Possible changes in soil cadmium content in relation to the use of fertilisers and organic residues in Lithuania

A. Antanaitis, J.Lubytė, S. Lazauskas, G. Staugaitis, Š. Antanaitis*
Lithuanian Institute of Agriculture, LT-58344, Akademija, Kėdainiai distr.; -sigislaz@lzi.lt*

Introduction

Relatively low natural soil fertility in Lithuania requires external inputs of major nutrients for economically viable crop production, which used to be traditionally managed by the application of commercial fertilisers. In market economy farmers need to manage crop nutrition with minimum costs and this can lead to risks such as use of materials containing plant nutrients along with heavy metals. A number of industrial waste products are already used in agriculture as conventional fertilisers or can be considered for use because of fertilisation potential (Werner, 1997). Sewage sludge, nutritious organic material, which is still not in a consistent legislative framework, can be of interest to farmers irrespective of the fact that the proportion of actual heavy metal concentration to the nutrient concentration is not favourable (Sothen, 2002). In “the new” EU-member countries such risks can be substantial and along with strict legal regulations are important to improve procedures, and practices in order to ensure safe and effective utilisation and distribution routes of sewage sludge (Przewrocki, 2004).

Accumulation of cadmium in the soil is an important indicator of risks to human health and environment arising from fertilisers and other materials, which are in use or has a potential to be used in agriculture. Comprehensive study done in Germany revealed an average Cd input surplus from all sources of ca. 7 g ha^{-1} a^{-1} Cd if fertiliser supply rates were based on average crop requirements and on average fertilisation recommendations. (Shützte *et al*., 2003). However, if calculations based on actual P fertiliser consumption, a surplus of ca. 3 g ha^{-1} a^{-1} Cd was obtained. Various data sets representing national scale are needed for such a study, and this is a major constraint for reliable assessment of risks of cadmium accumulation in Lithuania’s soils.

The aim of this study was to clarify possible risks of cadmium accumulation in the soil from fertilisers and other materials which can be potentially used in agriculture.

Material and methods

The study was performed at the Agrochemical Research Centre (ARC) of the Lithuanian Institute of Agriculture. Firstly, relevant data on land use, Cd soil content, etc. were collected along with the legal documents currently in force. Also, a limited number of samples of commercial and organic fertilisers, other materials were sampled randomly from the market and analysed for Cd content. During the next stage, Cd input and output was calculated and risks of Cd accumulation in the soil was estimated using available national or recommended data following the principles outlined by ERM (2000). In the third stage, pot experiments with lettuce, a vegetable widely grown by small producers and channelled through small local markets, were performed to assess risks of Cd accumulation in traditionally used fresh vegetables.

Results and discussion

Lithuanian soils are naturally relatively low in cadmium (Salminen *et al*., 2005), however, there is a rather large variation between regions as well as between estimations. The most extensive survey of cadmium content in agricultural land soils, covering all regions of Lithuania, was performed during 1993-1997 by ARC and soil map for Cd content in arable layer for Lithuania was prepared (Mažvila *et al.*, 2001). Mean value of Cd content in the topsoil of mineral soils in the Western part of Lithuania was 0.41±0.16 mg kg^{-1}, central part – 0.52±0.25 mg kg^{-1}, and eastern – 0.40±0.17 mg kg^{-1}. For organic soils the figures were 0.5±0.24 mg kg^{-1}, 0.81±0.42 mg kg-1 and 0.73±0.24 mg kg^{-1}, respectively.

During 1996-2000 ARC periodically performed analyses of Cd content in sewage sludge samples collected from 19 municipal waste water treatment plants (Table). Variation in Cd content was rather high: from 0,02 to 7,83 mg kg^{-1} with a mean value of 2,71 mg kg^{-1}. Sludge coming from industrial sources generally contained more Cd - up to 27,5 mg kg^{-1}. The same is true for the period 2004-2007, however, Cd content was slightly lower - 1,55 mg kg^{-1} (mean).

Table. Content of Cd in sewage sludge, commercial fertilisers, farmyard manure and some other materials (mg kg^{-1})

Material/period of survey	n	Min	Max	Mean	Median
Sewage sludge (1996-2000)	93	0.02	27.5	2.71	1.70
Sewage sludge (2004-2007)	145	0.04	5.60	1.55	1.30
Commercial fertilisers (2006)	12	0.04	22.00	4.40	1.28
Tyres (2006)	2	0.32	0.92	0.62	
Flax boon (2006)	1			0.66	
Sawdust (2006)	1			0.13	
Industrial ash (2006)	5	2.34	834		
Farmyard manure (2006-2007)	17	0.09	0.28	0.18	0.16

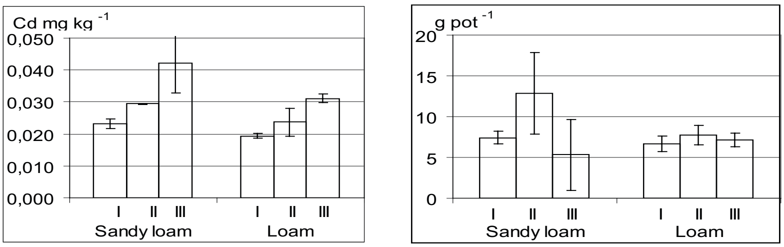
Analyses of Cd content in commercial fertilisers, manure, sewage sludge and organic residues of different origin showed that rather heterogeneous input materials must be considered when calculating soil Cd balance. Our preliminary inventory of current Cd inputs to agricultural soils in Lithuania gave rather approximate estimations of major sources, which included atmospheric deposition (0.86 g ha^{-1} a^{-1}), commercial (<0.5 g ha^{-1} a^{-1}) and organic (0.27 g ha^{-1} a^{-1}) fertilisers. Relatively low Cd input figures for commercial fertilisers can be explained by the low rates of P fertilisers, which on the national level are lower than recommended for good crop performance, and relatively low average stocking rate. There is no detailed freely available information regarding the use of sewage sludge in agriculture, however, expert judgments suggest that sewage sludge has low share in Cd inputs to agricultural land – on the national level well below 0.1 g ha^{-1}. Output of Cd with crop production was estimated as 0.21 g ha^{-1} a^{-1} , but the major source of output – leaching, was hard to estimate - calculated values ranged from 0.82 to 2.57 g ha^{-1} a^{-1}.

Our estimations of possible Cd accumulation in soil in relation to the P fertilisation level under prevailing Lithuanian soil and climatic conditions, showed that an increase in Cd content in arable soil layer probably can start with application of 50 kg ha^{-1} a^{-1} P_2O_5 using fertilisers or other material as phosphorus source with Cd/P ratio above 40 mg of Cd per 1 kg of P_2O_5. Such level of phosphorus nutrition is adequate to the needs of the majority of arable crops and grasses and the rate of accumulation of Cd in soil, estimated following EU principles on risk assessment related to Cd in phosphate fertilisers, is not so high as to reach the limits for Cd content in soil currently in force (1.0 mg kg^{-1} for light and 1.5 mg kg^{-1} heavier soils (LAND 20-2005), over period of 100 years.

However, results of estimations performed on the national level have limited relevance for the field or farm scale. Fertilisers are the major source of Cd input in soil, which is under farmer's, as a key actor on this level, control. It seems that nutrient management according to principles outlined in Codes of Good Agricultural Practice in general can be an efficient tool for safeguarding agricultural land from excessive accumulation of heavy metals from commercial fertilisers and organic manures. However, in individual cases this measure is not always effective, and as was noted by Nicholson *et al.,* (2003) on the individual field scale sewage sludge, livestock manure and industrial wastes could be the major source of many metals where these materials are applied.

In pot experiments lettuce was grown in the soil mixed with typical municipality sewage sludge (containing 2 mg kg^{-1} Cd) creating two load levels. First level was targeted at 50 kg ha^{-1} of P – corresponding to 41.7 t ha^{-1} of sewage sludge and 83.4 g ha^{-1} of Cd. The second level was a modelled case, which is likely in small vegetable growing plots, when an irresponsible grower tries to benefit from sewage sludge instead of applying farmyard manure. This level amounted to 250 t ha^{-1} of sewage sludge or 500 g ha^{-1} of Cd. Lettuce yield was substantially increased only in the pots with sandy loam and with application of lower dose of sewage sludge. In loam soil the effect on lettuce yield was rather low. However, the effect of sewage sludge on Cd content in lettuce was clearly expressed in both soils. The content of Cd in lettuce, grown in sandy loam soil, doubled with the application of high dose of sewage sludge.

Fig. Content of Cd in fresh lettuce (left) and yield of lettuce (right) per pot.



Conclusion

Phosphate fertilisers and manure are major source of Cd input in agricultural land in Lithuania, which is under farmers' control. The share of other investigated materials (tyres and industrial ash, flax boon, sawdust, sewage sludge) in Cd inputs on national level currently are low, but there is a significant risk on the individual field scale level, especially in a case of sewage sludge.

In pot experiments sewage sludge applied at rates corresponding to 41.7 and 250 t ha^{-1} had increased Cd content in lettuce in both loam and sandy loam soils, with higher effect in sandy loam soil.

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