CONCERTED ACTION AROMIS ASSESSMENT AND REDUCTION OF HEAVY METAL INPUT INTO AGRO-ECOSYSTEMS

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ABSTRACT

Heavy metals which enter agro-ecosystems through various agricultural and industrial activities can accumulate in soils and may have long-term implications for soil health and function, the quality of agricultural produce and the wider environment.

Against this background, the EU financed the AROMIS Concerted Action, set up by KTBL and 23 research institutions from across Europe. The consortium aimed to provide a cross national assessment of heavy metals in European agriculture. The first step of the project consisted of the compilation of data on heavy metal contents in all relevant media. In a second step heavy metal balances on farm level were calculated for a selection of production types to have an instrument at hand for evaluating the relevance of the various input and output pathways. In a third part of the project the available options for reducing the heavy metal input were described and evaluated. It became apparent, that there is scope for reducing the heavy metal input in animal nutrition and animal hygiene as well as by changes in fertilisation management.

INTRODUCTION

Heavy metals which enter agro-ecosystems through various agricultural and industrial activities can accumulate in soils and may have long-term implications for soil health and function, the quality of agricultural produce and the wider environment. It is well known that a considerable share of the inputs of heavy metals into soils is a consequence of agricultural activities, namely fertilisation and the use of organic residual materials like animal manure, sewage sludge or compost. Additionally inputs not deriving from agriculture, such as atmospheric deposition, can contribute significantly to the heavy metal load on farmed land.

Still there are a lot of gaps in the knowledge about the pathways of heavy metals into the farms and finally into the soil. This refers to the significance of the various input pathways as compared to the total input, as well as to the options at hand to achieve a metal input reduction.

In view of the activities of the European Commission to develop a soil protection policy on European level (European Commission, 2002), European co-operation in heavy metal related research gains in importance.

The AROMIS Concerted Action was set up by KTBL and 23 research institutions from across Europe, representing EU-25 Member States, Accession Countries and Associated States aiming to provide a cross national assessment of heavy metals in European agriculture.

The main objectives of AROMIS can be summarised as follows:

- Assessment of the pathways of heavy metals in agro-ecosystems and evaluation of the significance of the various paths for the metal input and output.
- Provision of information on current legal regulations regarding heavy metals in agriculture.
- Description of technical and legal measures to reduce the heavy metal input and assessment of the effect of those strategies regarding their potential and the prospects of implementation in practice.
- Identification of future research and technology transfer demand.

- Creation of Europe-wide contacts between research institutions to link heavy metal related research activities in Europe and enhance the exchange of knowledge on ecological, economic, technical, and legal aspects.

Description of work

The project was divided into three major sections:

1.- Data collection

Collection of data and background information on heavy metals in agriculture in the participating countries. This includes the sources of heavy metals, the legal regulations on European and national level and the research activities in this field. To handle this data a MS-Access based database was set up.

2.- Heavy metal balances

An essential part of the project were heavy metal balances on farm level, designed to illustrate the inputs, outputs and internal flows of heavy metals and enable the simulation of the effect of input reduction strategies. For this an MS-Excel based balance tool was developed which allows the calculation of farm level balances. For a number of selected countries, where the data availability was sufficient, balances were calculated taking into account typical or model farms for livestock farming and crop production in the relevant country or region.

3.- Input reduction measures

Based on the balance results in the next step of the project options for the reduction of the heavy metal input were described and evaluated regarding performance as well as economic and ecological consequences.

In addition to the reduction measures the future research and development needs were identified, derived from the results of the assessment of the input reduction measures and the data gaps which became apparent when setting up the data base.

RESULTS

Input and output pathways

Atmospheric deposition is an important source of heavy metals to agricultural land, especially for Cd, Ni and Pb. However, a variety of different monitoring methods are being used by the AROMIS participants to measure deposition and the results obtained are not directly comparable between countries.

Mineral fertilisers, namely P-fertilisers, are important sources for Cd input, but might as well contribute significantly to the input of Cr and sometimes Ni. For the farms balanced in AROMIS, Cd and Cr inputs by mineral fertilisers, if used, had an average share of 30 and 40 % respectively of the total inputs.

Organic waste, like composts, sewage sludge, or industrial wastes, where applied, can be an important source of many heavy metals. There was considerable variation in the quality of sludges from the different countries. Zinc concentrations ranged from 242 – 3000 mg/kg ds, Cu from 94 - 1000 mg/kg ds; Cd from 0.5 - 20 mg/kg ds and Pb from 26 - 700 mg/kg ds. A similar variation of quality was found for composts. The application of sewage sludge might lead to a significant balance surplus of metals on farm level, depending on the level of metal contents in the material. This holds true even if sludges with much lower contents of metals are used as permitted according Council Directive 86/278/EEC. On a national scale organic wastes represent a relatively minor source of heavy metals to farmed land, because the area used for application is comparably small in most countries. Still, due to the relevance on field level, the inputs of metals

by these organic wastes should be carefully monitored.

In livestock farming one of the most important input pathways is animal feedingstuffs. Heavy metals are present in livestock basal diets (e.g. cereals, grass) at background concentrations and may be added to certain feeds as supplementary trace elements to maintain health and normal development and performance, for welfare reasons, or as growth promoters (Nicholson, 2002). For example, Cu is added to growing pig diets as a cost-effective method of enhancing performance, and is thought to act as an anti-bacterial agent in the gut. Zinc is also used in weaner pig diets for the control of post-weaning scours. Other metals (e.g. Cd, Pb) are not deliberately added to livestock feeds, but may be present as contaminants in the basal feeds or mineral supplements. Cr and Ni, even though considered essential trace elements, are not regulated. Only a very little fraction of the metals is retained in the animal, most of the metals in the feedstuffs are excreted and finally spread to the soils with the manure (Schenkel, 2002). Especially in pig and poultry production elevated levels of Cu and Zn can be found in the manures. It has to be taken into account that a considerable share of the metals in the feedstuffs derive from home-grown feeds, which means that those metals are not inputs into the farm but are cycling within the unit.

Apart from feedingstuffs other pathways like disinfectants are of relevance for livestock farming systems. The use of Cu-disinfectants ($CuSO_4$) in cattle farming leads to an significant input of Cu into these systems (UBA, 2004).

Leaching and crop uptake, the latter provided that the crops are exported from the farm and not used as home-grown feed, are the main metal output pathways, considered in the farm gate balances. Output with animal product like meat, milk or eggs is of minor importance. Due to the variety of soil properties and technical problems with a reliable measurement of leaching general valid conclusions concerning the leaching of heavy metals to the groundwater and the uptake into plants are difficult to be drawn (Wilcke and Döhler, 1995). Therefore in many cases, if no on site measured data was available, default values for leaching to the groundwater and crop uptake were used to calculate the balances.

Input reduction measures

Based on the AROMIS farm level balances a number of measures to reduce the input of metals into the system was evaluated.

Fertilisation: Based on the maximum nutrient supply as defined in the Dutch MINAS system, a range of scenarios was calculated showing the influence of fertilisation management on metal inputs. In the scenario using mineral fertilisers only, Cd, Cr and Zn inputs into the farming system are dominated by fertilisation as compared to the input by atmospheric deposition. The same holds true for all six metals in the scenario using sewage sludge and for Cu and Zn in the animal slurry scenarios, especially the one using pig slurry.

Animal nutrition: A survey of available literature on the options to reduce supplementation showed, that for most animal categories there is some scope for reducing the level of Cu and Zn in the diet even below the new MPL´s (maximum permitted levels) as defined in the Commission Regulation (EC) No 1334/2003, even though there are uncertainties regarding the options for ruminants.

Model calculations to evaluate the effect of a reduced supplementation of Cu and Zn in pig production on the balance result were carried out, based on data of a typical pig production farm. In the three scenarios, based on different levels of supplementation, a reduction of 27 to 62 % for Cu and 41 to 68 % for Zn could be achieved. Since feed supplements are often contaminated with other, undesirable metals (UBA, 2004), reducing the supplementation of Cu and Zn might

as well have an effect on those other metals. The extent of this effect could only be estimated.

Animal hygiene: In an example dairy farm, used to evaluate the input of Cu by hoof disinfectants, the inputs with this product were 334 g/ha a (=240 g/livestock unit a) corresponding to 35 % of the total Cu input. The abandonment of $CuSO_4$ reduced the Cu-surplus for this farm from 908 g/ha a to 574 g/ha a. Such measures however, have to be accompanied by increased hoof care for the animals to avoid infections and thus an increased use of anti-biotics.

Whereas for some input reduction measures the available knowledge is sufficient for realisation in practice, for others the basis for implementation is not given and more research and development activities are required.

Research demand / demand for future action

From the results of the project it becomes clear that often reliable data is missing to evaluate the input pathways of heavy metals into agro-ecosystems, the behaviour of metals in the soils and the changes of soil metal contents with time. The implementation of a farm monitoring network is recommended covering the main geographical regions and main agricultural production types in Europe. Additionally systematic trials to investigate the effect of low metal input systems on animal health and welfare and on economic performance should be carried out. Furthermore the transfer of information on the options to reduce the input of heavy metals is considered necessary.

The final report of the AROMIS project including the data base will be published in autumn 2004.

Acknowledgements. The authors wish to thank the European Commission for the financial support of the project and all AROMIS project partners for their contributions. Special thanks to Dr. Anne Bhogal, Bartosz Golik, Dr. Harald Menzi, Dr. Fiona Nicholson, Dr. Paul Römkens and Dr. Roger Unwin.

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