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Letter to the editor

In defence of plants as biomonitors of soil quality

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The use of plants as biomonitors of soil quality has important advantages, particularly on a large scale.

Abstract

Biomonitors are organisms that provide quantitative information on environmental quality. There are some constraints and limitations for the use of plants as biomonitors of soil pollution, as pointed out recently by some authors in this journal. However, we defend the use of plants as biomonitors, and argue that they have important advantages over soil analyses as indicators of soil quality, particularly when investigations are made on a large scale.

Keywords: Plant biomonitoring; Plant–metal interactions; Risk-based assessment; Soil quality

1. Introduction

Biomonitors are organisms that provide quantitative information on environmental quality (Bargagli, 1998; Markert et al., 2003). In a study of the plant–soil relationships in areas along the Guadiamar river, Southern Spain, that were affected by the 1998 mine tailings collapse, we concluded that the leaves of white poplar (*Populus alba*) could be used as biomonitors for soil Zn and Cd (Madejón et al., 2004).

In a recently-published invited paper in this journal, Mertens et al. (2005) cited our study "to illustrate some of the logical flaws which occur in the scientific literature". While conceding that our conclusion was correct, Mertens et al. (2005) went on to point out practical constraints and limitations of biomonitors compared to soil analyses. Briefly, they considered that plant biomonitors of soil quality were limited by five factors: (1) metal bioavailability and uptake is dependent on plant species and variety, therefore biomonitoring will be restricted to the range of that plant, (2) no single plant species responds to a wide range of contaminants, (3) leaf metal concentrations are a function of time, plant development and other environmental factors, (4) tree height can make leaf sampling difficult, and (5) roots may actively avoid metal hotspots. We accept the relevance of these points. However, we disagree with their conclusion that foliar analyses have little value for biomonitoring soil pollution. We would like to clarify the role of biomonitors as tools to measure soil quality, as distinct from the total metal concentration in the soil, which we agree, is best measured by direct soil analyses.

2. Biomonitoring soil quality

Soil quality can be defined as *"The capacity of a soil to function within ecosystem boundaries, to sustain biological productivity, maintain environmental quality, and promote plant and animal health"* (Doran and Parkin, 1994). Obviously, we do not propound that soil analyses should be forgone. The most effective way of determining the total metal concentration in the soil at any given point is, clearly to measure it directly, as we did it in our soil-poplar study (Madejón et al., 2004). Biomonitors indicate soil quality. They are not an analytical method to

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measure the total metal concentration. Plants as biomonitors have several important advantages over soil analyses when investigating soil quality, particularly on a large scale. By definition, biomonitors exhibit the effect of metal on living organisms, thus revealing information on soil quality that is difficult to measure using direct soil analyses. Regulatory authorities are increasingly adopting a risk-based approach when assessing soil quality (e.g., Swartjes, 1999; Tarazona et al., 2005). Risk-based assessment investigates the effect of contaminants on humans and ecosystems, rather than simply using the total contaminant concentration in the soil. Here again, biomonitors provide a direct measurement of a biological effect, rather than inferring values using soil extractions.

3. Advantages of plant biomonitoring

Consideration of the aforementioned constraints and limitations of biomonitors is essential when selecting biomonitors and interpreting data. Nevertheless, when compared to direct soil analyses, some of these apparent constraints and limitations are advantageous for evaluating soil quality. That metal bioavailability and metal uptake is a function of plant genotype (Points 1 and 2) means that a suitable plant biomonitor should be selected that best represents the risk associated with a future land use. For example, plants with a high root–shoot transfer are the most suitable biomonitors for land that is to be used for agriculture. This can give a worst-case scenario and elucidate which areas need remediation. Conversely, the soil quality of land that is to be left as a natural ecosystem may be best assessed by biomonitoring with plant species that are the most important primary producers, and most relevant in the food web of the ecosystem.

Polluted soils do not usually contain just one contaminant, and it is unlikely that one would find a universal biomonitor for a suite of contaminants (Point 2). Therefore, more than one plant species should be used. For example, in the case of biomonitoring soils affected by the Aznalcóllar mine failure, we have studied, in addition to poplar trees, some herbaceous plants, such as *Hirschfeldia incana* that accumulate thallium in their flowers and fruits (Madejón et al., 2005). Soil contaminants are often mutually correlated, because they are derived from the same source, e.g. a mine tailings collapse. Therefore, in some cases, biomonitoring of a single contaminant can provide information on the degree and extent of the general soil pollution. Moreover, the extent that a biomonitor accumulates a contaminant may indicate its relative impact on soil quality. Caution needs to be applied when using biomonitors in this way, as the mobility of individual contaminants in soil may differ.

Plant metal uptake is affected by a plethora of variables besides the total soil metal concentration (Point 3). This limits the usefulness of a biomonitor as an analytical method to investigate the total soil metal burden, but enhances its ability to measure soil quality. Biomonitors can provide site-specific information on soil quality, as they incorporate the local environment (Wright and Welbourn, 2002). Studies on the biology of metal uptake by potential biomonitors such as poplar (*Populus* sp.) and willow (*Salix* sp.) trees (Laureysens et al., 2004) increase their usefulness by elucidating the effects of plant age and management on metal uptake. Just as soil sampling requires a spade or auger, there is no special difficulty in sampling tree leaves from varying parts of the canopies using a pole pruner or similar device (Point 4).

Roots have been demonstrated to avoid or forage (Whiting et al., 2000) contaminant hotspots (Point 5), thus knowledge of the biomonitor's root strategy is essential to determine the presence of any hotspots on the scale of the individual plant. Ideally, such hotspots can be measured using a spatial grid of systematic soil analyses; however, this requires extensive sampling. Biomonitors are intended for large-scale screening, to distinguish heavily-contaminated from less affected areas and to detect gradients or borders for contaminated environments. For such purposes, the most widespread and well exposed plant species in the study area should be used (Bargagli, 1998).

At present, the greatest limitation to the effective use of biomonitors is the lacuna in understanding the biological component of plant–metal interactions. Site investigations based on plant biomonitoring need a number of different species. Since each is specific for a limited environment and contaminant range, having a large index will provide more tools for environmental assessment. Such indices could form a database from which suitable biomonitors can be selected to address a particular environmental problem. It is therefore disingenuous to dissuade future work on the use of plants as biomonitors of soil quality, because the biomonitor knowledge-base is in its infancy. Rather, investigations should continue apace, to augment the environmental tool kit available for risk assessment.

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