Evaluation of odour from portable toilets in a four-bed hospital ward

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K.Nakajima, M.Kasegawa, M.Suzuki, T.Tamura. Evaluation of odour from portable toilets in a four-bed hospital ward. Gerontechnology 2003; 2(4):324-331. **Objective.** Unpleasant odours in hospital wards arising from patients' use of portable toilets is a significant problem. The odours in a four-patient hospital ward were evaluated by using semiconductor odour sensors to evaluate the ambient odour. All the patients in the ward used a conventional portable toilet for four successive days, and then an odourless portable toilet for six successive days. **Method.** Four semiconductor odour sensors were used. They were mainly sensitive to hydrogen sulphide, ammonia, chemicals of light molecular weight (A sensor), and chemicals of heavy molecular weight (B sensor), respectively. Air was collected from near the ceiling of the hospital ward and transported to the sensors via Tygon® tubes. **Result.** In comparison with the conventional portable toilet, the odourless portable toilet resulted in a decrease of 14% in levels of hydrogen sulphide, 30% in ammonia, 58% in chemicals of light molecular weight and 44% in chemicals of heavy molecular weight. **Conclusion:** The ambient odour in the hospital ward was significantly improved by using the odourless portable toilet.

Keywords: portable toilet, semiconductor odour sensor, hospital ward, ozone

Toilet hygiene is important in the maintenance of patients' dignity. A portable toilet is typically used for patients who cannot use a toilet by themselves. The cleaning of a portable toilet promptly after its use is desirable to minimise unpleasant odours. At the same time, some patients do not want to burden a busy caregiver with the cleaning of a portable toilet promptly after its use, and they may feel especially embarrassed after defecation. Nurses would guess that it was the rotavirus stool, because it had a characteristic smell[1]. However, unpleasant odours may make other patients in the same ward uncomfortable.

Japanese hospital wards accommodate from two to four patients. A portable toilet is typically used after a meal. Because patients may eat at different times, unpleasant odours may be present in a hospital ward while some patients are eating. Although the use of fragrance can mask an unpleasant odour, it is often difficult to find an appropriate product that does not risk provoking patient allergies[2].

For these reasons, an odourless portable toilet was developed. It uses an ozone gas bubble to decompose the smell, and it keeps the excrement in a sealed cassette tank. In this study, we compared odours from odourless and conventional portable toilets by using semiconductor odour sensors.

METHOD

Participants

Before beginning the study, formal approval was obtained from the ethics committee of the Chubu National Hospital. We explained the aim and the details of this study to 11 patients. Six patients, all female, participated in the study, and five patients refused. Written informed consent was obtained from the six participants. Table 1 shows the participants' age, main medical diagnosis, and the number of days of toilet use.

Portable toilets

Figure 1 shows the portable toilets used in the study. The conventional portable toilet (Portable Toilet DX, Aron Chemical Co, Japan) is simple in design. The procedure for using it is as follows. The lid is opened and the patient sits on the toilet seat. The excrement falls into a container under the toilet seat. After use the lid is closed to prevent diffusion of faecal or urinary odour. A deodorant spray is applied to the container when it is flushed. This spray contains a surfactant, an organic acid, ethanol, and a fragrance.

The odourless portable toilet (Miraclet, Aishin Co., Aichi Japan) consists of a lid, an urethane toilet seat, a flushing system, a bidet system that uses warm water, an ozone gas generator, an one-litre tank of detergent (2% non-ionic surfactant) for the bubble, a five-litre tank of water for flushing and for the bidet system, and a sealed cassette tank of six litres in which excrement is stored. The odourless portable toilet requires a power supply of AC 100V or DC 12V. Power consumption is 117W at maximum function and 4W at minimum function. The procedure for using the odourless portable toilet is as follows. When the lid is opened, an ozone gas bubble automatically fills the toilet bowl. The ozone gas is released for three seconds in every eight seconds. Maximum concentration of ozone gas was 0.05 part per million (ppm) when the generator generated ozone gas continuously in a

Table 1. Patients' age, main medical diagnosis, and number of days of toilet usage

participant			days of using portable toilet	
number	age	main diagnoses	conventional	odourless
1	80	diabetes mellitus	3	7
2	80	myocardial infarction, diabetes mellitus	3	1
3	73	brain infarct	3	1
4	85	brain infarct, left-hemiplegia	3	7
5	90	osteoporosis	0	3
6	89	diabetes mellitus	0	2

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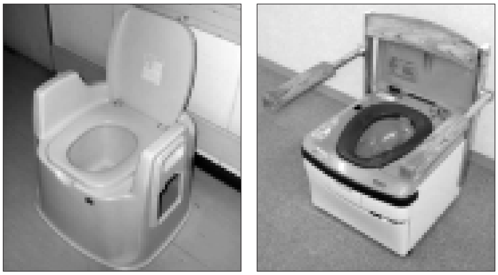

a b

Figure 1. Photographs of the portable toilets. (a) Conventional portable toilet is composed by a body, a lid, arms, a toilet seat, and a container. All of those are of plastic material. (b) Odourless portable toilet is composed by a steel body, a plastic-lid, wooden arms, wooden back, an urethane toilet seat, a flushing system, a bidet system, an ozone gas generator, tanks for fluids, and a sealed cassette tank for sewage.

sealed box of two cubic meters[3]. A patient sits on the urethane toilet seat. When the flushing button is pressed or the patient leaves the seat, the flushing water enters the sealed cassette tank containing the excrement. The lid is then closed in preparation for the next use. The sealed cassette tank is cleaned daily by pouring 10 millilitres of a deodorant liquid into the tank. The principal ingredients of this deodorant liquid are an anti-bacterial medicine, an organic acid, a non-ionic surfactant, and paraffin.

Odour evaluation

Four conventional portable toilets were used for three successive days in a four-bed hospital ward. Four odourless portable toilets were then used for six successive days in the same hospital ward.

Figure 2 is a schematic diagram of the arrangement of portable toilets and sensors in the ward. Air was collected from the ceiling in the centre of the ward and transported to the sensors via Tygon® tubes. Temperature and humidity sensors (HMP45A, Viala, Austria) were positioned beside the inlets of the Tygon® tubes in the ceiling. A pair of magnetic sensors (GLS-S1

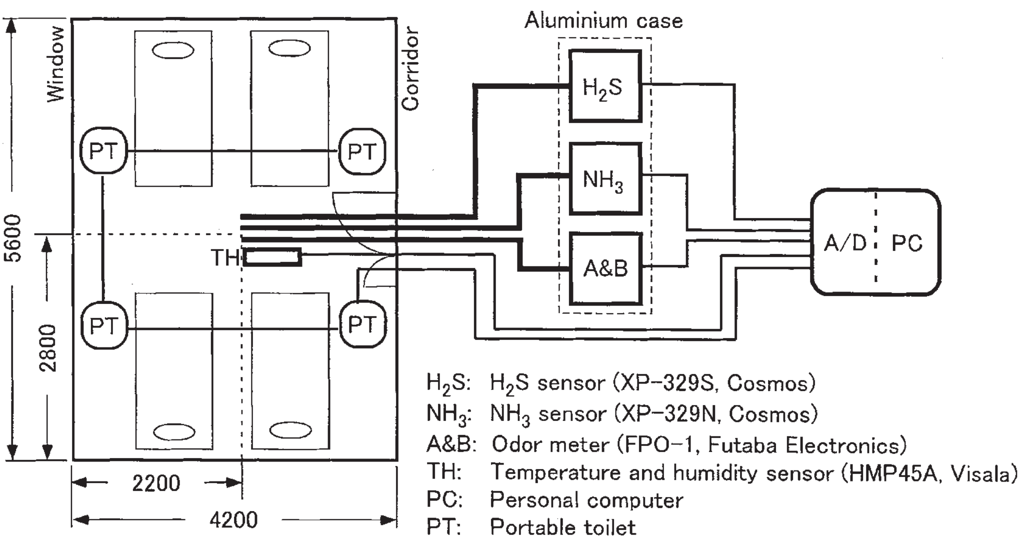

Figure 2. Schematic diagram of the arrangement of the portable toilets and the sensors in the hospital ward. Air of the hospital ward was collected from the ceiling in the centre of the ward and transported to the odour sensors. The open/close of each lid was monitored with the magnet sensor.

and GLS-M1, Omron, Japan) was used to register whether the lid of the portable toilet was open or closed. Odour evaluation by humans is difficult[4]. A number of different types of odour sensors have been developed[5,6], for instance mass spectrometric and gas chromatographic techniques, metal oxide gas sensors[7], quartz crystal[8] or acoustic gas sensors, and conducting polymer sensors[9]. Odour perception is attempted using new techniques of a gas sensor array[10], visualisation of gas[11], and a neural network[12]. Some of these sensors are now commercial products and the number of applications of odour sensors is growing[13]. We used four metal oxide gas sensors because of the following advantages: least sensitive to moisture, least amount of 'drift' over time, electrical response proportional to the log of the intensity of the stimulus, quick recovery time[6]. The main substances to which the sensors are sensitive are hydrogen sulphide (H_2S sensor: XP-329S, Cosmos, Japan), ammonia (NH_3 sensor: XP-329N, Cosmos), and chemicals of light and heavy molecular weight (A and B sensors: FPO-1, Futaba Electronics, Japan, respectively). Typical chemicals of light molecular weight are alcohol and ammonia (A sensor: FPO-1). Typical chemicals of heavy molecular weight are aromatic compounds containing a benzene nucleus (B sensor: FPO-1). The Tygon® tubes were 15m long and air took about five seconds to travel down the tube from ceiling to sensor. All sensors have analogue output of the metal oxide gas sensors. Analogue output of both XP-329S and XP-329N are within a range from 0 to 200 mV, and analogue output of both A and B sensors in FPO-1 are within a range from 0 to 5 V. Analogue outputs of all sensors were loaded into a PC at the rate of 1 Hz. There were four patients occupying the ward during the testing of the conventional portable toilet, and between two and four during the testing of the odourless portable toilet.

In this study, the patients did not record the times at which they defecated or urinated. The period during which the air in the ward was evaluated extended from when the lid was opened to 10 minutes after the lid was closed. The odour was evaluated using the following equation.

$$\triangle \text{Output} = \text{Output}_{max} - \text{Output}_{base}$$

Output_{max} is the maximum output of the sensor during the evaluation period, and Output_{base} is the output at the time when the evaluation period started. A two-tailed t-test with a 0.05 threshold for significance was performed using *StatView 5.0* (Hulinks), to compare the output of the two types of toilet.

Average air temperatures in the ward during the odour evaluations of the conventional portable toilet and the odourless portable toilet were 25.4 ± 0.6 °C and 24.5 ± 1.8 °C, respectively. Average humidity during the odour evaluations of the conventional portable toilet and the odourless portable toilet were 64 ± 8 % and 64 ± 6 %, respectively.

RESULTS

During the evaluation periods, the conventional portable toilet and the odourless portable toilet were used 48 times and 77 times, respectively. Figure 3 shows typical results of the outputs of the odour sensors. The lid number in Figure 3 correlates with the patient number in Table 1. In the odour evaluation of the conventional portable toilet (Figure 3 a), Lid 2 was opened immediately after Lid 1 was opened. About two minutes later, the output level of A and B sensors increased slightly and temporarily. About seven minutes later, Lid 2 was closed. When Lid 1 was closed about 20 minutes later, the output levels of all sensors began to increase significantly. The output levels of all sensors decreased when Lid 1 was opened for one minute about 35 minutes

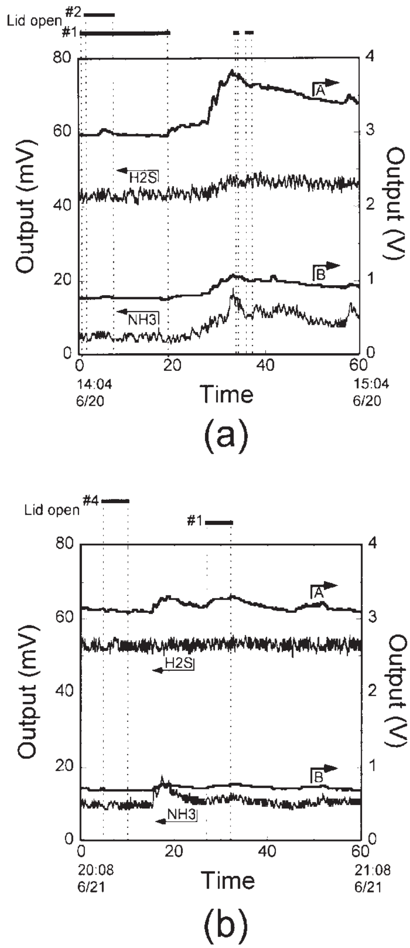

Figure 3. Typical example of the outputs of the sensors in the hospital ward. (a) Conventional portable toilet (b) Odourless portable toilet. Bold lines over the figures indicate an open state of each lid.

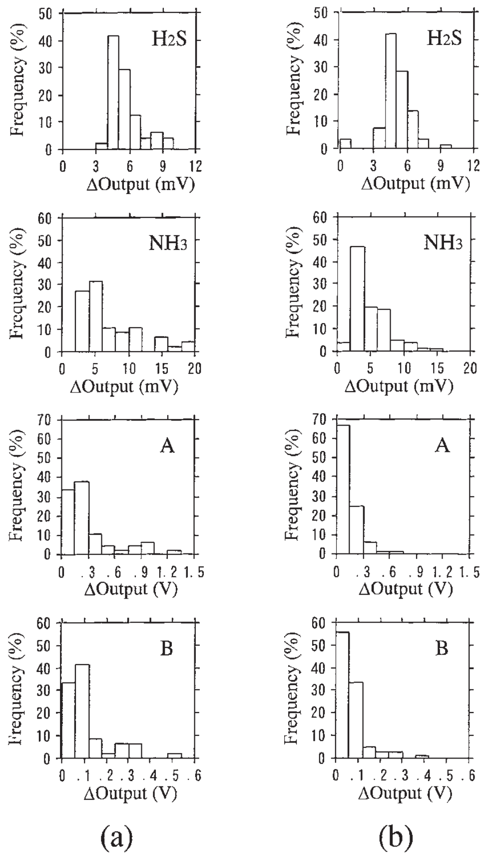

Figure 4. Frequency histograms of the outputs of the sensors. (a) Conventional portable toilet (n=48); (b) Odourless portable toilet (n=77).

later. Lid 1 was reopened for one minute about 38 minutes later. In the odour evaluation of the odourless portable toilet (Figure 3 b), Lid 4 was opened for about six minutes. The output levels of A, B and NH_3 sensors increased temporarily after five minutes when Lid 4 was closed. The output levels of A and B sensors increased temporarily while Lid 1 was opened. They decreased when Lid 1 was closed.

The time delay between the opening of the lid and the reaction of the odour sensors is mainly due to the diffusion process of the various gases from the toilet to the inlet of the tubes. The molecular weight of the gases as compared to air might play a part here. Molecular weight of H_2S is at 34 somewhat heavier than air at about 29, NH3 is at 17 lighter than air. The traveling time within the tube is about five seconds only and the sensors react immediately.

Figure 4 shows frequency histograms of the delta outputs of the sensors. For all sensors, the peaks of frequency distributions for the odourless portable toilet were lower than those for the conventional portable toilet. Figure 5 shows a comparison of the averages of the

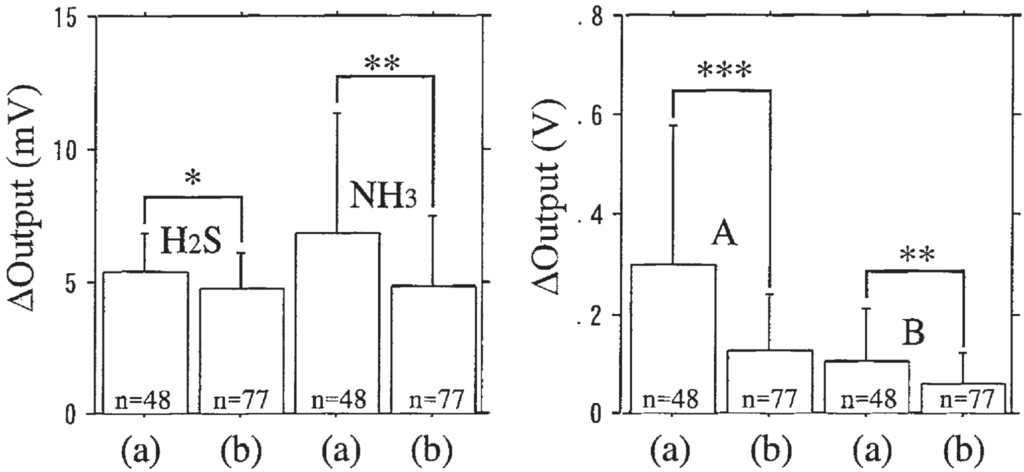

*Figure 5. Mean outputs and standard deviations of the sensors on (a) conventional portable toilet and (b) odourless portable toilet. Significant differences were observed by t-test, *: p<0.05; **: p<0.005; ***: p<0.01.*

delta-outputs of the sensors. The average output of the H_2S sensor for the odourless portable toilet decreased by 14% compared with that for the conventional portable toilet. The average output of the NH_3 sensor for the odourless portable toilet decreased by 30% compared with that for the conventional portable toilet. The average outputs of the A and B sensors for the odourless portable toilet decreased by 58% and 44% respectively, compared with those for the conventional portable toilet. Significant differences were observed for all sensors.

DISCUSSION

In our study, concentration of H_2S is only marginally affected by ozon depletion. The main reason for this is that the inlet of the tube was placed at the ceiling of the ward. If the inlet of the tube had been placed at floor of the ward, the difference in H_2S between conventional portable toilet and odorless portable toilet in H_2S would have been more substantial, because H_2S is somewhat heavier than air.

In this study, we evaluated the ambient odour in a four-bed hospital ward with four portable toilets. We explained the aim and the details of this study to 11 patients, but almost half of them were unwilling to participate to this study. The reason of the rejection may be an embarrassment to the odour evaluation of excrement. There seemed to be no concern about their excrement odour while using it. A patient in the four-bed hospital ward was able to use the odourless portable toilet without anxiety, even if the other three patients were eating.

Unfortunately for this study, the patients did not record their urination or defecation when they used the portable toilet. Figure 3 (a) might record a time of defecation by patient number one. When Lid 1 was closed, the outputs of all sensors increased greatly. Two subsequently observed brief operations of Lid 1 might indicate the processing of faeces by a nurse. The conventional portable toilet has to be cleaned by a nurse after every use by a patient. The odourless portable toilet retains excrement in its sealed cassette tank, which the nurse has to clean only once a day. However, several nurses complained that the sealed cassette tank was heavy when full, and that it took longer to clean than the container of the conventional portable toilet.

Ozone pollution occurs around urban areas and a lot of effect of the ozone exposure on lung function parameters has been reported. Effects of environmental ozone on lung function of senior citizens have been investigated with the result that there was no effect to ozone of 0.100 ppm in the ventilation rate of the senior citizens[14]. Also, no relevant ozone related effects were found on the lung function parameters and on the subjective reports of irritations[15]. A minimum concentration of the breath function influence in single time exposure experiment to healthy volunteers was 0.5 ppm[16]. The Japan Society for Occupational Health recommends the occupational exposure limits as reference values for preventing adverse health effects on workers and occupational exposure limit of ozone gas concentration is recommended 0.1 ppm[17].

In the present study, patients reported no irritation to the vulva, urethra, or anus while using the toilet, nor to the eyes or nose despite the proximity of the face to the source of the ozone gas in the odourless portable toilet. The nurses reported no complaints about irritation. Unfortunately, we did not monitor concentration of the ozone in the ward. The ozone gas from the odourless portable toilet is expected to have no effect to the patients because *(i)* maximum concentration of ozone was 0.05 ppm in the sealed box[3], *(ii)* ozone is heavier than air, and *(iii)* the half-life of ozone indoors is between 7 and 10 min[18]. The use of ozone gas in the odourless portable toilet provides a significant sanitary advantage because it oxidizes, bleaches, and disinfects. This study has found that the ambient odour in a hospital ward was significantly improved by the use of an odourless portable toilet.

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