Biological Monitoring in Air Quality Policy in England and Wales

L. DAVIES*, J.N.B. BELL*, C.H.K. LEUNG*

The term biological monitoring is defined in the forthcoming EU Standards on Air Pollution (CEN, 2011) as 'the use of biological systems to monitor environmental change over space and time'. This broad definition is often used by policymakers to include a range of biological management regimes that, whilst not all directly linked to the cause or causes of biological change, nevertheless provide information that can be used in conjunction with appropriate pollution datasets.

The largest and longest running biological survey is the Countryside Survey (Carey *et al.* 2008), which provides scientifically reliable evidence about the state or 'health' of the UK's countryside today. Data have been collected at regular intervals since 1978 and are used to identify change (and the relative rate of change). This evidence is used to inform policies that influence management of the countryside. Data is publicly available and can be used in combination with for example air pollution data.

Biodiversity Indicators are used to monitor progress towards delivering responsibilities under the Convention on Biological Diversity (United Nations, 1992) by showing changes in aspects of biodiversity, such as the population size of important species, or the area of land managed for wildlife. The Research on the Eutrophication and Acidification of Terrestrial Ecosystems (UKREATE, 2010) programme, funded by the Department of Environment, Food and Rural Affairs (Defra) and the Natural Environment Research Council (NERC) is of mostrelevance to air pollution controls. The project, covering 135 field sites, has several aims, including: to collate data, which provide evidence for damage or recovery in a range of terrestrial habitats due to nitrogen deposition; to determine whether factors, such as the form of nitrogen, grazing pressure or traits of plants present, modify the impacts observed; to test proposed indicators of change in both experimental and survey settings. Early studies using bio-indicators have been inconclusive. The project is linked to a range of European responsibilities.

The UK conservation agencies (Williams, J.-M. *et al.,* 2006) have developed common standards for monitoring a range of vegetation including lichens and mosses. Although they are not directly linked to air pollution they have some methodological aspects in common with the forthcoming CEN Standard on Air Quality – Biological monitoring: assessing epiphytic lichen diversity.

Collaboration at the European level using bio-accumulators, organisms that accumulate substances present in the environment at the surface and/or internally, is delivered through the auspices of the United Nations Economic Commission for Europe's (UNECE) Long-Range Transboundary Air Pollution Convention (LRTAP, 2011) under the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) Moss Bio-monitoring Network. The objective is to determine and predict the state of ecosystems (or catchments) and their changes over a long-term perspective with respect to the regional variation and the impact of air pollutants including effects on biota. Data have traditionally focused on metals but have been extended to nitrogen in recent years. Such applications provide information on metal concentrations, highlight hotspots and trends, and can be used to validate computer modelling.

Research was commission in 2007 (Bealey *et al.,* 2008a, 2008b) by the Environment Agency (EA), the responsible body in England and Wales for permitting the largest, more potentially polluting industries under the European Union Integrated Pollution Prevention and Control Directive (96/61/EC), to assess the value of bio-monitoring for use in industrial regulation. A number of studies was completed, covering a range of bio-monitoring techniques, although not using mosses or lichens. The purpose of the study was to determine the effectiveness of such approaches in tightening the coupling between emissions and their consequences (harm) primarily as a more cost-effective measure than ambient air concentration-based regulation.

The study concluded that there was:

- insufficient information on the links between emissions and their environmental consequences, under realistic, site-specific conditions and taking into account such confounding factors as local climate and topography as well as growing conditions such as soil type and availability of water;

* *Centre for Environmental Policy, Imperial College London, London SW7 2AZ.*

- a lack of sampling protocols and monitoring tools which could be implemented with sufficient statistical rigour to assess ecological status at the required levels of temporal and spatial sensitivity;
- a lack of a rigorous framework for assigning monetary and especially non-monetary values to a particular system.

Despite these concerns further development work was recommended.

The Environment Agency and other UK statutory bodies, through a collaborative framework, maintain an online information service on air pollution and vegetation (APIS, 2011) which includes a range of biological monitoring methods. The methods are categorised based on the pollutant and ecosystem of interest and cover the following pollutants: acid deposition, nitrogen oxides, ammonia, nitrogen deposition, ozone, sulphur dioxide, dusts, VOCs, halogens, heavy metals and persistent organic pollutants. To assist the user in deciding whether to consider a method or not, each method/pollutant combination has been ranked on robustness, ease of use, and state of development. Approaches include monitoring ammonia with lichens based on a methodology developed in France (Lallement, 1999) and monitoring ozone using *Nicotiana tabacum* drawing on a range of research under Eurobionet (Klumpp *et al.,* 2004) and other sources.

The EA sometimes uses biological data as part of its permitting process. Computer models may be used to generate contour maps illustrating the pollution emission footprint and these can then be linked to conservation data to identify areas of sensitivity for species or ecosystems. Field-based investigations may subsequently be commissionedto validate the information. A survey was commissioned, for example, when protected lichen species were identified within the footprint of a regulated process. Data from the British Lichen Society (BLS, 2011) was made available to the Environment Agency but a survey was commissioned by the EA to substantiate the record. Where sensitivities are identified, plant operators may be required to investigate improvements to their emissions. Also the EA may require the plant operator to commission a monitoring programme. If sufficient evidence of harm is found, permits can be tightened.

Where deemed appropriate, the EA and the conservation agencies, as their statutory consultees under IPPC, may commission biological monitoring studies at site level for processes such as intensive agriculture (Pig & Poultry Farming), where very localised emissions of substances such as ammonia may affect lichen and bryophyte populations and community structure. This serves to determine the footprint of the emissions (there may be several local sources) as well as monitor its impact.

In a recent review of bio-monitoring practice in the UK (Leung, 2011) a number of reasons were given by interviewees (policymakers and industry) when questioned about the limitations of bio-monitoring:

- Prosecution for non-compliance: It was generally felt that whilst biological changes could often be clearly determined, it was difficult to attribute these directly to a particular emission source. In addition, it was felt that there are confounding factors, such as climate or disease, which are open to questioning and can further weaken the evidence required to support any legal action.
- Harmonisation: It is widely recognised that national standards do not exist and therefore methodologies are not comparable across the UK and at European level. The widespread application of bio-monitoring in Germany, for example, is widely attributed to national guidelines produced by the German Association of Engineers (VDI, 2011).
- Funding: All forms of monitoring for regulatory purposes have resource implications. Investment in computer model development and in biological databases in recent years has greatly reduced costs and increased monitoring efficiency. Similar levels of investment in biological monitoring are unlikely unless this technique is incorporated into IPPC Monitoring Guidelines (BREF Notes Ref) and other management frameworks.
- Timescales: Repeat sampling is required for biological monitoring requiring significant long-term commitment of resources. Governments tend to fund programmes over the short term although monitoring programmes, once established, tend to remain in place.
- Expertise: Declining interest in taxonomy and field-based studies was considered a limiting factor for lichens and bryophytes.
- Communication: It was suggested that bio-monitoring is not as easy to convey as the current numerical threshold effects system used in the EU Air Quality Framework Directive (Directive 2008/50/EC).

In conclusion, it appears that interest in biological monitoring by the regulatory authorities is increasing although there are no plans to introduce national monitoring at the present time.

New developments at the European level may however expedite matters. A review of the IPPC BREF on Monitoring is currently under way at European level with biological monitoring recommended by several member states under the ‘wish list’ of items for consideration. Forthcoming EU CEN Standards for monitoring air using grasses, *Nicotiana tabacum*, mosses and lichens may help to address the issue of harmonisation. The need to rebuild ecological skills particularly in species, especially amongst lower plants, has been acknowledged in a number of studies and endorsed by a recent report commissioned by the Institute of Ecological and Environmental Management (IEEM, 2011).

Evidence that large-scale public biological monitoring programmes do raise awareness of the important issue of pollution and a healthy environment, and can lead to a more empowered and active local community is increasing. The educational benefits were illustrated in projects in the 1960s (Mellanby, 1974) and more recently through programmes such as the Eurobionet programme (Eurobionet, 2011) where schools and communities were able to take part in local bio-monitoring projects (Calatayud & Sanz, 2008; Bucker *et al.,* 2008). Further evidence of general public interest in the topic is arising through the OPAL project (Davies *et al.,* 2011), an England-wide programme (OPAL, 2011) that includes biological monitoring surveys covering pollution (air, water and soil), biodiversity and climate. Over 20,000 sites have been surveyed by communities to date, including 2,000 schools, demonstrating that biological monitoring can help to convey complex information in a fun and enjoyable way whilst also providing useful environmental data.

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