Environmental Management Strategies

EuroBionet: A Pan-European Biomonitoring Network for Urban Air Quality Assessment


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Abstract. EuroBionet, the 'European Network for the Assessment of Air Quality by the Use of Bioindicator Plants', is an EU-funded cooperative project currently consisting of public authorities and scientific institutes from 12 cities in 8 countries. In 2000, the bioindicator plants tobacco (Nicotiana tabacum Bel W3), poplar (Populus nigra 'Brandaris'), spiderwort (Tradescantia sp. clone 4430), Italian ryegrass (Lolium multiflorum italicum) and curly kale (Brassica oleracea acephala) were exposed to ambient air at 90 monitoring sites according to standardised methods. Visible injuries and growth parameters were assessed and the accumulation of toxic substances in leaves determined. The exposure of tobacco resulted in a gradient with low levels of ozone-induced foliar injury in N and NW Europe, and medium to high values in the southern and central regions. The results of heavy metal and sulphur analyses in rye grass samples generally showed low to very low sulphur and low to medium heavy metal concentrations in leaves. In some cities, however, local hot spots of heavy metal contamination were detected. Analyses of the PAH contents in curly kale leaves gave low to medium values, with locally elevated levels at traffic-exposed sites.

Keywords: Air quality; bioindicators; biomonitoring; curly kale; EuroBionet; heavy metals; ozone; mutagenic substances; polycyclic aromatic hydrocarbons (PAH); poplars; standardisation; standardised grass culture; tobacco; tradescantia; urban air quality assessment; urban pollution

Introduction

Despite a successful reduction of emissions during the last decades, air pollution is still a matter of concern in many European cities. Today, transport is considered the most important source of pollution in urban areas. The rapid growth of the private car fleet and the average vehicle mileage is going to counteract the diminished emission rates of the individual automobiles after the introduction of catalytic converters and low-pollution fuels [1,2]. In 1995, it was estimated that about 25 million people of 115 large cities all over Europe (including Non-EU countries) were exposed to winter smog conditions, with WHO air quality guidelines for SO2 and particulate matter (PM) exceeded at least once a year, and about 37 million were exposed to summer smog conditions [1]. According to model estimates, a further improvement of urban air quality is expected until 2010, but the air quality objectives will still be exceeded for a considerable percentage of the urban population, particularly considering NOx and PM10 [3,4].

In accordance with the EU Air Quality Framework Directive [5] and with national legislation of the member countries, the air quality in urban agglomerations and zones where exceedances of limit values are expected is being assessed by the help of emission inventories, modelling and measurements of ambient pollutant concentrations. This approach allows the control of whether the air quality complies with the standards established by the so-called daughter directives or by national laws. The results of such procedures, however, do not permit the drawing of direct conclusions on the effects of the determined concentrations on living organism as the response to environmental pollutants does not only depend on the pollutant dose, but on numerous other external and internal factors such as climate, nutrition, predisposition, and age. Additionally, the simultaneous exposure to various pollutants and/or other biotic and non-biotic stress factors may alter the sensitivity of organisms to pollutants. Particularly the effects of chronic exposure to low concentrations of different contaminants can hardly be detected by means of conventional air pollution measurements. It is therefore of fundamental importance for air quality control to verify whether the measured air pollutant concentrations cause negative effects on living organisms.
Biomonitoring is an appropriate means to detect and to monitor air pollution effects. The exposure of accumulative bioindicator plants which accumulate toxic substances in their tissues, and of sensitive indicator species which respond to ambient air pollution with visible injury symptoms, provides information on the air pollution impact complementing the data obtained by physical and chemical measurements and modelling [6,7]. The effects of tropospheric ozone and heavy metals on crops and wild plants, for instance, is being addressed by the UNECE’s ICP Vegetation [8] using bioindicator plants mainly in rural and remote areas. Biomonitoring of air quality in urban agglomerations has been in practice mainly in Germany, Austria and the Netherlands for many years, but the routine use of bioindicators in urban areas is still not very common in most European countries. A prerequisite for the comparability of results from different studies, and thus for the acceptance of this biological method for air quality control by public authorities and technical institutions, however, is an exhaustive standardisation of the methods regarding cultivation, exposure, effect assessment and data evaluation [9,10].

Besides these scientific and technical aspects, bioindicator plants are adequate means of communicating aspects of environmental pollution to the broad public, as especially visible injury symptoms are much more perceptible and comprehensible for laymen than data on ambient air pollutant concentrations can ever be. Bioindication makes air pollution problems visible and understandable to people directly and within their everyday life, whereas these problems are normally quite abstract [11,12].

This was the background for the implementation of the project 'European network for the assessment of air quality by the use of bioindicator plants' (EuroBionet) in 1999. This network consisting of local authorities and scientific institutions from 12 cities in eight EU countries, co-ordinated by the University of Hohenheim and backed by the LIFE Environment Programme of the European Commission, aims at establishing local bioindicator networks under strongly standardised methods in order to

- establish the use of bioindicators for the assessment of urban air quality at European level
- contribute to the standardisation of methods
- analyse and evaluate the urban air quality in Europe
- compare pollution types among different cities and regions
- demonstrate the effects of air pollutants in a way easily comprehensible for laymen
- contribute to a sensitisation of the urban population towards environmental issues
- stimulate initiatives in schools, companies, public authorities and private households
- use the city’s commitment for environmental protection in municipal marketing campaigns.

Below, the structure of the project, the methods of bioindication and summarised results of the first year of plant exposure in the field are presented. For the communication concept and practical examples on its use, please refer to [13].

1 The Network
The following local and regional authorities are currently participating in the EuroBionet: the cities of Copenhagen (DK), Düsseldorf (D), Edinburgh (GB), Glyfada (GR), Klagenfurt (A), Sheffield (GB), Valencia (E) and Verona (I), Grand Lyon (F), Grand Nancy (F) and the regional government of Catalonia/Barcelona (E). On a local level, most of the municipal authorities are co-operating with scientific institutes for the execution of parts of the working programme. The city of Ditzingen (D), in the northwest of the conurbation of Stuttgart, is collaborating as an associate partner.

In each of the cities, local bioindicator networks consisting of 8–10 exposure sites were implemented, including one or two reference sites with low levels of primary air pollutants, as well as urban, suburban, and traffic sites. As far as possible, the bioindicator stations were installed at or near to already existing air monitoring stations in order to facilitate the comparative evaluation of air pollution, climate and bioindication data. The network of Ditzingen consists of six stations which, for the presentation of data, were joined with four stations on the university campus and in the southern part of the urban agglomeration of Stuttgart to form one local network of Ditzingen/Stuttgart. Altogether, 90 bioindicator sites were in operation in 2000.

The University of Hohenheim has installed a co-ordination centre which, besides the general administrative and scientific co-ordination, is in charge of elaborating and supervising the standardised methodology guidelines, training of local working groups and acquisition and distribution of plant material, consumables for cultivation and exposure equipment. Plant analyses as well as data evaluation are also organised centrally. The local working groups, by contrast, are responsible for the installation and maintenance of the bioindicator networks, the cultivation and exposure of bioindicator plants, the assessment of visible symptoms and growth, the sampling of plant material, the provision of air pollution and meteorological data, and the implementation of the communication concept.

2 Materials and Methods
The following bioindicator species were chosen for the assessment of effects of ozone, sulphurous compounds, heavy metals, polycyclic aromatic hydrocarbons (PAH) and mutagenic substances.

**Tobacco** (*Nicotiana tabacum*): The ozone-sensitive tobacco strain Bel W3 is cultivated from seeds according to the draft of the VDI guideline 3957/6 [14]. 4–6 plants are exposed at each station for eight consecutive periods of two weeks each between the end of May and mid September. At the end of the exposure, the percentage of ozone-induced lesions on three pre-determined leaves is estimated in steps of 5% of leaf area with the help of a photo catalogue.

**Poplar** (*Populus nigra*): Cuttings of the ozone-sensitive poplar clone 'Brandaris' [15] are continuously exposed at each of the bioindicator stations for the whole period between the end of May and mid September. Visible injuries, number of leaves and shoot height are determined bi-weekly.

**Curly kale** (*Brassica oleracea acephala*): Curly kale plants are cultivated from seeds according to the method proposed by [16]. Four plants are exposed at each station for a period of eight weeks between October and December. Afterwards,
PAH concentrations of a mixed sample of 8 pre-determined leaves of each plant are analysed by GC-MS.

Italian rye grass (Lolium multiflorum italicum): Standardised grass cultures are produced and exposed following the draft of the VDI guideline 3957/2 [17]. In all 5 exposure periods are performed between May and October. The sampled leaf material is dried, ground, digested in a microwave oven and analysed for heavy metal contents by AAS. Dry leaf powder is used for the determination of sulphur concentrations using an automatic S analyser. Standard reference material BCR 129/281 serves for quality control. By a statistical treatment proposed by VDI [17], local background levels for each element and each study area were determined, and European reference levels were calculated by pooling all data. Based on these European background values for the exposure year 2000, a four-stage classification system was developed for the evaluation of the analytical results, and local background values of the different cities and mean values of the individual sites were classified according to this system.

Spiderwort (Tradescantia sp. clone #4430): The Tradescantia micronucleus (Trad-MCN) test is carried out according to a standardised protocol [18]. Cuttings from the stock culture in Hohenheim are dispatched to the participating cities by express courier. After 24 hours of recovery, 15 cuttings are exposed at each station for 12 to 30 hours. The inflorescences are then sampled, fixed and returned to the co-ordination centre where the formation of micronuclei in the pollen mother cells is microscopically scored.

For the cultivation of all species, a mixture of standardised soil type ED73 and river sand is used, except for rye grass where soil type 0 (without fertiliser) and nutrient solutions made from reagent-grade chemicals is taken. All plants are grown in plastic pots in the greenhouse, using a semi-automatic watering system (glass fibre wicks). The exposure of tobacco, curly kale and poplar in the field is done on metal racks at a height of about 1–1.2 m above ground, with plastic basins as water reservoirs, styrofoam plates with drillings to accommodate the pots and shading fabric (except for curly kale), according to the system proposed by [6]. For grass cultures, the system described by [17], providing an exposure height of 1.5 m above ground, is used. The Tradescantia cuttings are exposed in little containers covered with shading fabric at a height of 2 to 2.5 m above ground.

The methods of cultivation, exposure, injury assessment, sampling and data evaluation are described in an internal manual of methods that was distributed to the working groups.

3 Results and Discussion

The following are some exemplified results of the exposure experiments performed in 2000. No data from Barcelona, Valencia and Glyfada were included as these cities joined the network at a later stage. Detailed results are given at www.eurobionet.com and will be published elsewhere.

Fig. 1 gives the summarised results of the tobacco exposure during four periods between July and September 2000 as well as the local variation of O₃ effects due to differences in atmospheric levels of O₃ precursors and microclimatic conditions. A gradient from the N and NW of Europe to the southern and central regions can be recognised, with low injury degree in the UK, Denmark and NW-Germany and high to very high levels of O₃ injury in France, Italy, Austria and S-Germany. The very low injury levels in the British cities, Copenhagen and Düsseldorf can probably be explained by the cool and rainy summer experienced in northern Europe during that year. Comparisons between different cities should always be done very carefully as climatic parameters strongly influence the response of plants to elevated O₃ concentrations, and should therefore only be made on the basis of the observed foliar symptoms without drawing direct conclusions on the O₃ levels responsible for the development of leaf damages. Further conclusions will only be possible after an accurate evaluation of the O₃ exposure characteristics and climatic parameters measured at the air monitoring stations located at or near to bioindicator sites.

During last summer, campaigns with the Trad-MCN test were performed which proved the suitability of the established methodology. Due to the relatively high variability, the differences

Fig. 1: Percentage of ozone-induced leaf injury on tobacco leaves (mean values of 4 exposure periods between July and September 2000). Classification as shown in the http://www.eurobionet.com web page

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of the micronuclei rates observed between the individual sites of the local networks were not statistically significant in most cases. However, we found two sites in Edinburgh and one in Verona with a significantly increased number of micronuclei when compared to other sites in the same city. All these sites are characterised by high traffic emissions whose mutagenic potential has been demonstrated in previous studies [19].

On the whole, our background values for grass cultures were in good agreement with published background values from several German monitoring networks [17]. Concerning the S accumulation in rye grass samples, the local background in most cities lied in the range of low to very low concentrations. Elevated or distinctly elevated mean values were found at several sites in Nancy, Edinburgh, and Sheffield. Most of the local background values for heavy metals were also in the range of low to very low concentrations applying the concept explained above. Different from the impact of ozone, the results of rye grass exposure did not show a general geographic distribution, but reflected local emission conditions. The economy of Sheffield, for example, is still based on steel plants, although a diversification into other sectors is taking place. As a result of the emissions from local industrial sources, one site in Sheffield is exhibiting an extraordinarily high Cr value and also the highest Cd, Fe, Pb, and Ni levels of the whole bioindicator network. Another example for the importance of local sources is Düsseldorf where relatively high Cd, Cr, Fe, and Pb levels and the highest Cu concentrations of all cities were obtained at two sites in the city centre and at a road crossing with intense automobile traffic. Fig. 2 illustrates the example of Pb for which we observed quite low levels at most stations of the network, reflecting the general reduction of Pb pollution after the adoption of unleaded petrol [1]. In some cases, however, elevated levels were found at sites with high traffic and/or industrial emissions.

Fig. 3 gives the overall results of the PAH analyses of curly kale leaves displaying the sum of 16 'priority pollutants' according to US-EPA. The concentrations were mostly below

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Fig. 2: Follar lead concentrations (μg/g dw) in rye grass cultures (mean values of up to 5 exposure periods in 2000). Classification as shown in the http://www.eurobionet.com web page

Fig. 3: Follar PAH concentrations (μg/g dw, 16 priority pollutants according to US-EPA) in curly kale leaves after eight weeks of exposure in October–December 2000
1 µg PAH g⁻¹ dw, but maximum values of up to 2.7 µg g⁻¹ dw were found at several traffic-exposed sites in Klagenfurt, Lyon, and Verona. These PAH levels are comparable to data from Germany and Austria [16,20]. A more detailed analysis of the concentration levels of the individual components and the ratios between them as well as on the possible influence of climatic parameters [21] is under way.

4 Conclusion

This paper can only give a rough survey of the objectives and methods of the present project, as well as some preliminary results of the first year of field experiments. A detailed evaluation of the results will only be possible after conclusion of all analyses in 2002. However, it can already be stated, on a worldwide scale, that there is no other bioindicator network of comparable extension using such highly standardised methods. The exposure trials may therefore be considered as a demonstration experiment as well as a test campaign for a Europe-wide standardisation of biological methods for environmental quality control. With the same intention, a cooperation with the UNECE/ICP Vegetation has been settled. In this way, we hope to contribute to an establishment of biological air quality monitoring on a European scale and particularly within the environmental policy of the European Commission.

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