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Elimination of Malodors and Management of Human Waste in Pit Latrines Using Indigenous Microorganisms

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Abstract

Simple pit latrines are the most affordable and feasible options for most rural households, because they are inexpensive to construct, operate and maintain and they qualify as improved sanitation technologies when they are properly constructed, and their sanitary status maintained. However, the quality of service of simple pit latrines is frequently limited by the buildup and dispersal of foul odor and presence of nuisance insects, such as houseflies, drain flies and cockroaches. The need to find cheaper, environmentally friendly, and effective methods of enhancing pit latrine hygiene by reducing odors is therefore not only urgent but also apparent. This study thus aimed to evaluate the efficacy of using IMO to reduce buildup and dispersal of malodors in pit latrines. Kisii Ndogo and Bahati villages located in Mau Summit location, Kamara ward, Kuresoi North sub county, Nakuru County in Kenya were selected for this study. Kisii Ndogo is an informal settlement while Bahati is a rural settlement. Field measurement of odor intensity involved taking recordings at 3 different points: 5 meters upwind, inside and five meters downwind from the latrine. Scoring of the odor intensity was based on the Linkert scale. Ambient weather conditions: temperature, UV intensity, wind speed, wind direction, and relative humidity in and around the pit latrines, were measured. Results of the study show that use of IMO significantly reduced the intensity of the smell in the pit latrines from very strong to slight. The nuisance insects were eliminated or significantly reduced to negligible levels. The study thus concluded that IMO can be used effectively to reduce malodors, encourage use of pit latrines and reduce open defecation. The use of IMO can also significantly contribute to reduction in spread of diarrheal diseases through elimination of nuisance insects. Further studies involving measurement of changes in volatile compounds resulting from use of IMO, and effect on sludge levels are recommended.

Subject Areas

Environmental Sciences

Keywords

Indigenous Microorganisms, IMO, Malodor, Human Waste Management

1. Introduction

Access to basic sanitation services remains a significant challenge worldwide. At least one third of the global population consisting of approximately 2.3 billion people, lacked access to basic sanitation services in 2015 at the end of Millennium Development Goals (MDG) period. About 900 million people are reported to practice open defecation, and 856 million people use unimproved facilities such as pit latrines without a slab, hanging latrines and bucket latrines [1]. The aim of Sustainable Development Goal (SDG) goal 6.2 is to achieve adequate and equitable sanitation and hygiene for all and eradicate open defecation globally by 2030 [2]. Commendable progress was made between 2000 and 2015, with a reduction in the number of people who practiced open defecation from about 1.229 billion to about 892 million respectively, however this pace must be accelerated to meet the set targets [1].

In Kenya, an estimated five million people practice open defecation and up to thirteen million people, 29 per cent of the population lack access to basic sanitation. It has been documented that open defecation is very common in streams, rivers and springs, because they allow for after defecation cleaning, but this practice contaminates water sources and propagates waterborne illness [3]. An estimated thirty-two million people, 72 per cent of the Kenyan population live in rural areas without or with limited access to improved sanitation facilities consisting of pit latrines without a concrete floor, hanging latrines and bucket latrines [4].

For most rural households, simple pit latrines are the most affordable and feasible options, because they are inexpensive to construct, operate and maintain [5] [6]. When properly constructed, they qualify as improved sanitation technologies [7]. However, the quality of service of simple pit latrines is frequently limited by the occurrence of foul odour and presence of nuisance insects, such as flies, silver fish, drain flies and cockroaches [7] [8]. The offensive odours have been reported to undermine the use of the simple pit latrine and cause the people to practice open defecation [9]. Surveys conducted in rural Niger and Malawi showed that up to 25 per cent of latrine owners perceived bad smell from human faeces to be a major disadvantage of installing a latrine near the home [10] [11]. Past research in Ghana, confirmed foul smell as a major impediment to household latrine adoption [12].

Furthermore, in areas with poor soil drainage, heavy rainfall and a high-water table, establishment and use of pit latrines is challenging, because they often fill

with water and overflow to residential areas [4] [13] [14]. Additionally, buildup of malodors inside and around the simple pit latrines discourages their construction near houses and usage hence posing a health risk.

To address the issue of open defecation and improve access to proper sanitation facilities, the government of Kenya has increased awareness through extension services through the ministry of public health. There has also been a significant intervention from non-governmental organizations such as the WASH program and construction of improved pit latrines like Double Vault Urine Diverting (DVUD) composting latrines. However, the success rate is slow and scattered. The problem of accumulation of malodors in pit latrines has been persistent and difficult to eradicate. Homemade solutions include adding wood ash, sawdust, radio batteries (dry cells) to the pit latrine, and use of insecticides to get rid of the insects. These methods are however ineffective, and the use of insecticides is unsafe, environmentally hazardous and unsustainable. The need to find cheaper, environmentally friendly, and effective methods of reducing pit latrine odors is therefore not only urgent but also apparent.

Microbial-based biotransformation and bioremediation of contaminated ecosystems has received increasing attention in recent years, in the face of prospection for sustainable ways of remediating polluted environments [15] [16]. Biotransformation and bioremediation methods utilize diverse naturally occurring microorganisms to degrade, accumulate or transform pollutants such as human waste.

IMO has proved to have the ability to suppress malodors of human and animal manure, through either direct or indirect mechanisms [17]. The beneficial microorganisms in IMO transform NH4+-N to NO-N, thereby decreasing the potential for N-volatilization and increasing the potential for nitrogen fixation (through photosynthetic bacteria). The beneficial indigenous microorganisms establish and suppress the growth and activity of the indigenous putrefactive types that cause malodors in the manure and transform proteins and amino acids into NH33-N and NH4+-N; [3]. This is the "anti-oxidation theory" originally proposed by Dr. Teruo Higa, the innovator of EM technology [18]. The use of IMO has also been reported to lower the amount of sludge and therefore prevent filling up of the pit latrines.

The EM technology has been harnessed and applied to reduce buildup of sludge and odors in pit latrines in different counties with significant success such as, China [19], South Africa [20], Ghana [21], and Uganda [22]. However, this innovation has neither been adopted nor utilized efficiently in Kenya. This study thus aimed to evaluate the efficacy of using IMO for deodourisation of pit latrines.

2. Materials and Methods

2.1. Study Design

2.1.1. Study Approach and Sampling Techniques

Purposive convenient sampling method was employed in the study. Purposive

sampling was adopted to target poor villages; Kisii Ndogo is an informal densely populated village with poor drained soils which limit depth of the latrines, when it rains the latrines fill up with water and flood the village with sewage, the situation is made worse by lack of drainage facilities. Kisii Ndogo residents are, post-election violence survivors and resource poor farmers residing on less than 0.0625 Ha of land. Bahati village is composed of resource poor farmers residing on average of 0.107 Ha of land. The 4 and 2 simple pit latrines in Kisii Ndogo and Bahati villages respectively were select based on convenient accessible sampling technique.

2.1.2. Location and Demographics of the Study Area

Kisii Ndogo and Bahati villages were selected for this study. Kisii Ndogo is an informal settlement located along Molo-Mausummit Road in Sarambei sub location, Mausummit location, Kamara ward, Kuresoi North sub county, Nakuru County in Kenya. Bahati village is a rural settlement located in Mau summit sub location, Mau Summit location, Kamara ward, Kuresoi North sub county, Nakuru County in Kenya. According to the Kenya populations' census report 2019, Kisii Ndogo has a total of 88 households and 445 residents while Bahati has 95 households and 380 residents.

2.2. Field Measurement of Odour

2.2.1. Test Standardization and Selection of Field Measurement Panelists - Nasal Chemosensory Performance

Odour screening was conducted using a modified odour Kit, which consisted of a set of 5 handkerchiefs of different colour immersed in different odours. The respondents were asked to identify the smell, and a five-point Linkert scale was administered to assess the intensity of the smell. The odour agents used for olfactory threshold screening were perfume, paraffin/Kerosene, lemon peels, and β-mecarptoethanol. The Odour Inspector study group was made up of selected Baraka Agriculture college employees and Kisii Ndogo and Bahati residents. Two test administrators were used in the study.

All the respondents were tested following the Standard Procedure for Testing Individual Odour Sensitivity. The standardization procedure was used to assess the detection threshold of the respondents. Only the respondents who passed this test by correctly identifying the correct substance for the odor were involved in the study.

The age and gender of the respondents were not considered as factors for inclusion in the study.

2.2.2. Target Pit Latrines and Field Estimation of Odour Intensity

In total, 6 simple pit latrines, located in two villages were assessed: 4 in Kisii Ndogo and 2 in Bahati. The simple pit latrines selected were constructed out of wooden and mud floor and mud or tin/iron sheet walls while the improved latrine consisted of brick walls and concrete slabs. All the latrines were used by members of

one household consisting of between 4 and 9 people. Pit latrines made of mud walls and wooden and mud floors are the commonly used facilities in Kenya and specifically in the study area (rural Molo).

Field measurement of odor intensity involved taking recordings at 3 different points; 5 meters upwind from the pit latrine, inside the pit latrine and five meters downwind from the latrine. The respondents were required to stand at the three points and breathe in for 30 seconds and record the intensity of the smell on a five-point scale (Table 1). The presence of insects such as houseflies, drain flies and cockroaches was also recorded.

The study was carried out before application of the EM and then three months after application.

Table 1. Five-point Linkert scale for field estimation of smell/odor intensity.

Scale	Intensity of smell/odor
1	None
2	Slight
3	Moderate
4	Strong
5	Very strong

2.3. General Characteristics of the Pit Latrines

The general characteristics of the pit latrines included the latrine state and odour strength, latrine condition, clean or dirty, smelly or not, and presence of insects or not, were noted through observation, based on a scale used in an earlier study by [23].

2.4. Weather Conditions

Ambient conditions of temperature, UV intensity, wind speed, and relative humidity in and around the pit latrines were measured. Weather data was collected using Weather[R] phone app available at http://www.weather.com/. This set of data was collected to help appreciate and explain the results of the ambient odor measurements.

2.5. Statistical Analysis

Data from the questionnaires were entered into the Statistical Package for the Social Sciences (SPSS) software program (Version 20.0) for further analysis [24]. Data were presented as means ± S.E. and were analyzed using two-way analysis of variance (ANOVA) using significant level of ($P < 0.05$). Specific group differences were determined using Duncan's multiple range test as described by [27].

The characteristics of the ambient and environmental conditions of the pit latrines investigated were presented using descriptive statistics and presented in bar graphs. Significant variations in the environmental conditions around and within

the pit latrine, and with respect to terrain and pit latrine type, and treatment were assessed using analysis of variance (ANOVA).

3. Results

3.1. General Characteristics of Pit Latrines

All the pit latrines used in the study were simple pit latrines characterized by lack of a concrete slab and brick or stone superstructure. Before treatment with IMO, 84% exhibited a strong smell, 62% had few flies, 72% were dirty and had odour strength levels that ranged from 1 to 5, indicating inadequate performance.

Odour dispersal was also high with most respondents (85%) recording a bad smell 5 meters upwind from the pit latrine, 94%, 5 meters downwind and 100% inside the latrines (Figure 1).

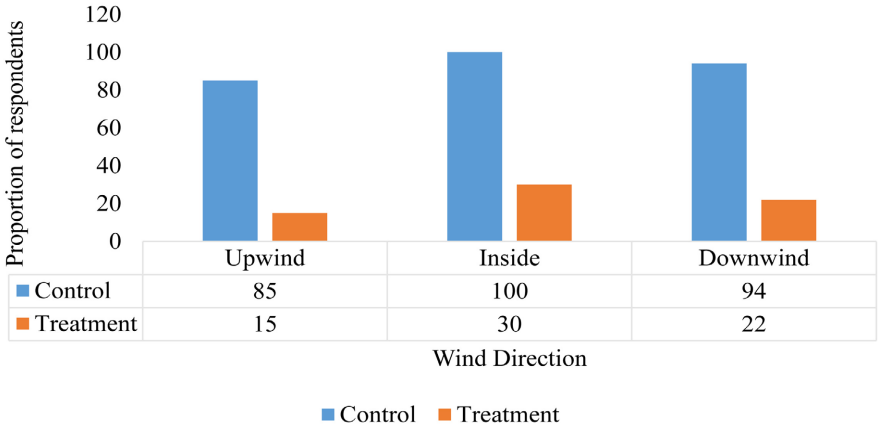

Figure 1. Perception of odor from the pit latrines by the respondents at different estimation points.

3.2. Ambient Conditions Around and Inside the Pit Latrine Structures

The climatic conditions around the pit latrines of temperature ranged from 12.3˚C to 23.3˚C, relative humidity from 45% to 78.6%, UV index from 4 to 16 and wind speeds of between 7.0 and 15 kph. The recorded values are typical of the average tropical highland climate (14.8˚C) in Molo. The low ambient wind speeds in Kisii Ndogo compared to Bahati could be attributed to obstruction from the surrounding buildings as pit latrines in Kisii Ndogo are placed close to the houses due to crowding and by the fact that Bahati is on a higher ground above sea level (2350 m) compared to Kisii Ndogo (1900 m).

The temperatures within the pit latrines ranged between 14.5˚C to 23.3˚C with an average of 19˚C while the relative humidity recorded was between 68.8% and 81.4%.

3.3. Nuisance Insects

Three types of nuisance insects were assessed (houseflies, drain flies, and

cockroaches) because they are the most common types of insects in pit latrines, and they pose the highest risk of disease transmission. In the control experiment, the number of houseflies varied between 15 and more than 25 and an average of 20 flies. The number of drain flies varied between 20 and more than 25 and an average of 22 flies per pit latrine. The number of cockroaches varied between 10 and 15 with an average of 10 cockroaches per pit latrine.

Three months after application of IMO, it was observed that the number of nuisance insects reduced. The number of houseflies were below 5 in two pit latrines and absent in the other two while the number of drain flies ranged from below 5 to 10 with an average of 8 flies per latrine. Cockroaches were absent in all the pit latrines examined (Figure 2).

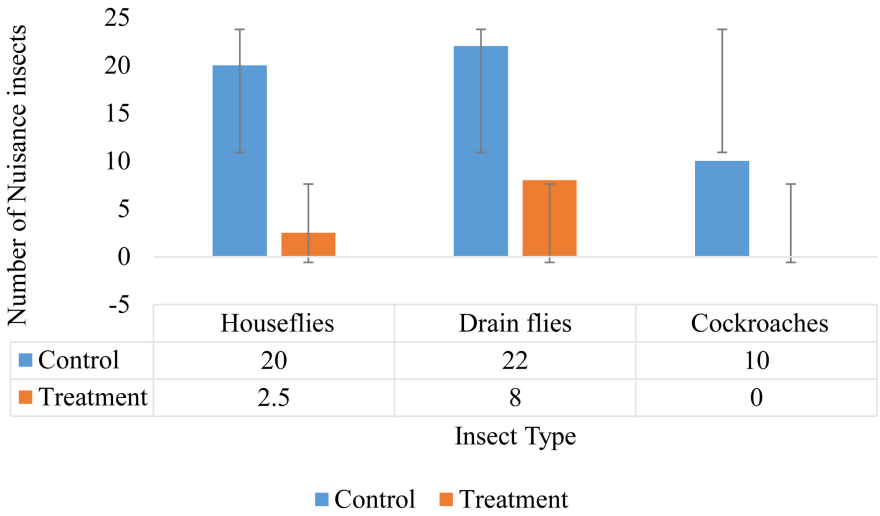

Figure 2. Average numbers of nuisance insects in control and treatment experiments.

3.4. Odor Intensity

A total of 182 respondents were used in the study to evaluate the intensity of malodors from pit latrines at 3 points: 5 meters upstream, inside the pit latrine and 5 meters downstream. A five-point scale was used to assess the intensity of the smell (Table 1).

When odor dispersion was assessed, it was determined that the intensity of smell was significantly influenced by distance from inside of the pit latrine and direction of wind (upwind or downwind) for both the control and the treated latrines.

Most of the respondents reported that the intensity of the smell from both the untreated and the treated pit latrines was strongest inside the pit latrines, followed by 5 meters downstream and lowest 5 meters upstream.

There was no significant difference in odor intensity across the evaluated latrines but L001 had comparatively overall lower odour intensity while M002 had the highest. This may be explained by the fact that L001 pit latrine had a well-constructed wooden and earthen floor and had a tin roof that prevented rainwater

from getting into the pit. The floor of M002 pit was made up of wood logs and earth leaving gaps, additionally, the roof was porous allowing rainwater to get in limiting microbial decomposition of the waste.

Significant variation in malodor intensity was observed between the treated and untreated pit latrines. For untreated pit latrines, malodor intensity varied between 2.81 (5 m upwind) and 4.45 (inside) while for treated latrines, the odor intensity varied between 1.25 (5 m upwind) and 2.43 (inside) respectively. Overall, the intensity of malodors was eliminated around and inside the treated pit latrines (Table 2).

Table 2. M ± SE odor intensity upstream, inside and downstream of the pit latrines, *significant at (P < 0.05).

		Control			Treatment			
Variable	Latrine Code	M ± SE	Min	Max	M ± SE	Min	Max	Pr (T > t)
Odour upwind	L001	2.813 ± 1.051**	2	4	1.25 ± 0.678**	1	2	0.0063
	M002	3.231 ± 0.636**	3	5	1.456 ± 0.462**	1	3	
	C003	2.843 ± 1.089**	2	4	1.234 ± 1.467**	1	3	
	F004	3.274 ± 1.042**	2	4	1.378 ± 0.769**	1	2	
Odour inside	L001	4.397 ± 0.564**	2	5	2.046 ± 0.076**	1	3	0.024
	M002	4.541 ± 0.049**	3	5	2.430 ± 0.065**	1	4	
	C003	4.673 ± 1.0743**	4	5	2.253 ± 0.321**	1	3	
	F004	4.463 ± 0.0875**	3	5	2.306 ± 1.003**	1	4	
Odour downwind	L001	3.583 ± 1.121*	2	4	1.245 ± 0.412*	1	3	0.0018
	M002	3.847 ± 0.982*	3	5	1.461 ± 0.039*	1	4	
	C003	3.654 ± 0.923*	3	5	1.307 ± 0.872*	1	3	
	F004	3.765 ± 0.234*	2	5	1.200 ± 0.094*	1	3	

4. Discussion

The practicability of eliminating malodors and management of human waste in pit latrines using effective microorganisms was assessed in the study. General assessment of the pit latrines for smell, general cleanliness and nuisance insects showed that all the latrines did not meet the threshold for hygienically safe sanitation facilities. Past studies have recorded that filled up, smelling, dirty latrines that are infested with nuisance insects result in limited use and are a public health hazard because they encourage open defecation [25]-[27]. The findings reported are consistent with previous studies in urban slums [23] [26].

The climatic conditions around the pit latrines of temperature range from 12.3˚C to 23.3˚C, relative humidity from 45% to 78.6%, UV index from 4 to 16 and wind speeds of between 7.0 and 15 kph are typical of average tropical highland climate (14.8˚C) in Molo. The low ambient wind speeds in Kisii Ndogo compared to Bahati could be attributed to obstruction from the surrounding buildings as pit latrines in Kisii Ndogo are placed close to the houses due to crowding and by the

fact that Bahati is on a higher ground above sea level (2350 m) compared to Kisii Ndogo (1900 m).

The high odor intensity recorded across the studied pit latrines is consistent with past studies that have associated simple pit latrines with bad odours, mainly due to improper design and construction [5] [7] [9]. The malodors in the latrines have been reported to be caused by buildup of volatile compounds mainly hydrogen sulphide and ammonia in the simple pit latrines. This has been confirmed in different settings such as Ghana, and Uganda [28].

Indigenous microorganisms have been applied for reduction of smell and bioremediation of polluted environments. This has been attributed to the powerful sterilizing properties of lactic acid bacteria that are abundant in IMO [23]. The lactic acid bacteria suppress putrefying micro-organisms and enhance breakdown of human waste and other organic substances. Indigenous butyric acid-degrading bacteria break down butyric acid, a short-chain fatty acid commonly associated with foul odors in environments like pit latrines, anaerobic digesters, and wastewater treatment plants [20] [21]. Treatment of pit latrines with IMO also provides an inoculum of aerobic microbes that enhance aeration and biofilm formation which results in aerobic decomposition that is less odorous than anaerobic decomposition [19] [20]. As such IMO significantly reduces production, build up and accumulation of foul odors in the pit latrines. This explains the significant reduction in malodors after treatment with the IMO product.

5. Conclusions

Residents of Kisii Ndogo and Bahati use simple pit latrines that are characterized by poor construction and unsanitary conditions and are prone to intense malodors and nuisance insects. The prevailing conditions make the pit latrines unsafe, discourage usage and pose a threat of diarrheal diseases.

Treatment of the pit latrines with IMO significantly reduced the intensity of malodors, and nuisance insects and therefore enhanced usage and reduced threat of disease.

The study thus concluded that IMO can be used effectively to reduce malodors, encourage use of pit latrines and reduce open defecation. The use of IMO can also significantly contribute to reduction in spread of diarrheal diseases through elimination of nuisance diseases.

Recommendations

Diversity studies characterize the populations of effective microorganisms in the IMO and mode of action of those involved in bioremediation and deodourisation. Further studies involving measurement of changes in volatile compounds resulting from use of IMO, and effect on sludge levels are also recommended.

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Conflicts of Interest

The authors declare no conflicts of interest.

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