Biomonitoring: measuring air quality

White Paper

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Biomonitoring: certainty about air quality

Industries that release airborne particulates must meet strict emission standards set by the Dutch government. Even so, farmers and local residents still routinely question whether these emissions are ending up in their immediate surroundings. Biomonitoring – the use of plants to measure air quality – addresses the concerns of the farmers and local residents alike. What are the possibilities that biomonitoring has to offer, and how can such a programme be established?

Safe and hygienically grown agricultural products

Consumers and companies want agricultural products to be grown under safe, hygienic conditions. Eventually, farmers in the immediate surroundings of a large factory or plant, who see a plume of smoke streaming 24 hours a day, seven days a week from one or more smokestacks, begin to wonder what exactly the plume contains and what risks this may represent for their crops and products. The fact that the plants generally comply with Dutch rules and regulations and regularly conduct measurements of their smokestacks does not entirely assuage these concerns. Quality assurance and traceability (track & tracing) - the ability to follow a product through the chain from farmer to consumer, is becoming increasingly important. Demonstrating the absence of foreign substances in their products provides farmers with business certainty.

Sustainability and corporate social responsibility

Companies are striving for the most sustainable production process possible that can respect the health and safety of their employees and local residents, while offering with best possible environmental protection. Consulting with local residents about how business operations can contribute to a better quality of life in the area fits in with this aim. Agreements can be formed on how companies are to take responsibility for their production processes in order to prevent damage to agricultural and horticultural corps in the immediate surroundings. For companies, using biomonitoring to ensure product quality can help them realise their business objectives regarding sustainability and corporate social responsibility.

Support for communications with local residents

Provincial governments are generally responsible for issuing licences and supervising companies that release airborne particulates. The supervision and biomonitoring of crops and product quality offer provinces additional opportunities to communicate with local residents about the results of the smokestack measurements. Organisations like *Land- en Tuinbouw Organisatie Nederland* (LTO Nederland) - the Dutch Federation of Agriculture and Horticulture - and the Animal Health Service (GD) can use these measurements to estimate the potential risks for agricultural production and, should this prove necessary, to take action.

What is biomonitoring?

Plant-based biomonitoring is a technique that has been deployed extensively at both national and international levels. Plants are used either as *indicators* or as *accumulators*.

- *Indicators* are sensitive plant species with specific and general, observable symptoms that react to a particular air pollution compound.
- *Accumulators* are plant species that absorb and store a particular airborne compound relatively quickly, without displaying visible effects. These plants can be sampled and chemically analysed.

In both cases, the goal is early detection of the potential effects of the emissions released by the installation. Due to the choice of sensitive plant species, combined with other relevant agricultural products like cow's milk, biomonitoring programmes take on a warning function. This means that as long as the measuring points around the relevant installation(s) do not clearly exceed norms or background values, no negative effects are to be expected for the other crops and products cultivated in the vicinity of the installation. This approach has the advantage of only requiring a limited measurement programme to obtain adequate indications of the environmental quality around the installation. The investigation can only be extended to field crops if the results of the measurement points so warrant it.

Which substances can be monitored?

The compounds that can be included in a biomonitoring programme depend on the emissions being released. The properties of a given substance, such as toxicity, volatility and demonstrability, and its societal relevance, dioxins being an example, also play a role when assessing biomonitoring's possibilities.
Examples of the compounds identified in various monitoring programmes include heavy metals, polycyclic aromatic hydrocarbons (PAHs), dioxins and fluorides.

How is biomonitoring performed?

Biomonitoring programmes are established by setting up multiple physical measurement points at sites in and around the emissions source where sensitive and hyper-accumulating plant species are grown with standardised cultivation methods

Example of a biomonitoring measurement point. The air supply from the direction of the source should be impeded as little as possible by buildings and/or vegetation. Each location covers about 20 m2 and is cordoned off with mesh that is approx. 1 m tall, as well as a windbreak.

Assessments and analysis

After the plants have been cultivated for a specific period in the source's environment, they are visually assessed and analysed for several relevant air pollutant compounds. The analysis results are assessed by comparing them to the levels measured at a reference location outside the direct sphere of influence of the source (a local background level), national background levels and standards for consumption or animal feed quality.

Figure 1 below shows an example of the trend in the annual average PAH concentration found in spinach and kale in the immediate surroundings of the waste incinerator. See figure 2 for the trend in the dioxin levels found in cow's milk.

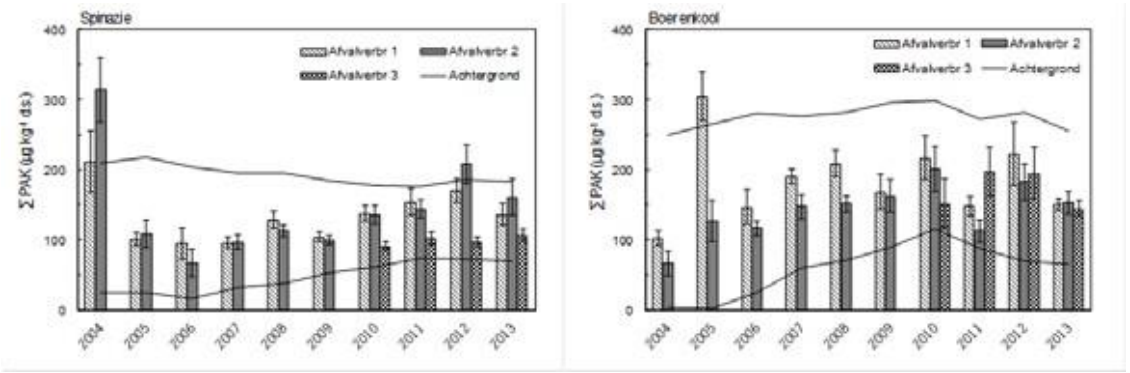

Figure 1 *Annual average (± SE) PAH concentration (µg/kg dry matter) in spinach (left) and kale (right) from the immediate surroundings of three waste incineration plants taken in years spanning from 2004 to 2013. The black lines indicate the bandwidth of the background level (Van Dijk et al., 2015).*

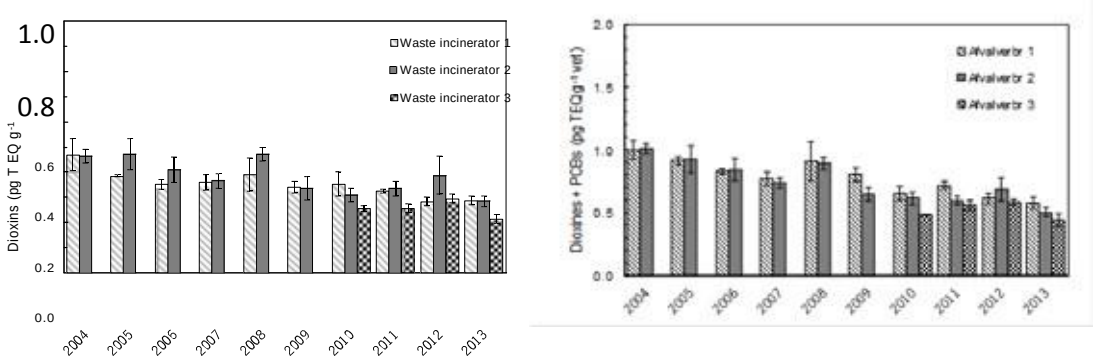

Figure 2 *Average level of dioxins (left) and dioxins+dioxin-like PCBs (right) found in cow's milk (pg TEQ/g fat) from several dairy farms in the immediate surroundings of three water incineration plants. The maximum acceptable levels for dioxins and dioxin-like PCBs in milk and milk products are respectively 2.2 and 5.5 pg TEQ/g fat (Vaughan et al., 2015).*

Container plant cultivation

The ongoing biomonitoring programmes primarily utilise accumulators: the plant species that absorb and store a given airborne compound relatively quickly, without developing any immediately visible effects. The crops are grown using standardised cultivation methods and, after a specific time period, they are analysed for select compounds. To be able to properly interpret the analysis results, the plants are grown in containers with standard, clean potting soil rather than out in the open. Doing so ensures that the airborne absorption is only determined for those

parts of the plant that are aboveground, thereby excluding the influence of local differences in the soil quality. Additionally, the dioxin and PCB levels are usually determined and tested at one or two dairy farms in the area and subsequently compared to the national background level. Table 1 shows an overview of a 'standard' interpretation.

Table 1

Overview of the plant species to be used for a biomonitoring programme, the compounds determined and the associated annual sampling frequency.

Crop/product	Response	Compound	Period	Annual sampling frequency
Spinach	Accumulation	Heavy metals (Cd, Hg, Pb) PAHs	Spring/summer	5
Kale	Accumulation	Heavy metals (Cd, Hg, Pb), PAHs	Autumn/winter	3
Cow's milk	Accumulation	Dioxins/PCBs	Spring/summer	2
Grass	Accumulation	Fluoride	Year-round	13 (every four weeks)
Gladiolus	Indicator	Fluoride	Summer	3

Seasonally determined programmes

The seasons determine the implementation of plant-based biomonitoring programmes. Assessments and/or analyses take place at different points throughout the year. See table 2 for this data.

Table 2

Overall planning for observations and sampling per calendar year.

Crop/product	Calendar week number											
Spinach				•	•	•	•	•				
Kale	•									•		•
Grass	•	•	•	•	•	•	•	•	•	•	•	•
Cow's milk					•				•			
Gladiolus						•	•	•				

What are the applications of biomonitoring?

Biomonitoring monitors the air quality around waste incineration plants, ore-processing industries and airports.

Farmers gain insight into the environmental impact on their crops

Biomonitoring provides farmers in the vicinity of a source insight into the environmental impact of foreign substances. Monitoring programmes established around waste incinerators have demonstrated that the concentrations of heavy metals, PAHs and dioxins match the background levels. Incidentally, some excessive levels were observed in the fluoride standard for animal feed (in grass). Although no causal relationship with the source could be demonstrated, the contribution of emissions to the levels found at the dairy farms could not be completely ruled out. Research has shown that biomonitoring is a suitable instrument for monitoring the effects of emissions on crops.

Improved relations between a company and the environment

Due to the mostly positive results (no effects), the programmes have contributed to a better relationship between the relevant companies and the surrounding area. Open communications are central to the results of the monitoring programme. Experience has taught us that this can reduce the anxiety of farmers and residents in the immediate surroundings. The key point is that any criticisms and areas of concern can be raised for discussion. To open the lines of communication, a supervisory committee was set up for most of the programmes that consisted of representatives for the parties involved (such as industry, local residents, the agricultural sector, the province and the administrator of the biomonitoring programme). The supervisory committee meets one to two times per year to discuss the outcomes of the biomonitoring programme. Potential adjustments to the programme are also discussed at this time. After drawing up the annual report, these outcomes are generally made public.

Biomonitoring: reliable and scientifically sound

The biomonitoring measurements performed by Wageningen University & Research are reliable and scientifically sound. Agricultural interest groups such as LTO Nederland and various provinces and industries have asked Wageningen University & Research to perform these measurements.

Biomonitoring offers the significant advantage of being a simple, insightful method to demonstrate that an industry's air emissions do not affect crop quality in the immediate surroundings. Biomonitoring measurements offer farmers reassurance about the continuing high quality of their crops. For local residents, these measurements offer a sense of security about the environment in which they live.

Appendix: Examples of biomonitoring programmes

Municipal Solid Waste Incinerator (MSWI); Alkmaar, the Netherlands

Biomonitoring research is conducted at the Municipal Solid Waste Incinerator in Alkmaar every year. The goal, on one hand, is to provide early detection of the effects on the quality of agricultural products and crops and, on the other hand, to establish whether the increase in background levels is attributable to the emissions released by the MSWI.
This biomonitoring programme, which was established in the early 1990s in consultation with farmers and LTO Nederland, has been repeated every year since its inception.
The biomonitoring research developed at the initiative of the MSWI is now being carried out by other waste processors in the Netherlands. 'The biomonitoring research further substantiates the MSWI's appreciation for open and transparent dealings with the environment', says Wim van Lieshout, general director of the MSWI.

Waste-fired Power Station (REC), Harlingen, the Netherlands

A monitoring programme was established here in Harlingen in 2010, while the plant was still under construction. Measurements from 2010 gave an indication of the current environmental impact on the agricultural area (northeast of Harlingen), without any contributions from the REC. The plant was operational by April of 2011, after which it released cleaned waste gasses into the air from a central smokestack.
At measurement points in and around the REC, spinach was grown during the spring and summer months, with kale being grown during the autumn and winter. The biomonitoring programme is scheduled to continue for an indefinite period.
Year after year, it is vital that agriculture stay abreast of any developments. To date, the measurement points have provided outcomes that match the national averages. The levels of the particulates that could originate from the REC and that are potentially harmful for crops and milk have remained within the norms for consumption quality.

Lelystad Airport

A monitoring study was carried out following the publication of the '*Convenant monitoring en nadeelcompensatie voedselveiligheid in de omgeving van de luchthaven Lelystad*'. This covenant detailed an agreement to study the effects of the airport expansion on food safety in the surroundings of Lelystad Airport, particularly in relation to requests for loss compensation.
As part of the monitoring, a year-long field research project was initiated in the spring of 2014: establishing a zero-measurement in the environment around Lelystad Airport and a reference measurement in the environment around Bremen Airport. In terms of size and air-traffic capacity, Bremen Airport is comparable with the planned expansion of Lelystad Airport, which will entail 45,000 aircraft movements with large aircraft. In both field researches, the deposition was measured for heavy metals and polycyclic aromatic hydrocarbons (PAHs) in food crops with a large leaf area that absorb airborne compounds air relatively quickly.
The biomonitoring research has shown that Lelystad Airport does not have an adverse impact on food safety in the environment of the airport. Furthermore, the heavy metal levels, for example, found in the agricultural crops of the environment will not increase if, in the future, there are additional aircraft movements.

More information?

Visit our website for examples of our biomonitoring projects (in Dutch only): { HYPERLINK "http://www.wageningenur.nl/biomonitoring-luchtkwaliteit" \h }

Interested in the opportunities biomonitoring can offer? Then contact us!

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