KNOWLEDGE BASED CLASSIFIER FOR LANDFILL OLFACTIVE INJURIES

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Abstract − This paper shows some of the most significant aspects addressed during the development of an odour classifier. In particular for one devoted to the monitoring of olfactive injuries caused by the presence of a municipal solid waste (MSW) landfill. A description of the methodologies used in the sensor array choice and in the development of the measurement chamber is given after a brief description of the state of the art and the state of the research in the field of waste disposal. The paper ends with the more significant results obtained.

Keywords: municipal solid waste, olfactive injuries, knowledge based classifier.

1. INTRODUCTION

In the modern society three are the methods mainly used for MSW disposal: landfill, incinerator and composting plant. The most common one is the landfill, because it is cheap and its development is easy and fast. Moreover the landfill is always necessary even if another method is used as either incinerator or the composting plant produce waste that needs to be stored.

Valuable alternative to the use of a landfill in the near future seem to be pyrolysis, water plasma, fuel conversion and waste compression in blocks. These techniques are in the early experimental stage and haven't yet reached a sufficient level of reliability in terms of efficiency and environmental safety.

The use of a landfill has also some drawbacks as the big area occupied and the possibility to pollute soil, water and atmosphere. These problems increase their importance as much as the landfill is located near an urban centre.

Nowadays the air pollution, and in particular the emission of bad odours, is reduced by gas collection and site chemical spraying, but the effectiveness of this method must be monitored. The main approaches used to this scope are the use of gas chromatographic techniques and the panel of human experts. The former gives the chemical composition of the air but cannot give information of its quality as it is perceived by a human being. The latter gives a description of the air quality but its judgement can be influenced by habituation, subjectivity and psychophysical condition of its members. Moreover none of the two approaches can be used in a continuous way and the panel of experts cannot work in conditions where the life of its components is at risk.

An artificial olfactory system can be a successful approach to the monitoring the effectiveness of the olfactive injuries reduction methods. Moreover it can be used in a continuous way and gives an objective judgement on the quality of the air.

2. PROBLEM ANALYSIS

Methane and carbon dioxide are the gases mainly produced during the decomposition of MSW, but the olfactive injuries are due to a lot of other substances that are typically present in concentration of some percents or less. Table I shows a list of the substances that can be normally found in a landfill with their olfactive threshold or their typical concentration, if at least one of these values is available.

TABLE I. Substances typically found in a landfill and their concentration (C) or olfactive threshold (T)

Substances	Concentration [μg/m^3]
Isobutane	N/A
Butane	N/A
Benzene	*500* (T)
Xylene	*350* (T)
Toluene	*8000* (T)
Trichloroethylene	*1100* (T)
Perchloroethyleme	*32000* (T)
Hydrogen Sulphide	*50000-200000* (C)
Methylmercaptane	4,2(T)
Carbon Disulphide	*24* (T)
Dimethylsulphide	*4000* (C)
Isopropyl alcohol	*22000* (C)
Acetone	*50000* (T)
Methylethylketone	29500(T)
Limonene	*100000* (C)
Trimethylamine	0,5(T)

The main constraint in the choice of the most suitable sensor array is the need to detect the substances reported in Table I. Moreover other factors must be considered like availability, selectivity, reversibility and the need to obtain the more raw information, to be processed by the knowledge based system, that is possible.

The high number of substances that need to be detected, the lack of specific and highly selective sensors for each substance have suggested an approach based on the spurious sensitivity of commercially available sensors. This approach increases the *coverage degree* of the system on the application. This is achieved either giving information of substances whose specific sensors aren't not yet available either through information redundancy increasing the discriminating capability of the system for the various substances.

3. SENSOR ARRAY AND MEASUREMENT CHAMBER

Taking in consideration the needs and the proposed approach above cited the sensor array chosen is constituted by fifteen elements, thirteen gas sensors, one temperature sensor and one relative humidity sensor.

The gas sensors have been chosen in order to detect most of the substances reported in Table I. The type of the sensors and their reported sensitivity is shown in Table II.

TABLE II. Sensor family chosen and their reported sensitivity

Sensor Type	Sensitivity
Catalytic	Butane, Acetone, Toluene, Xylene, Methylethylketone, Isopropyl alcohol
SnO_2	Acetone, Benzene, Isobutane, Butane, Isopropyl alcohol, Toluene, Hydrogen sulphide
InO_2	Methylmercaptane, Hydrogen sulphide, Acetone, Toluene
Electrochemical cell	Methylmercaptane, Isopropyl alcohol, Hydrogen sulphide, Carbon disulphide

For each sensor type a dedicated electric conditioning circuit has been developed. Catalytic sensor is used in a full bridge configuration with a compensation device and current overload protection. Semiconductor based sensor use a full bridge with feedback configuration for the heater and a half bridge configuration for the measurement. With a full bridge configuration there is a better control on the heater temperature and so a better stability in the sensor performance can be achieved. The electric conditioning circuits for the electrochemical cell are the potentiostatic circuit for the three electrode configuration and a transimpedance amplifier for the two electrode configuration.

A dedicated measurement chamber has been developed to house the sensors. From the point of view of the operator the chamber has been designed in order to assure the maximum safety. With regard to the measurement process it is designed to offer the maximum repeatability and minimum interference from the surrounding environment.

Measurement repeatability is increased through atmosphere homogenisation and reducing interferences between sensors. The former is achieved by a forced air circulation circuit while the latter positioning only the sensing electrode of the electrochemical cells inside the chamber, because the gases produced at the counter electrode has been noted to influence the behaviour of some semiconductor based sensors. Fig. 1 shows the lab demonstrator used in this project.

Fig. 1. Measurement chamber, conditioning circuits and data acquisition system used in the project

4. DATA ACQUISITION AND ANALYSIS SYSTEM

The acquisition system is composed by a DAQ card and a software that manages the acquisition and the processing of the sensor raw data.

The software has been developed using the virtual instrument technology and written in LabVIEW. The choice of this graphic language is due to its easiness of learning, versatility, capability of instrument interfacing and availability of advanced data analysis tools.

The main feature of the developed software is the capability of on-line training of the knowledge based system. After the data acquisition procedure the program shows a graph with all the sensor outputs. At this time the user is asked to identify a time instant previous to the sample introduction and one following sensor output stabilization. With this two instants the difference in the sensor output is evaluated and the results are fed to the knowledge based system. At this time the user is asked to choose if the data has to be classified or used to increase the training set, in this case the user must classify the sample.

Fig. 2 shows the software front end where is visible a series of lights used to identify a class and a series of button used to classify a sample. The system can also save the acquired data into a file.

In this first release the knowledge based system is a probabilistic neural network. This choice is justified by the need to validate the proposed approach to the monitoring of olfactive injuries using standard analysis tool and not a dedicated one.
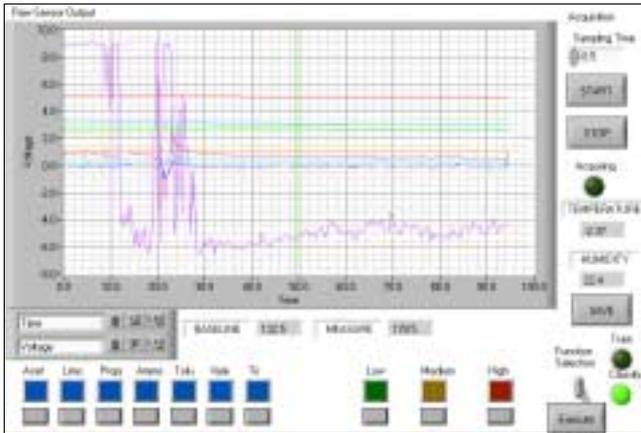
Fig. 2. Software front end

5. RESULTS

The designed system is for an "aggressive" environment where sulphurous compounds are present and can poison the sensors. The first series of tests are aimed to find out modification in the system behaviour after exposition to some of these substances in concentration similar to those present in a landfill. The substances used have been hydrogen sulphide and carbon disulfide. Fig. 3 shows the behaviour of the system to acetone after its exposure to hydrogen sulphide. From the graph no significant modification can be noticed. Similar results have been obtained with the use of carbon disulphide.
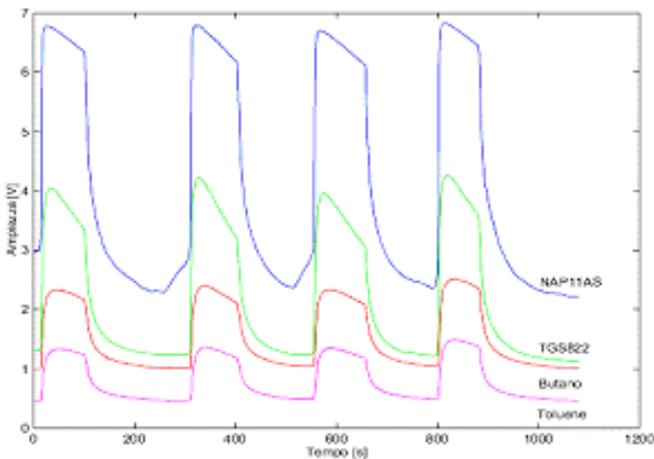

Fig. 3. Some sensor output to acetone after an exposure to hydrogen sulphide

The second test stage has been devoted to the characterization of the sensor array to their reported sensitivity in concentration near or in some cases less then the reported olfative threshold. The results of this test have been very encouraging as for each test a significant response has been get from more than one sensor.

The third test stage has regarded the increase of the sensor array coverage degree to substances very important for the application but whose specific sensors are not commercially available and manufacturers don't report them neither as spurious sensitivities.

TABLE III. Not reported spurious sensitivities found

Spurious Sensitivity	Sensor Type	Reported Sensitivity
Limonene	InO_2	Methylmercaptane, acetone, toluene
	SnO_2	Butane, acetone, benzene, isobutane
Trichloroethylene	Catalytic	Acetone, butane, methylethylketone, isopropyl alcohol
	InO_2	Methylmercaptane, acetone, toluene
	SnO_2	Toluene, isobutane
	Elec. cell	Carbon oxide sulphide
Perchloroethylene	Catalytic	Acetone, butane, toluene, xylene
	InO_2	Methylmercaptane
	SnO_2	Toluene, butane, isobutane
	Elec. cell	Carbon oxide sulphide
Carbon disulphide	InO_2	Methylmercaptane
	SnO_2	Butane, toluene
Trimethylamine	Catalytic	Xylene
	InO_2	Methylmercaptane, toluene, acetone
	Elec. cell	Isopropyl alcohol

Table III shows the results of these tests where in the first column is reported the substance, in the second one the sensor type that can detect it and in the third one the reported sensitivities for that type of sensor.

Actually the fourth test stage is checking the capability of the system to discriminate between different substances. This is done with single gases in three different concentration prepared in laboratory. The gases used are ammonia, limonene, isopropyl alcohol, acetone, toluene, xylene and trichloroethylene. Until now the results obtained have shown that a huge amount of samples is needed in this stage to obtain significant results. With about ten samples for each gas the system manage to recognize only two or three of them depending on the used concentration, but even for the gases it can discriminate it cannot evaluate the correct concentration.

6. CONCLUSION

In this initial phase of the development of an artificial olfactory system for the classification of odours in a landfill, a suitable array of commercial sensors has been chosen, an electric conditioning system and a data acquisition and analysis system developed.

The results obtained from the tests show that the sensors are not poisoned from the substances present in a landfill, moreover also their repeatability do not seem to be affected

from the aggressive environment they are supposed to work in.

Moreover the sensor array has been characterized to detect substances in concentration similar or even less than that found in a landfill. Substances of key importance in this application have also been detected by the sensor array even if they were not reported as sensitivity.

The discriminating capability of the system is yet not so high maybe due the insufficient number of sample used in the training process. This number will be increased in the future but this feature is not the so important as the system is designed not to give the chemical composition of the atmosphere but a qualitative judgement on it. So the next step in the development of the odour classifier is the system training on-site to classify the odours by a panel of human expert.

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