 3 m/s required by existing guidelines for using the 100 mm pipe should be reviewed downwards. Nevertheless, further investigations on the wind speed threshold for using the 100 mm pipe may be required to support this recommendation.

The proportion of toilets in the Ashanti and Central Regions provided with prefabricated ceramic seats (35 %) indicates increasing

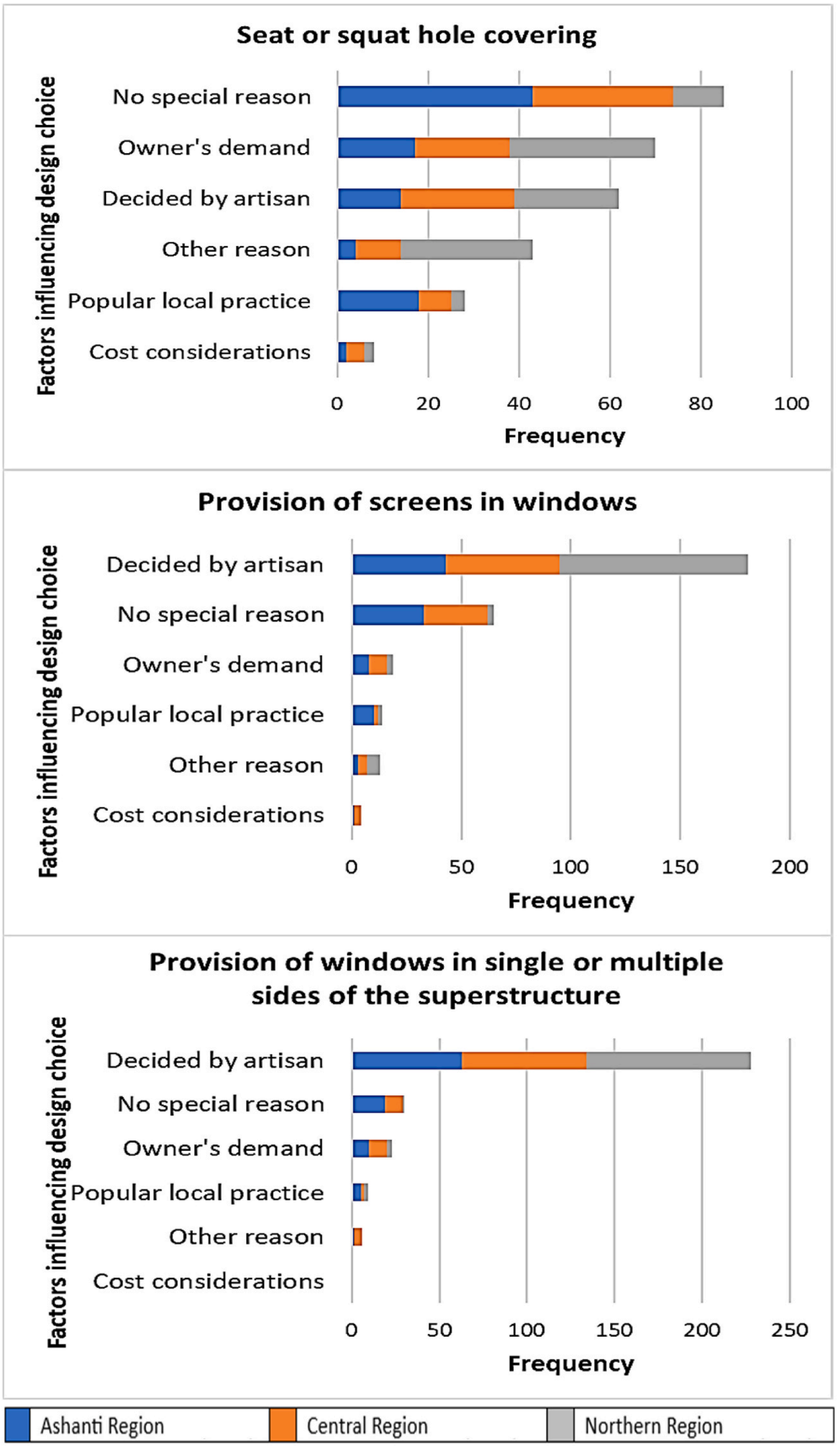

Fig. 6. (*continued*).

emphasis on aesthetics inspired by the water closet (WC) toilet, which is largely seen as the standard or ideal toilet. This has led to the tendency of making the VIP latrine mimic the WC. However, this has to be well balanced with a conscious effort to make industrially fabricated components such as seat covers and vent caps compatible with the VIP latrine design concept. Thus, seat covers to be used in VIP latrines may be partially lined with an insect screen to allow movement of air from the cubicle into the pit. Similarly, vent caps for VIP latrines should be designed to allow unhindered exit of air from the pit into the atmosphere. This calls for field investigations to advise industry and market research to assess the economic viability of such innovations.

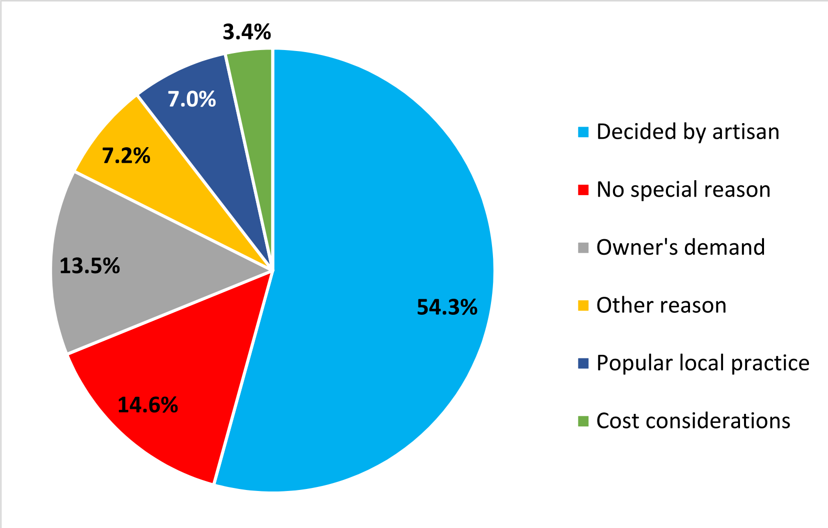

Fig. 7. Factors influencing all design and construction decisions.

Since cost was the factor that was least frequently cited by latrine owners as influencing the design of their toilets, practitioners, particularly the artisans, should not overly emphasise cost-cutting at the expense of a fairly reasonable level of service or convenience. This is supported by the fact that some of the latrine owners could have afforded the WC toilet but were compelled to resort to the VIP latrine due to some technical constraints. In the survey with the latrine owners, as high as 31 % of them indicated that they would have constructed the WC but were prevented by site restrictions, notably, lack of access routes to their houses by cesspit emptying trucks and irregular water supply which makes the operation of the WC cumbersome. Thus, practitioners should not always consider the VIP latrine as a 'poor man's choice' but aim for a beautiful toilet.

5.2. Implications for policy and institutional support

Considering the high influence of the decisions and advice of local artisans on the design and construction of the toilets, the incorporation of artisan training in some project interventions is laudable. However, project-based artisan training is mostly inadequate and unsustainable. Informally trained masons are mostly responsible for the grassroot construction of houses and toilets for most low-income households in Ghana. They usually receive training and supervision from Building Construction graduates from second-cycle Technical and Vocational Education and Training (TVET) institutions who are popularly referred to locally as 'foremen'. This suggests that equipping the Building Construction graduates with the fundamental concepts and key technical guidelines for construction of various toilet technologies would trickle down to the local artisans and influence the toilet construction skills at the grassroots of the Ghanaian construction industry. Unfortunately, Obeng et al. [19] found no specific contents on the fundamental design and construction principles of non-sewered sanitation systems in the curriculum of Building Construction and Plumbing programmes of second-cycle TVET institutions in Ghana.

This study reveals that an appreciable proportion (35 %) of latrine design decisions were based on no specific reason (14.6 %), demanded by the owner (13.5 %) or informed by popular local practice (7 %). This provides some basis for setting up information desks to offer prospective owners with the right information on the operational requirements of toilet technologies and the basic design guidelines that would deliver optimum performance or level of service. Proper information would guide latrine owners in reviewing and reconsidering the potential effect of their own preferences on the performance of their toilets as well as avoid arbitrary decisions or popular local practices that are counter-productive to the performance of their toilets. Such information services may be integrated into the operations of the Environmental Health and Sanitation Departments in the various Metropolitan, Municipal and District Assembly (MMDAs). The information desk could provide continuous training of informally trained artisans who are responsible for grassroot toilet construction in Ghana.

5.3. Implications for further research

As the most influential factor on the design and construction of VIP latrines in Ghana, there is the need to interrogate the basis of the decisions or design choices made by the local artisans. Research is required to understand what informs how the artisans build the VIP latrines. This would help to identify misconceptions that need to be addressed in the design of artisan training programmes. Furthermore, research is needed to properly understand the constraints artisans experience or anticipate in the adoption of the various design guidelines and how such guidelines may be adapted to local realities and peculiarities.

Further research is required to generate additional data to assess the potential of the 100 mm diameter vent pipe at lower wind speeds as suggested by Obeng et al. [38]. This is needed to inform a review of the threshold wind speed required to guarantee the delivery of adequate ventilation by the 100 mm diameter vent pipe. Finally, the increasing popularity of ceramic seats with covers and some types of vent caps, which are mimicked from the WC toilet, requires further research. Such research could aim at establishing the impact of the use of such accessories on the odour and fly control function of the VIP latrine and the kind of design innovations that would make such accessories compatible with or less disruptive of the technology's mode of operation. .

6. Conclusions

This study conducted a technical evaluation of private VIP latrines in the Ashanti, Central and Northern Regions of Ghana to assess their compliance to the conventional design guidelines for odour and fly control and to understand the factors that influenced the design and construction choices of latrine owners. Generally, the level of compliance shows a mixed outcome among the seven design and construction criteria that were assessed, with a latrine satisfying, on average, about half (3.6) of the seven technical guidelines that were assessed. The technical guidelines that were mostly complied with were the provision of a window or other openings in the superstructure (86 %), followed by the avoidance of an insect screen in the window(s) or opening(s) (77 %). The use of 150 mm diameter vent pipe was the least satisfied guideline (5 %), ostensibly due to the high cost and unavailability of that size of PVC pipe. Around 93 % of the latrines that use 100 mm diameter PVC pipes have been classified as not meeting the recommended size. The decision or advise of local artisans is the most influential factor in the design of the latrines. Aside these, the designs of the latrines were also influenced by artisans' and owners' tendency to follow existing local practices. In some cases, latrine owners could not associate some design decisions (about 15 % of all decisions) to any specific or special reason. Cost was the least mentioned factor cited by the owners.

7. Definition of technical Words

Bernoulli's principle: Bernoulli's Principle States that as the speed of a moving fluid (liquid or gas) increases, the pressure within the fluid decreases.

Buoyancy ventilation: Buoyancy ventilation results from the density differences between interior and exterior air mass. This variance causes the warm, lighter air to rise above the chilly, denser air and creates an upward airstream.

Dry sanitation: Dry sanitation is defined as the disposal of human waste without the use of water as a carrier.

Head loss: Head loss is the difference in pressure between points in a hydraulic system of piping as a result of friction, change in direction or some other obstacles.

Kinetic energy: Kinetic energy is the energy an object possesses because of its motion.

Onsite sanitation: A sanitation system in which excreta and wastewater are collected, stored and/or treated on the plot where they are generated.

Safely managed sanitation: This refers to sanitation facilities that are not shared with other households and where excreta are disposed of in a manner that prevents transmission of faecal-oral diseases.

Stack effect or Chimney effect: The stack effect or chimney effect is the movement of air into and out of buildings through unsealed openings, chimneys, flue-gas stacks, or other containers, resulting from air buoyancy. Buoyancy occurs due to a difference in indoor-to-outdoor air density resulting from temperature and moisture differences.

Suction effect: This is the act or process of exerting a force upon a solid, liquid, or gaseous body by reason of reduced air pressure over part of its surface.

Data availability statement

Data included in article/supplementary material/referenced in article.

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CRediT authorship contribution statement

Panin Asirifua Obeng: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Emmanuel Amponsah Donkor:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Eric Awere:** Writing – review & editing, Supervision, Project administration, Formal analysis, Conceptualization. **Sampson Oduro-Kwarteng:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Peter Appiah Obeng:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Formal analysis, Conceptualization. **Esi Awuah:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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