EVALUATING THE POTENTIAL OF AN ELECTRONIC NOSE FOR DETECTING THE ONSET OF ANAEROBIC CONDITIONS DURING COMPOSTING

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1. ABSTRACT

Most bad odours in composting plants are formed under anaerobic conditions and often they could be avoided if detected early enough. In this project an electronic nose was used to evaluate the odours produced during a composting process at bench scale. The electronic nose consists of an array of electronic chemical sensors with partial specificity and an appropriate pattern recognition system capable of recognising simple or complex odours. Their advantage is their rapid response rate and simplicity of operation.

Closed reactors were set up in water baths in the laboratory to enable their operating temperature to be changed. In the experiment described in this paper the temperature was kept at 40ºC and the waste used was the vegetable fraction of food waste. Each reactor was fitted with an aeration system which could maintain aerobic conditions inside the reactors when needed.

Samples of the headspace gas were analysed and the odour was assessed during the biodegradiation process. Oxygen was measured in the headspace gas, and parameters such as the oxidation reduction potential (redox) were measured in the solid material.

The reactors were initially operated aerobically and then the air was turned off. The changes in headspace gases and redox were then monitored as the conditions became anaerobic and the results compared to those of the electronic nose.

The initial results from the trials indicate that the electronic nose can detect an early transition from aerobic to anaerobic conditions, but at this stage more work is needed in the laboratory. Further trials are taking place in the field.

2. INTRODUCTION

2.1. Background

Composting is an aerobic process, so oxygen supply is fundamental for the metabolism and respiration of aerobic micro-organisms and for oxidising the organic molecules present in the waste material. If no oxygen is present, or the level of oxygen is low, the micro-organisms present will be mainly anaerobic, thus slowing the decomposition and producing volatile gases responsible for bad odours. Most frequent odours identified at composting plants are caused by sulphur and nitrogen compounds and volatile fatty acids (Walker; 1993; Wilber and Murray, 1991; Miller, 1993).

Complaints about odours have been reported as one of the major problems faced by composting site managers (Smalley, 1998; Walker, 1993), especially if municipal solid waste or other wastes containing readily biodegradable material are being composted. Different odours are formed, both in aerobic and anaerobic processes under a broad range of conditions,

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and some odorous compounds existing in the waste may be released during the composting process, therefore a zero odour discharge is virtually impossible. However, most offensive odours are formed under anaerobic conditions and often they could be avoided if these conditions were detected early enough.

One of the major problems faced when measuring odours comes from the fact that they are often a complex mixture of hundreds of compounds. Identifying and quantifying all the compounds is a major task and it does not allow a prediction of the resulting smell, given that the odour is not simply the sum of the odours of all those molecules found in the gas (Gardner and Bartlett, 1999). Also, the techniques that allow this characterization of odours are expensive and require trained staff. There is a need for an easy and fast method of identifying the onset of anaerobic conditions on-site.

2.2 Detection methods

The most commonly used method for identifying and quantifying an odour is by using odour panels and it will be described briefly as well as the methods used in this study.

2.2.1 Odour panels

Currently, odour panels are the most commonly used method for determining odour levels (ASTM, 1997;BS EN 1622: 1998). Panel members are presented with diluted odorous samples and other samples of clean air. The results are then expressed as odour threshold or concentration, which is the concentration at which half of the panel can smell an odour and odour intensity, which is a measure on a scale from "light" to "extremely strong".

The main disadvantages of odour panel tests are related to the variability of the results and the cost and time necessary to perform the tests. There are several possible sources of variability in this procedure, most of them associated with the fact that it is based on a human panel. To reduce this variability, the panel has to be selected and trained (Gardner and Bartlett, 1999). At least three trained panellists are necessary, but usually the panel consists of 6-12 people, involving a large amount of time and resources (ASTM, 1997;BS EN 1622: 1998). Therefore, odour panels are not a practical method for routine use in waste management operations.

2.2.2. Oxidation- reduction potential (redox)

"Soil redox potential is an important physico-chemical parameter used to characterise soil aeration status especially under flooded conditions." (BS EN 1622: 1998). Redox reflects not only the amount of oxygen in the soil but also the other species present. As a result, redox measurements can detect changes in the environment (Evangelou, 1998). Composting materials and soil have similar properties, so in this study redox was used to detect changes from aerobic to anoxic or anaerobic conditions in a composting material. Table 1 shows the range of redox values expected for soil under different oxidation conditions.

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Table 1. Range of Eh Measurements of Soil-Water Systems (Evangelou, 1998)

Very well-oxidized soil	800 mV
Well-oxidized soil	500 mV
Poorly-oxidized soil	100 mV
Much-reduced	-200 mV
Extremely reduced soil	-500 mV

2.2.3. Electronic nose

The electronic nose, or artificial nose, consists of an array of electronic chemical sensors with partial specificity and an appropriate pattern recognition system capable of recognising simple or complex odours (Gardner and Bartlet, 1999). There are some similarities with the human nose but some aspects of the electronic nose still remain very different. The volatile compounds react with the sensors, both in the electronic and mammalian nose. This generates an electronic signal that is pre-processed and amplified, before being sent to a recognition organ, either the brain or a computer. The operating principle, the number of sensors as well as the sensitivity and selectivity are, however, very different (Schaller *et al.,* 1998). The sensitivity of the human nose is undoubtedly far superior to that of any electronic equipment, but the variability in the results is also far greater and the practical difficulties of using a human panel for numerous operations poses a problem. The electronic nose, on the other hand, can provide faster results and is particularly useful for routine operations, where the cost of human panellists is prohibitive.

In a biological system like the one studied, that is evolving from aerobic to anaerobic, different gaseous compounds will be emitted, consequently different patterns will be produced by the electronic nose. The compounds produced will depend on the process conditions, namely temperature and waste material. Nonetheless, it is expected that the transition from aerobic to anaerobic might be detected in its early stages with this equipment.

3. MATERIALS AND METHODS

3.1. Design of the experiment

The laboratory reactor used in these experiments was a 2-litre glass vessel with a sealed lid. Air was supplied to the system using a small pump and a pipe with an aeration stone that was placed through the material. In each experiment, the reactor was kept in a water bath at a fixed temperature, to keep variations in the system to a minimum. To allow for easier and more significant measurements of the redox potential, the material used was a thick suspension of different solid wastes, namely vegetable food waste, with an average water content of 95%. During the first 24 hours the material was aerated; oxygen was measured in the headspace gas, redox was measured in the semi-solid material and samples of headspace gas were drawn into a bag for analysis in the electronic nose. After that time, the aeration was stopped and the headspace gas was recirculated to the material via the same pipe used for aeration to keep the contents agitated. Oxygen, redox and the headspace gas were analysed during that time. Since

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the purpose of the experiments was to detect the transition from aerobic to anaerobic, the measurements were carried out until the process was undoubtedly anaerobic.

3.2. Methods of analysis

Oxygen was measured with an oxygen probe (Oxyguard S/N 76910080, supplied by Partech Instruments) and redox was measured with a combined electrode (combined electrode, CEPTR11, supplied by Russell pH Limited).

3.2.1. Analysis with the electronic nose

Samples of headspace gas were collected in sample bags that could hold a sample without any significant alteration for at least 3 hours. The sample bag was then connected to the electronic nose and 5 replicates of each sample were analysed. Inside the electronic nose there is a pump that draws gas from the bag at a flow rate of 150ml/minute. An adsorption time of 5 seconds and desorption of 30 seconds were chosen after some trials. In total, each replicate took less than 1 minute to be analysed. After the gas was drawn into the nose the volatile compounds interacted with the 14 sensors, that then experienced a change in their resistance. Every time a sample was taken another sample of n-butanol 99.5% pure was also taken, to assess the stability of the sensors from one day to the other. The information from all the sensors was analysed by a built-in statistical software package. The electronic nose used was developed by Bloodhound Sensors Ltd (Gibson, 1997; Clements *et al*, 1998).

4. RESULTS AND DISCUSSION

The part of the work reported in this paper looked at the transition from aerobic to anaerobic conditions for the vegetable fraction of food waste in a water bath at 40ºC.

Figure 1 shows the change in the redox potential with time after the air was turned off and following the purging with nitrogen to clear any residual oxygen.

Figure 2 shows the data presentation for the nose generated from this experiment and including the output from all 14 sensors. This figure was produced using Principal Component Analysis, or PCA, that is part of the statistical software included in the electronic nose. Figure 2 shows a clear difference between sample number 1 and all the other samples. In fact, when looking at the redox values, the value for sample number 1 is very different from all the rest being above 150mV. All the other values are less than 50 mV, in fact, except for sample number 3, taken a few minutes after purging the system with nitrogen, all the other samples show redox values of less than -50mV. The results obtained from the electronic nose seem to reflect well the redox values. Further tests are needed to confirm this transition effect, using other waste types and other operating temperatures.

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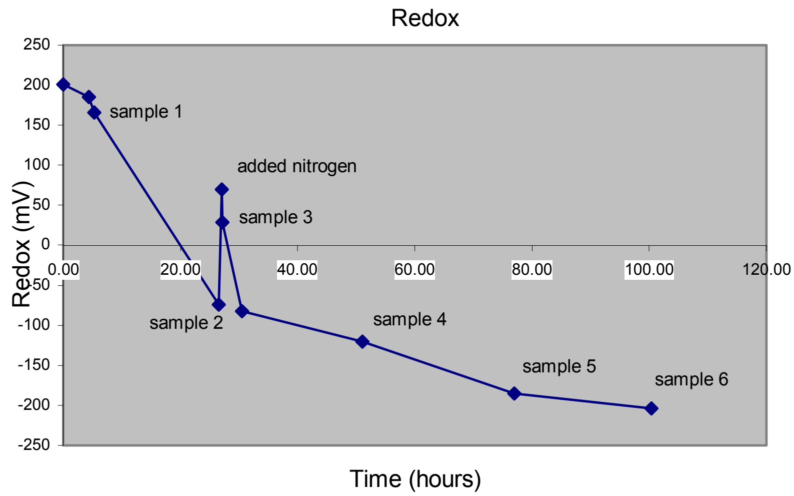

Figure 1. Redox measurements also showing when samples were taken for analysis with the electronic nose

The advantages of using the electronic nose instead of odour panels were explained before. Compared to chromatography techniques, for example destined to measure carbon monoxide, the electronic nose is easier to use than chromatography and cheaper. Redox is not practical to measure on-site because of the difficulty to use the probes on solid materials.

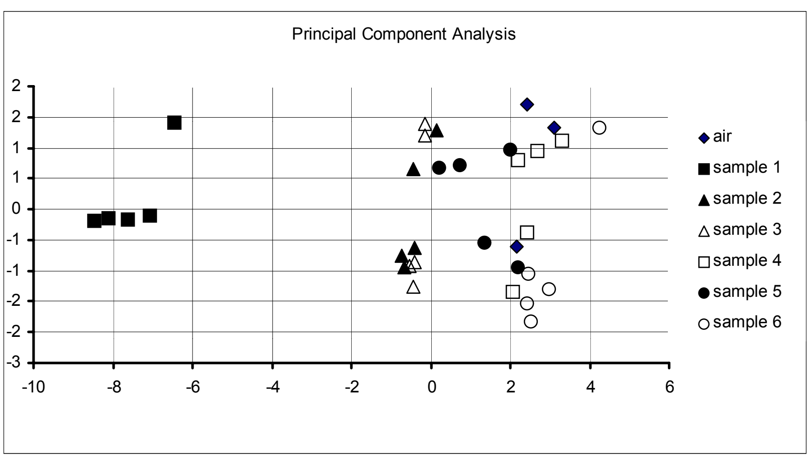

Figure 2. Outcome from the electronic nose

The next step in this work will be to analyse the results using the sensors that are thought to have a stronger response to the compounds expected to arise under anaerobic conditions. Different waste materials and operating temperatures will be tested, in an attempt to identify a combination of sensors from this array that are best able to detect the onset of anaerobic conditions. As part of this work, some samples will be taken at a full scale composting operation with known odour problems.

5. CONCLUSIONS

The electronic nose appears to be able to indicate the transition from aerobic to anaerobic conditions. The electronic nose offers some clear advantages over other techniques currently in use to determine odour levels. It is particularly useful in routine operations, due to its ease of use and rapid response rate. Further trials are needed to confirm and improve the performance of the electronic nose.

6. ACKNOWLEDGMENTS

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