



SENSPOL SURVEY OF SENSOR CAPABILITIES

Sensors for the Abatement of Water Pollution from Contaminated Land, Landfills and Sediment

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Executive Summary

This report is based on the findings arising from a questionnaire designed specifically to identify current sensor development research and the capability of the devices in monitoring groundwater, sediment and contaminated land pollution. The questionnaire was distributed in November 2002 amongst the European research institutions, universities, organisations and companies that are members of the SENSPOLE network. The questionnaire was well received, resulting in 48 returned questionnaires by December 2002. The present report analyses all responses from the questionnaire.

The report focuses on:

- heavy metals with specific attention to mercury-related problems;
- aromatics and non-chlorinated hydrocarbons;
- chlorinated volatile, semi-volatile chlorinated compounds with particular attention to DNAPLs (Dense Non-aqueous Phase Liquids);
- General pollutant toxicity testing.
- Other targets including: pH, conductivity and redox potential; phenolic compounds; anionic and cationic analytes; nitrogen dioxide gas.

The report features 42 sensors, biosensors and detection kits within the 32 included entries (7 Companies, 15 Universities and 10 Research Institutes), spanning 13 European countries. Many of the sensors featured are biosensors or immunoassay based platforms. However, there are other monitoring systems included that are able to measure the specific analytes addressed by this report.

The report is introduced with a brief account of sensors, instruments and relevant integrated technologies. The compiled inventory study goes on to give an overview of sensors that can potentially be applied to environmental samples. The report contains information on the status of development, the sensor characteristics in terms of sensitivity, detection levels, selectivity, usability and other relevant information.

Extra information was asked of the developer concerning their opinion of how they felt their sensor's development had been impeded and whether there was anything that

may have helped alleviate this problem. As much sensor development is co-partnered questions were asked about collaboration and commercial backing. Finally, as the aim of the report is to facilitate information transfer an order to close the gap between research development and end users, the responder was asked how they felt this could be addressed.

A report derived from the present full report has been supplied to the European Network on Industrially Contaminated Land (NICOLE).

Conclusions

The response to the sensor survey was very good. Of the 32 selected developers featured in the report 7 are companies, 15 were from universities and 10 from research institutes all coming from 13 European countries. The report features 42 sensors, biosensor and detection kits able to detect a wide range of analytes including DNAPLs, LNAPLs, aromatic, and halogenated compounds, heavy metals, toxicity, genotoxicity, gases, and anionic, cationic and phenolic compounds. Also general parameters like pH, conductivity and redox potential can be measured.

The targeted analytes and parameters were divided into four categories: hydrocarbons; heavy and trace metals; toxicity testing; and other targets (general parameters, gases, anionic, cationic and phenolic compounds). The following are the main extrapolated findings.

Sample extraction devices

Detection of hydrocarbons in the field for environmental samples often requires sample extraction and preparation prior to measuring, especially in soil and sediment matrices. The report features two different sample extraction field based approaches:

Cranfield University has developed a field based Supercritical Fluid Extraction (SFE) device and protocol that can be employed in the field for PAHs but can be adapted to other analytes. Exposmeter have developed a semi-permeable membrane that can accumulate the whole range of target analytes of interest such as DNAPLs, LNAPLs, aromatic, chlorinated and PAHs in environmental samples. Both devices can be used in conjunction with a variety of commercially available detection systems.

Hydrocarbons

Devices have been selected that target priority analytes such as DNAPLs, LNAPLs, aromatics and halogenated compounds.

Out of the 15 featured sensors measuring hydrocarbons, six are available as fully commercialised analytical devices or demonstration units. LNAPLs, DNAPLs and PAHs can be detected by six sensors, of which four are commercially available. The RIANA device is a fluorescence-based immunoassay biosensor that is adaptable to many analytes and has demonstration units commercially available. Detection levels of these units are in the sub-ppb range.

Heavy metals and trace metal detection

The sensors described cover the full spectrum of heavy and trace metals that are commonly measured in environmental samples.

Of the 14 featured sensors that can detect metals, there are four devices, from Niton Europe GmbH, the universities of Neuchatel and Geneva and DBM that are fully developed and commercially available. Heavy metals in environmental samples have sub-ppb detection requirements. The devices developed by Aboatox Oy, Ben Gurion University and VITO are all bacteria-based detection systems. The sensors utilise genetically engineered strains of a bacterium. The Ben Gurion device is easily deployable in the field and can also detect genotoxicity levels in the sample. The two (bacteria-based) systems from Aboatox Oy and VITO are commercially available.

Toxicity and genotoxicity

Bio-accumulation and high levels of persistent organic pollutants and heavy metals in the environment can have a toxic effect on many simple organisms, invertebrates and whole cells. By utilizing this phenomenon toxicity test kits have been developed that are able to give an early warning and semi-quantitative detection in environmental samples.

Only two of eight reported toxicity test devices (the Mosselmonitor[®] by Delta Consult and that produced by the University of Aberdeen/ Remedios Ltd) are available commercially. However, Cybersense Biosystem Ltd has a portable toxicity testing system that will be available commercially in the near future. All of the test kits and biosensors are able to detect toxicity in environmental samples.

Other targets: general parameters, gases, anionic, cationic and phenolic compounds

Sensor devices able to measure general parameters like pH, conductivity, and redox potential as well as analytes like calcium, potassium, nitrate, nitrogen dioxide, chlorine and phenolic compounds are featured here.

All but one of the sensing devices is based on the use of electrochemical principles (IMB-CNM, Cranfield University and University of Ulster) while the one that is not, is based on an optical principle (Coventry University). The sensor devices can be used in variety of sample matrices including freshwaters, gas samples, surface water, groundwater, soils and pore water in clay materials.

Bottlenecks in sensor technology

Bottlenecks that impede sensor technology can be categorised into three sections:

- **First stage:** sensor and sample experimentation conditions.
- **Middle stage:** design and conversion of a crude laboratory-based device into a prototype demonstration unit.
- **Last stage:** final design, production and sensor marketing.

Bridging the gap between sensor developers and end-users

There were a number of areas where developers felt improvements could be made to alleviate some of the problems they encountered during device development and commercialisation. These included:

- Greater communication between instrument developers and end-users.
- Information transfer and communication links between governmental regulators and technology developers (heightening awareness of available technologies).
- Closer collaboration and partnerships with other developers and specialists.

Suggestions that could address these problems were:

- Providing a complementary question survey designed for industrial and potential end-users, with the results published (anonymously if need be) for perusal by the developer and other interested parties.
- Regular workshops, symposia and networking meetings bringing end-users, government, regulators and developers together for information transfer and networking.
- Funding programmes and collaboration incentives for sensor development, based on end-user needs.
- Making funding application processes more efficient and shorter, with administrative benchmarks and more transparent selection procedures.

Several other devices that had not featured in the questionnaire replies were demonstrated in the SENSPOL Technical Meetings in Sevilla, Spain, in November 2002 and in Koblenz, Germany, in October 2003. These devices are briefly mentioned in the Conclusions and Overview section and some of them can be viewed on DVD/video.

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