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Odour assessment of school toilets in Gauteng, South Africa – before and after bioremediation

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Abstract

Sanitation in school toilets is often considered peripheral to the academic project, yet has a significant impact on productivity and the school experience. A micro-study, pilot project to quantify the perception of odours in toilets at two schools in Gauteng Province, South Africa, using olfactory tests, reveals the presence of select odour-forming compounds. The compounds of butyric acid, indole, p-cresol and dimethyl trisulfide, reconstituted faecal odour and stale urine odour were presented to staff at the two schools in the form of 'Sniffin' Sticks'. All the odours were identified in the toilets at levels of unbearable in School A which has a septic tank system, and tolerable in School B which uses a flush system, during the pre-test. A post-test was conducted after an effective bioremediation treatment product was applied. We found that 100% of the participants noted a marked improvement in the odours in the toilets after the treatments were combined with efficient cleaning regimes.

Keywords: Olfactory perception, bioremediation, school toilet odours, flush toilets, pit latrines.

Introduction

On March 11 2020, the World Health Organisation (WHO) declared the novel coronavirus (COVID-19) a global pandemic (WHO, 2020). The recommended non-medical interventions to reduce the spread of the virus included sanitising and thorough washing of hands and this, in turn, highlighted the need for access to water and adequate sanitation across the globe. However, the problem of inadequate sanitation is experienced by more than 2.5 billion people globally (Chappuis *et al.*, 2015; WHO and UNICEF, 2017) often owing to a lack of technologies, infrastructure and access to adequate resources, such as water and appropriate chemicals to treat and transport human excreta away from its source (Matz *et al*., 2005, Kaczala, 2006; Prüss-Ustün *et al*., 2019). It is estimated that 25% of the world's population do not have access to soap and water on-site and that only 26% of potential faecal contacts are followed by handwashing with soap (Matz *et al*., 2005; Wolf *et al*., 2018a; Prüss-Ustün *et al*., 2019). Furthermore, only 45% of the global population live in communities where the basic sanitation service coverage is above 75% (Wolf *et al*., 2018b). The UN General Assembly has recognised basic sanitation as a human right (UN General Assembly, 2015), but poor quality toilet environments create a fear of using the facilities; which in turn leads to associated physical and mental health problems (Chung *et al*., 2019).

The school environment is an important sector to explore the conditions of sanitation. Adequate sanitation is an essential service for the well-being of pupils and staff at schools, but it is often considered peripheral to the academic process. However, inadequate water and sanitation facilities have been reported as a major hindrance to productivity in schools (Jasper *et al*., 2015). A key component of adequate sanitation is the management of odours emanating from the toilets in schools. Odours are perceived differently by different individuals, based on their gender, background, smoking status, age and cultural background, and children perceive odours as more offensive than adults (Larsson *et al*., 2000; Talaiekhozani *et al*., 2016). Current and past studies have looked to reducing odours associated with wastewater treatment plants, landfills, and composting, but little research has been done on school sanitation (Chung *et al*., 2019). Here, we present a pilot, micro-study on the state of sanitation at two schools (referred to as School A and School B) in Gauteng Province, South Africa: one with a pit latrine and the other a flush system. We aimed to quantify the perception of the odours of the toilets, through an olfactory test, and determine the perception of the staff at the schools, of the odours before and after bioremediation treatment processes. While we do not endorse the treatment products, we used it as a remediation mechanism to test whether the odours could be mitigated in a non-harmful manner. The Minister of Education stated that there are 4 000 pit latrines in schools in South Africa, and therefore, based on the success of this pilot study, we plan to conduct these odour perception tests at various schools around the country.

Toilet systems and odour-forming compounds and bio-treatments

Waste treatment can be broadly categorised into on-site waste treatment and off-site waste treatment. On-site treatment mechanisms include pit latrines (often found in underdeveloped regions with access to little water or a functioning sewer network), or septic tank systems (in regions where there is access to water but not to a functioning sewer network) (Nakagiri *et al*., 2016). Off-site waste treatment includes flush toilets connected to a functioning sewer network (Jonsson and Vinneras, 2007). The problems experienced in both on-site and off-site waste treatment systems exist from both the presence of waste as well as the odours produced by untreated waste matter (Zhou et al., 2016).

On-site waste treatment systems such as pit latrines and septic tanks are prone to

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producing offensive odours (Nakagiri *et al*., 2016). A very simple method of correct and adequate ventilation of the pit latrine allows for the reduction or dispersal of odours and reduces other problems associated with pit latrines (Morgan, 1977; Liu *et al*., 2017; Chung *et al*., 2019). Other odour prevention techniques that have been used in water-scarce regions using dry toilet systems include the addition of lime, soil or ash into the pits. This absorbs excess moisture from urine that has not completely drained through and distracts flies from the faeces (Kaczala, 2006). A septic tank system makes use of the modern flush toilet to remove waste from the toilet environment but the waste then enters a tank instead of a sewer network (Brikké *et al*., 2003; Obeng *et al*., 2019). This waste treatment solution is used in regions that have no connection to a sewer network. A septic tank consists of a watertight chamber where human excreta is flushed and solids are separated from liquid waste (Still *et al*., 2015). Liquid effluent then moves into an additional tank called a soakaway (Brikké *et al*., 2003). Solid waste sinks to the bottom of the first tank where they are broken down by bacteria to form a sludge, which needs to be manually removed over 1-5 years, depending on the size of the tank and the number of individuals that the septic tank serves. Septic tanks also require a ventilation system to remove any odorous gases or other flammable gases such as methane (which are produced during the bacterial decomposition of the waste materials) (Chung *et al*., 2019). Proper functioning septic tanks should produce little odour except for the first few weeks after installation. These odours are produced while the system attempts to maintain an equilibrium between the bacteria and waste materials (Brikké *et al*., 2003). New systems lack the correct bacteria, and these may take a few weeks to colonise the new system.

Off-site waste treatment systems such as flush toilets are found in many modern, developed and developing regions that have access to flowing water and are connected to a sewer network. The functioning of the flush toilet has allowed for the great reduction of odours for two key reasons. The first is that the excrement is flushed away and the second is that the toilet is designed with a u-bend stench trap (Jonsson and Vinneras, 2007), or sometimes referred to as a p-trap, that allows odorous compounds to remain in the sewer network. As the bend in the p-trap fills with water after being flushed, the gases in the pipes leading to the sewer network are trapped. If the water level in the p-trap is too low, then gases can flow from the sewer network, over the top of the water and into the toilet system. Water is flushed from a cistern at the top of the toilet into the toilet bowl, allowing for the waste material to be transported through the p-trap and into the sewer network. P-traps minimise the contact between degraded or stale urine and the air in restrooms (Jonsson and Vinneras, 2007).

Toilet related odours may be derived from a vast array of chemical reactions between various VOCs, sulphur and nitrogen compounds, produced through the anaerobic decomposition of organic matter located within human faeces (Lewkowska *et al*., 2016; Talaiekhozani *et al*., 2016; Brancher *et al*., 2017). The olfactory perception of these compounds is determined by the interaction of these chemical compounds within the nasal passage and the environmental conditions in which these are experienced

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(Bliss *et al*., 1996; Brancher *et al*., 2017). Certain odour emission sites may release several hundred gas compounds, but only a small fraction are responsible for the production of odours (Ranau *et al*., 2005). Specifically, hydrogen sulphide (Talaiekhozani *et al*., 2016), mercaptans, nitrogen compounds (ammonium), organic acids, aldehydes, ketones and other hydrocarbons (Barbusinski *et al*., 2017 and Brancher *et al*., 2017).

Prior studies have shown that urine upon release does not produce harmful odours, as 75-90% of the nitrogen is in the form of urea and only 7% in the form of ammonia (Kaczala, 2006; Jonsson and Vinneras, 2007). However, the urea is rapidly degraded upon contact with bacterial enzymes which transforms the urea into ammonia. As ammonia evaporates it produces an odour that can increase in intensity with the reaction with other malodourous components (Andreev *et al*., 2017). As the nature and character of odours changes over time as urine and faeces become stale, their composition changes with changes in decomposition rates (Chappuis *et al*., 2016). Treatment methods for offensive odours can be broadly categorised into chemical, physical and biological treatment methods (Alfonsín *et al*., 2015; Barbusinski *et al*., 2017). There are many benefits to using biological treatment methods as they have a lower impact on the environment. They make use of natural biological, rather than chemical or physical, processes to break down compounds into their constituent parts that do not have long term and severe impacts on the environment (Barbusinski *et al*., 2017).

Biological treatment methods can be summarised into three main types. The first is biofiltration where odorous gas is passed through a bed material into a biofilm consisting of microbes that oxidise and break down the unpleasant odour causing compounds). The second is bio trickling, similar to biofiltration, but with the addition of an aqueous solution that is trickled over the biofilm, providing it with the nutrient required to stimulate microbial growth within the biofilm (Talaiekhozani *et al*., 2016). The third is bio-scrubbing, which is a separation of odours in the liquid phase within an absorber unit. This is then followed by biological treatment in a liquid phase bioreactor which allows for the efficient cleaning of gases with highly soluble components. (Alfonsín *et al*., 2015; Barbusinski *et al*., 2017). These techniques are developed for large scale odour treatment at wastewater treatment plants (WWTP) (Alfonsín *et al*., 2015). Microbial action has become a very popular topic in the cleaning and sanitation market in recent years (Arvanitakis *et al*., 2018). This is due to the basic physiology of microbes and specific strains of bacteria (Arvanitakis *et al*., 2018; Spök *et al*., 2018). These products rely on the ability of the microbes to break down, through enzymatic processes, any waste products that are associated with food waste (Spök *et al*., 2018). These wastes include grease, fats, food particulates that remain after cooking and the wastes produced once this food has passed through digestive systems (Spök *et al*., 2018). This is specifically useful in the break down many of the organic compounds responsible for producing toilet-related odours.

Reconstitutions of toilet odours with the isolation of key compounds are very effective in quantifying sensory perceptions of toilet-related odours (Lin *et al*., 2013; Chappuis *et al*., 2016). Chappuis *et al*., (2016) identified key compounds to imitate pit latrine odours, which were: butyric acid,

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2-methylbutyric acid, 3-methylbutyric acid, phenylacetic acid, p-cresol dimethyl trisulphide, indole and skatole. To mimic odours produced from stale urine, trimethylamine, indole, p-cresol, dimethyl disulphide, 2-methoxy-4-vinylphenol, p-cresol and dimethyl trisulfide were used. Lastly to reconstruct stale toilet faeces, butyric acid, indole, dimethyl trisulphide and p-cresol was used. These compounds were placed into master perfumers to mimic the smell and to allow a participant to only smell the given compound (without having the sample become contaminated by the surrounding air) (Chappuis *et al*., 2016). These master perfumers can take the form of a 'Sniffin' Stick' (Kobal *et al*., 1996; Hummel *et al*., 1997; Chappuis *et al*., 2015; Sorokowska *et al*., 2015) which can be used to determine the nasal chemosensory ability of the human nose (Hummel *et al*., 1997; Chappuis *et al*., 2015; Sorokowska *et al*., 2015). These perfumers have been used extensively throughout olfactory tests, globally since their origin in 1997. These felt-tipped 'Sniffin' Sticks', containing odorous compounds are developed to test three levels of the olfactory system (Sorokowska *et al*., 2015). Firstly, they are used to determine the threshold limits of participants using them. Secondly, they can be used to determine the overall offensiveness of certain compounds. Lastly, they can be used in the identification of odours (Sorokowska *et al*., 2015).

The Research Sites: School A and School B

Research was conducted at two schools in Gauteng Province, South Africa. The schools were selected based on their willingness to participate in the study (requests were sent out to several schools). One school (School A) was selected because it had a septic tank system and the other (School B), was selected because it had a flush toilet system. School A is in a peri-urban environment north of Pretoria, which had recently been integrated into Gauteng from North West Province and is ranked as a Quintile 1[1] school. School B is in an urban metropolitan area, east of Johannesburg has a well-established infrastructure and is ranked as a Quintile 5 school.

School A was a secondary school and had a pupil enrolment of 1180 learners and 42 staff members. The normal ratio of toilets available to the learners is 1:49 if all toilets are functional. However, during the study period, an entire ablution block consisting of four toilets was out of bounds due to maintenance issues, thus the ratio was 1:69 instead. Of the 42 staff members, four were responsible for the cleaning and maintenance of all the toilets. The sanitation system at School A was unique in that it made use of regular toilets connected to a septic tank system without a connection to water to flush the toilets. Instead, a bucket of water containing bleach and pine gel was used at the end of every day to flush contents into the septic tank. Toilets were blocked and as a

[1] Government subsidies are allocated to schools based on the Quintile System which ranks schools according to their socio-economic profiles. The ranking starts with Quintile 1 schools being the poorest up to Quintile 5 schools being the wealthiest (Bell & McKay, 2011; https://www.education.gov.za/Programmes/EMIS/EMISDownloads.aspx).

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result, the toilets odours were noticeable. Learners had free use of the toilet when needed, but cleaners were not always available to monitor the cleanliness of the toilets throughout the day. There are no water pipes connected to the toilets so they cannot be flushed. Some of the toilet outlets were broken and when flushing occurred at the end of each day, most of the waste in the toilet bowl would run onto the restroom floor, contaminating the floor, and allowing bacteria to colonise in hard to reach places. We noted that cleaning of the toilet floors did not happen regularly. Stains, excrement patches and waste were in the same position as the first time we visited (Figure 1).

Figure 1. Conditions of the toilets for students at School A on the first site visit.

A second visit occurred two weeks later. The floors had not been cleaned during this period. Toilets were overflowing with excrement, general waste (chip packets, cigarette butts, bandages, plasters and other forms of plastic waste) as well as containing used sanitary pads and wrappers. Toilet conditions were badly deteriorated and barely usable with broken outlet pipes leading to the leaking of liquid excrement onto the floors and into the grout. We were told that these toilets could not flush as they

Figure 2. Conditions of the toilets at School B were acceptable as these were cleaned often and had access to water for the flushing mechanism to work.

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were blocked but that the toilets were cleaned twice daily. Upon the third return, the toilet environment had seen some improvement but there was no significant change to the overall cleanliness of some of the floors. However, toilet blockages had been resolved. It was then decided that the floors would be cleaned by the research team, and the staff were shown exactly how to clean the floors and toilets using the treatment products. The conditions at School B were in stark contrast to that of School A. School B was a primary school, located in an urban area and made use of flush toilets connected to a sewer system. There were 569 students enrolled at the school and the ratio of pupils to toilets was 1:38. The cleaning regime comprised cleaning between three to five times daily. Children were not given access to toilets during class time, except for emergencies. Cleaners were also constantly in the vicinity of the toilets to ensure that the conditions were not allowed to deteriorate. The cleaning staff at School B consists of two cleaners, one for the girl's toilet and one for the boy's toilet. Toilet aeration and deodorisation were maximised through adequate ventilation together with an industrial deodoriser. The conditions of the toilets were tolerable (Figure 2).

Methodology

An olfactory pre-test was performed by 27 staff members from the two schools before the toilets were treated with a bioremediation product. The treatment was then followed by an olfactory post-test, conducted two weeks later. The olfactory test was adapted from Chappuis *et al*. (2016), which made use of 'Sniffin' Sticks' containing the key odour causing compounds for stale urine and faeces. Each 'Sniffin' Sticks' perfumer (Figure 3) contained one of the compounds responsible for the most common odours found in toilets, namely: butyric acid, indole, p-cresol and dimethyl trisulfide (Chappuis *et al*., 2015, Chappuis *et al*., 2018). In addition, one 'Sniffin' Stick' contained a mixture of chemicals to mimic faecal odour and another mixture for mimicking stale urine odours. Two additional mason jars were also provided, one of which contained no smell at all (the control jar) and the second jar contained a pleasant smelling, easily identifiable lemon essential oil. The 'Sniffin' Sticks' were generously made available for this study by Christian Starkenmann (Firmenich, Switzerland). The bioremediation treatment[2] for the toilets was provided by Kyle Odgers (Kleen Health, South Africa). The treatment consists of a nontoxic bacteria that digests faecal matter; a universal deodorant spray that breaks down ammonia and any bacteria that converts urea to ammonia; and a solution designed to reduce solid fat that blocks the pipes, to liquid, which can then be flushed away. All experimental procedures were explained to the participants and they provided written, informed consent to participate in the study. The conditions of the toilets were recorded both before and after the olfactory tests and treatments. This included noting general toilet conditions, cleanliness, personal

[2] For detailed information on the bioremediation treatment see www.kleenup.kleenhealth.co.za

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perceptions of the odours, as well as general atmospheric conditions (wind speed and temperature). Participants were asked to enter the toilet environment and rate the smell on a Likert scale ranging from 0 to 5 with 0 = no smell and 5 = very strong, an unbearable smell detected. The participants were then asked to smell and rate the 'Sniffin' Sticks' and jar odours on the same scale from 0 to 5. Participants were shown how to use the wafting method for smelling the compounds. While none of the compounds was in concentrations that could be deemed harmful, the odour in some was offensive, hence the use of a wafting technique. The ratings determined which of the two (the toilets or the perfumers) the participants found least /most offensive. Conditions when smelling the 'Sniffin' Sticks' were kept as uniform as possible, with attempts to conduct the tests at the same air temperature, humidity levels and wind speed levels. The olfactory tests with the 'Sniffin' Sticks' were also conducted out of range of the toilets, to reduce the possibility of the toilet odour interfering with the smell test. Once the olfactory tests were completed, the bioremediation products were applied to the toilet environments and given time to work. This was repeated at each school and, to maintain uniformity throughout data collection procedures, the same concentrations of odorous compounds were used in the 'Sniffin' Sticks', before and after the application of bioremediation products. The amount of the faecal digesting bacteria required for each treatment was dependent on the conditions of the toilet environments. Firstly, each toilet and urinal received 50 ml of the treatment solution.

Secondly, a universal deodorant spray was applied to all surfaces in and around the toilet environments to break down the ammonia before the third solution designed to reduce solid fat to liquid was applied. 25 ml of this solution was added to every toilet, urinal and every functioning basin. This last treatment was also repeated in the school's kitchen. Upon returning to School A after the first treatment, it was assessed that additional treatment of a higher concentration would be required to rectify issues of incorrect maintenance from cleaning staff during the working period of the bioremediation technique. As a result of this additional

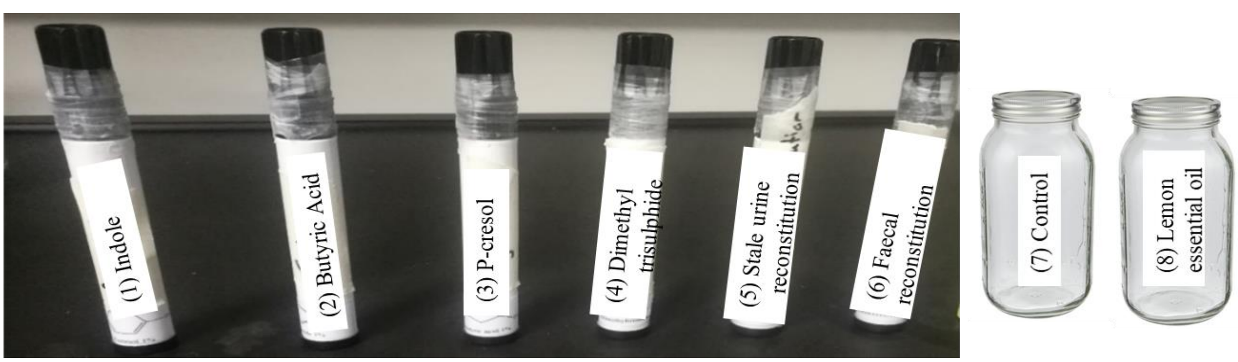

Figure 3. The 'Sniffin' Sticks' numbered 1-6, with each of their constituent compounds and the two mason jars containing air and lemon essential oil, numbered 7 and 8.

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treatment, the second sampling session at School A had to be delayed.

Sampling occurred over two sessions, separated by a period that allowed the treatment application to work. The effectiveness of the bioremediation products on the removal of odours was assessed using a structured questionnaire, which comprised close-ended questions, asking some basic demographic data as well as the ratings of the toilet environment odour before and after the treatment. The overall sample size was different before and after treatment, but the members that participated in the post-treatment sampling had already taken part in the pre-treatment sampling. The only difference was that some participants from the pre-treatment sampling did not take part in the post-treatment sampling. For both schools, none of the participants in the post-treatment sampling was new to the sampling technique. There was a deficit of three participants in the posttreatment sampling for School A.

The air temperature at both schools during the first sampling session was 24°C at the first sampling session and 26°C on the day of the second sampling session. On the previous day (both pretreatment and post-treatment), School A experienced high wind speeds which led to large amounts of dust being placed into the air. On the first day of sampling in the pre-treatment sampling session, there was a strong smell of burning food and other sources of unidentifiable odours in the air at School A. In addition, toilet odours were high enough to force sampling to be done at least 20 m away from the toilets to minimise the effect of the toilet odour on the way the 'Sniffin' Sticks' were perceived. In the post-treatment sampling session, the odour had been reduced to the point at which the sampling for the 'Sniffin' Sticks' could be done outside the door of the toilet environments. The sampling for the post-treatment was still conducted at the same position as the pre-treatment sampling session to maintain uniformity.

Results and Discussion

Participants were asked to rate, on a Likert scale, whether there was a significant difference between the pre-treatment and post-treatment odour ratings of the toilet environments (Figure 4). There is a clear change in the number of people who gave the toilet a rating of 4 and 5 in the pretreatment, compared to the post-treatment sampling. This confirmed that participants noticed an improvement in the toilet conditions before and after the treatment had taken place, and more so at School A. This was further confirmed with the use of a two-tailed t-test which yielded results to suggest that there is a significant difference between the ratings received by both schools in pretreatment and post-treatment sampling sessions. These t-test results were obtained at 99% confidence and 95% confidence. Confirmation was also found in an increase in the number of participants that gave the toilet environment a rating of 2 on the Likert scale in comparison to the pre-treatment data (Figure 4). A reduction in the percentage of ratings 3-5 also suggests that participants noticed an improvement in the toilet odour conditions.

School B had a distribution closer to the expected distribution for 'Sniffin' Sticks' 4-

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6. 'Sniffin' Sticks' 3 ratings for School B were quite evenly distributed. An unexpected rating distribution for School B was 'Sniffin' Sticks' 2. Here we saw the majority of the ratings lie within the ranges of 2-3. This 'Sniffin' Stick' rating saw more than 70% of the participants providing a rating of 5. In addition, it should be noted, that there seemed to be a greater sensitivity to these odour-causing compounds amongst the participants at School B compared to those at School A. This is seen in a greater proportion of the participants providing ratings higher than those received for the same 'Sniffin' Sticks' at School A

Furthermore, analysis was done to assess whether there was a change in the various compounds that could be identified in the toilet environments pre-and post-treatment of the schools. This was assessed to see whether the changes in the toilet odours were noticeable or not. Figure 5 shows that the identification of the odour compounds in the 'Sniffin' Sticks' was also identified within the toilet environments. For 'Sniffin' Sticks' 4-6 (4 = dimethyl trisulphide, 5= stale urine reconstitution, 6= faecal reconstitution), there was a strong consensus that these compounds were within the toilet environments. The results showing that 'Sniffin' Sticks' 7 and 8 compounds (which acted as a control and a pleasant smelling compound respectively), were not present within the toilet environment were expected. For 'Sniffin' Sticks' 1-3, there was also a strong consensus that the compounds were present within the toilet environment, but not as dominant as with 'Sniffin' Sticks' 4-6. At least 40% of the participants from School A identified the specific compounds contained within each of the 'Sniffin' Sticks' to also be present within the toilet environment before the treatment (Figure 5). As expected, neither 'Sniffin' Sticks' 7 nor 8 were identified at School A with a near-even distribution across the 'Sniffin' Sticks' whether they were identifiable within the toilet environments. Surprisingly, 'Sniffin' Sticks' 7 and 8 were identified within the toilet

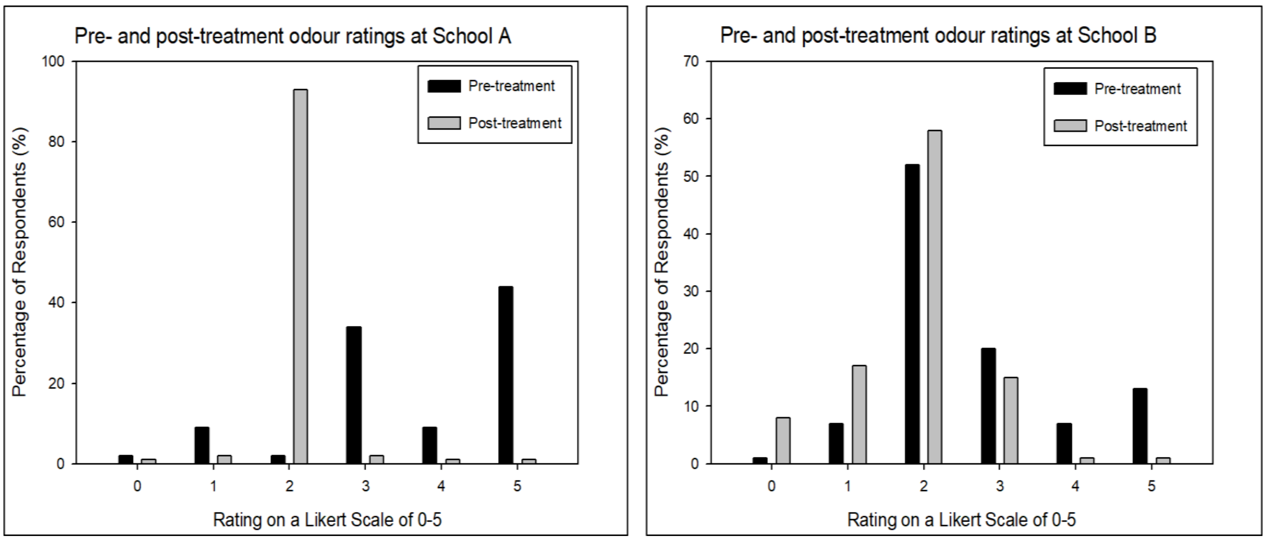

Figure 4. Pre- and post-treatment ratings of the odours at each school. The Likert scale ratings are: 0= no smell detected, 1= pleasant smell detected, 2= Unpleasant smell detected, weak but is bearable, 3= Unpleasant smell detected, moderately bearable, 4= Unpleasant smell detected, strong and unbearable, 5= Unpleasant smell detected, very strong and completely

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environments by the participants at School B.

improvement is recorded by all participants. These results have shown a significant improvement in the odour reduction of the

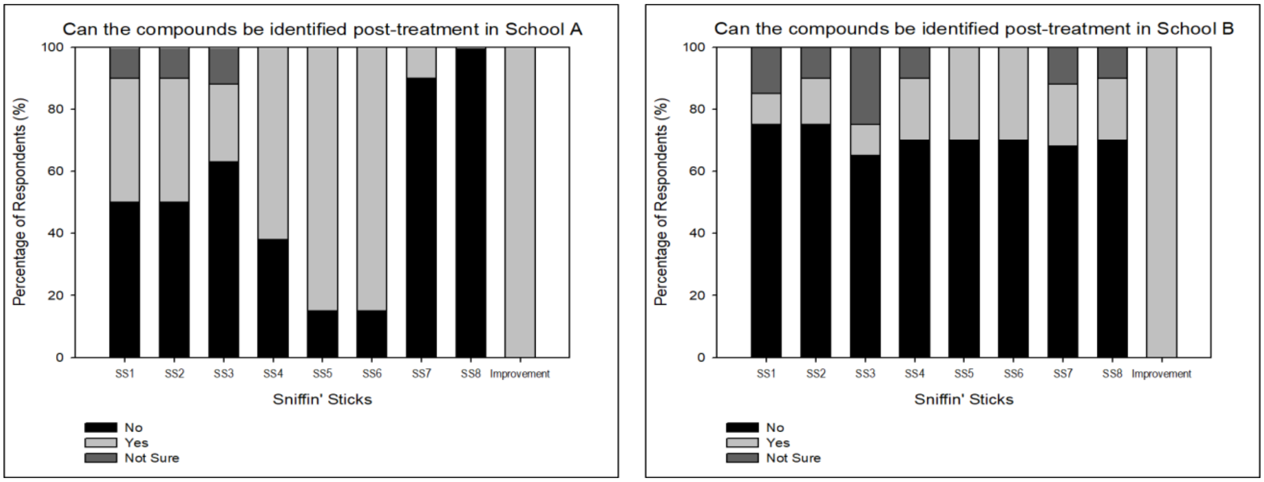

Figure 5. Olfactory test to determine whether the compounds could be identified in the toilets before the treatment products were applied at both schools. SS1 = indole, SS2 = butyric acid, SS3 = p-cresol, SS4 = dimethyl trisulphide, SS5 = stale urine reconstitution, SS6 = faecal reconstitution, SS7 = control (no smell), SS8 = lemon essential oil

In the post-treatment sampling, the identification of the compounds of the 'Sniffin' Sticks' within the toilet environments was also compared for the two schools. The results for this have shown that for School A there is a shift in the identification of the smells in the toilet environments (Figure 6). This shift is positive as it identifies a reduction in the presence of the harsh odours when participants were asked whether they noticed an improvement in the toilet odour compared to the pre-treatment conditions. Significantly, this question provided a unanimous answer across both schools, with 100% of the participants noticing a definite improvement in the toilet odour reduction (Figure 6). Similarly, Figure 6, shows the changes in the identification of the various odorous compounds present in the toilet environments at School B, and an overall treatment technique.

One of the main objectives of the research was to assess the effectiveness of the chosen treatment method on reducing odours within the toilet environments. Successful results were obtained and are shown in Figures 5 and 6. The treatment method combined with a thorough cleaning regime chosen were successful in improving odours from the toilet environments as the last column shows that 100% of the participants noticed an improvement in the toilets.

One way of confirming whether the results were accurate was to notice whether there was a decrease in the identification of the odorous compounds in the toilet environments. If the participants had noticed a change in the odour levels from the toilet environments, it would be evident in whether

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they were able to smell certain compounds in the toilet environments posttreatment. Most of the participants stated that they were no longer able to smell certain of the compounds in the toilet environments post-treatment (Figure 6). A significant decrease in the rating of the toilet environments may also be due to increased habituation (Andersson *et al*., 2009; Andersson *et al*., 2011; Pellegrino *et al*., 2017). As people become more familiar with an environment (even if the said environment is unpleasant) they are more likely to improve the rating of the environment with each visit (Andersson *et al*., 2011; Pellegrino *et al*., 2017).

The way in which the flush toilet system at School B works is very similar to the functioning of the toilet system at School A (see Brikké *et al*., 2003). The only time a septic tank would have had an impact on the way toilet-related odours are perceived is if the septic tank was situated near the toilet environment being studied. This is not the case as the septic tank in School A was situated approximately 50 meters away from the area where sampling occurred, so had a limited effect on the results. The noticeable difference in conditions between School A and School B may be attributed to a lack of infrastructure. The integration of School A into Gauteng resulted in an upgrade from pit toilets to flush toilets using a septic tank. This was problematic as they had no water connecting to the toilets at this stage and had to make use of the bucket system to flush away the waste. Essentially, these flush toilet ceramic bowls were acting as smaller pits that would accumulate waste matter over a day and then be flushed into a septic tank. In addition, the treated water contained bleach which hampered the bioremediation product (Arvanitakis *et al*., 2018; Spök *et al*., 2018) thereby requiring multiple visits to School A.

If the toilets had regular flush systems with built-in p-traps there would have been reduced odour release from these toilets (Brikké *et al*., 2003). The reason for more drastic odour ratings from School A may be related to the lack of an adequate flushing mechanism, thus undermining the purpose of the flush toilet and its p-trap. A second cause

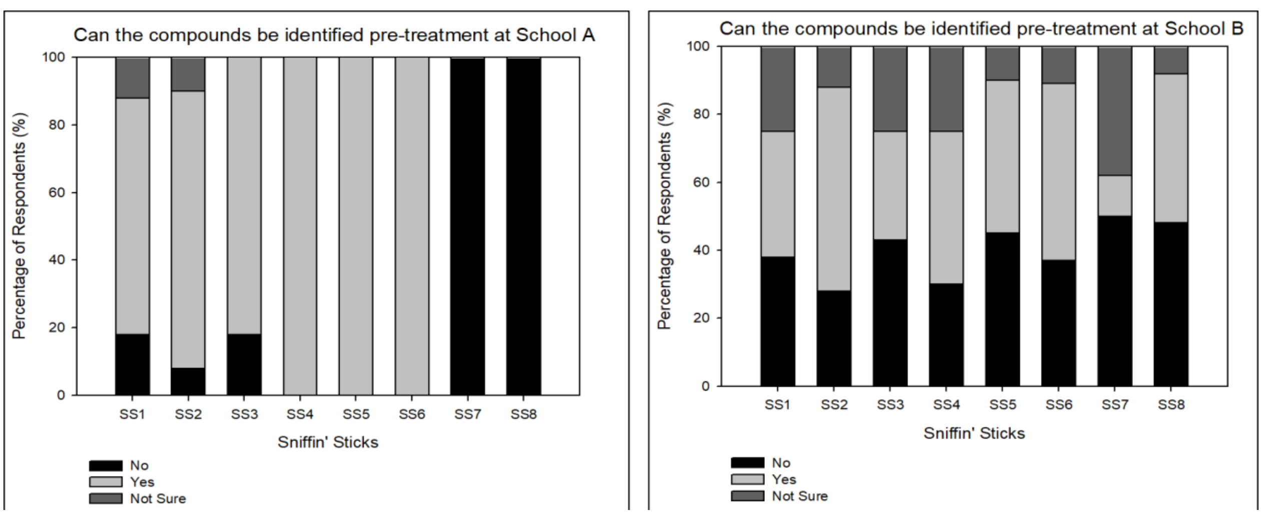

Figure 6. Olfactory test to determine whether the compounds could be identified in the toilets after the treatment products were applied at both schools. SS1 = indole, SS2 = butyric acid, SS3 = p-cresol, SS4 = dimethyl trisulphide, SS5 = stale urine reconstitution, SS6 = faecal reconstitution, SS7 = control (no smell), SS8 = lemon essential oil.

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for the odour release from School A toilets may be derived from the mixing of both urine and faecal matter into one toilet bowl that was flushed only once daily. By allowing these materials to mix, it allows for the urea to convert into ammonia upon contact with the bacterial enzymes already found within the bowl (Kaczala, 2006; Jonsson and Vinneras, 2007). Another potential problem at School A may be a lack of discipline and toilet etiquette within the school. A lack of adequate hygiene training and implementation strategies may also have led to the drastic degradation of the toilet environments (Majid and Burenhult, 2014; Majid, 2015). This is evident in both the lack of adequate cleaning regimes by the staff, as well and the presence of unwanted substances within the toilets (i.e. chip packets, used sanitary pads, cigarette filters and polystyrene cups). There were no noticeable bins for the disposal of waste material. Access to the toilets was not restricted or controlled in any way and cleaners were often away from the toilets. The greater ratio of students to toilets at School A also contributes to the ever-growing concern regarding toilets. McKay (2015) noted that the higher the ratio of pupils to toilets resulted in greater maintenance problems which in turn discouraged learners from using these facilities. This ratio is almost double that which is required by the South African Schools Act of 1:34 (Motshekga, 2009), as opposed to 1:69. This ratio may be reduced if the school was operating within the maximum number of students that are allowed per secondary school (1020 instead of 1180). However, with this maximum number being almost 200 students over the maximum limit.

Cleaning regime and thoroughness was also brought into question upon returning to School A. The excrement and stains were found in the same position on the floors in some of the restrooms highlighted the environmental and human health threats to the students and staff (Brikké *et al.*, 2003; Still *et al.*, 2015). When human excrement accumulates throughout an entire day harmful pathogens can colonise the environment and students in close contact or proximity to this exposed excrement have a significantly increased risk of contracting many of the bacteria and illnesses that are associated with these conditions.

School B made use of regular flush toilet systems with built-in p-traps, which combined both urine and faecal matter into one system. The difference in the odour released between the two schools may be attributed to the increased presence of cleaning staff as well as greater enforcement of toilet rules and etiquette at School B. In addition, limiting the use of toilets during class times also limits the amount of unsupervised access to the toilets, coupled with a member of the cleaning staff constantly being in the vicinity of the restrooms to ensure cleanliness and order. The presence of enough bins within both boys' and girls' toilets also prevented unwanted substances from entering the toilet and sewer systems. School B toilets were cleaned regularly, and this was evident in the conditions of the toilet environment. The toilets were cleaned with regular cleaning materials (no industrial strength cleaners),

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but rather regular household cleaning items. The frequency of cleaning and the thoroughness of the cleaning also contributed to the reduction of odours within these environments. By removing any human waste from the floors and from between the tile grout, the ability of bacteria to colonise the environment was reduced and their chances of survival diminished through the removal of them with the use of antibacterial cleaning products.

Interestingly, there was a reduction in the number of participants from the pre-treatment sampling compared to the post-treatment sampling as some of the participants were not comfortable taking part in the second sampling session owing to some side effects from the pre-treatment sampling. The participants mentioned experiencing mild headaches as a result of the 'Sniffin' Sticks' and that the odours from them lingered too long. The lingering of these odours around the participants' nasal passages, therefore, had an effect on their ability to enjoy lunch and as some mentioned, even their dinner that evening. In addition, many of the teachers at School A, including those who had not participated, noted that they had seen an improvement in the productivity of the children between the pre and post-treatment sessions. Many of them had also noted that the odours from the toilets were no longer strong enough to reach the classrooms as they had previously. One teacher situated approximately 15 m away from the toilet environment mentioned that on a day before the treatment, she was able to smell the odours emanating from the toilet environment in her classroom. This teacher then mentioned that after the treatment had been performed, she noticed a dramatic decrease in the odour identification in her classroom as little as one day after the treatment session had begun.

Conclusion

The olfactory test showed that the compounds that produce odours in toilets were present in two school toilets before a bioremediation treatment product was applied to the toilets. The 'Sniffin' Sticks' proved useful in identifying the compounds in the toilets; and while butyric acid, indole, p-cresol and dimethyl trisulfide are highly offensive in low concentrations and small amounts, they were easily identifiable in the toilets at both schools. There was a noticeable improvement in the toilets after the bioremediation products were applied. In both schools, 100% of the participants noticed the improvement in the toilets. However, cleaning alone is not sufficient to remove the odours, as we noted at School B, neither is the bioremediation product on its own sufficient to remove odours, as noted in School A. Instead, a combination of a bioremediation treatment product with regular cleaning and maintenance of the toilets are essential to reduce the odours.

Microbial cleaning products have received a lot of attention in recent years and the products applied to both schools were successful in reducing the odours within the toilet environments. Limitations existed in terms of data analysis and these constraints were mainly due to a smaller sample size of this pilot study, which did not allow for adequate statistical analyses to be performed. In addition, the differences in the size of the schools and the levels (one being a primary school and the other a secondary school) made the comparisons difficult. However, based on the success of this study, and the lessons we learnt from it, we will roll out the

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olfactory test and bioremediation treatment to more schools nationally as 4 000 pit latrines still exist in the country and access to adequate sanitation is critical to academic success.

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