Cadmium from Plough to Plate

Report from a Cadmium Seminar on 12 June 2002 in Uppsala, Sweden

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Preface

The FOOD 21 – Sustainable Food Production Programme and the Swedish Cadmium Network (Kadmiumrådet) arranged a one-day Cadmium Seminar on 12 June 2002 at the Swedish University of Agricultural Sciences (SLU) in Uppsala.

The aim of the Seminar was to create a meeting point between scientists and different actors within the food chain: farmers/producers, advisors, the agricultural industry, retailers, consumers, relevant authorities, policy makers etc.

The day gave an overview of recent and ongoing international and Swedish research related to the presence and transport of cadmium in the soil-plant-food/feed-animal/human system. Examples were given of efforts being made to better predict and to prevent cadmium uptake (bioavailability) by plants as well as by humans/animals. Experiences from different measures to reduce or minimise cadmium in the food chain were discussed in relation to agricultural management (incl. plant breeding), certification schemes (marketing of quality labelled products), legislation and environmental policies.

Included in this report are all the extended abstracts from the Seminar, a summary of the discussion and some concluding remarks. The Seminar was sponsered by FOOD 21 and The Cerealia Foundation.

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Dear friends of the cadmium challenge,
With experience of more than twenty years in cereal business I can say that there are questions and challenges facing the food industry that are of such dimensions that they can not be solved in-house, even if you are a relatively big company.

I normally use the heading ”uneasy questions” for topics like GMO, sewage sludge and cadmium. These are questions that are not easily communicated to consumers in relation to food quality, but they are also questions that must be tackled in order for us to be able to respond to initiated customers and consumers. You must, however, have a strategy for these kinds of questions if you are to reach or maintain a position as market leader in your business sector. If you are a company or aim to be the market leader in your business in Northern Europe, the presence of cadmium in the food chain can not be neglected. Therefore, together with other companies, we have chosen to take an active role in improving knowledge about cadmium throughout the whole process of food production, from, for example, seed varieties to intake of food and the disposal of food waste, including our own.

As a company owned by Swedish Farmers, whose business concept is based on the health impact of cereals, Cerealia has found it necessary to set long term goals for cadmium. These relate to the presence of cadmium in our food products and the already known and possible effects on humans related to food intake. Since to my knowledge cadmium is unlikely to have any positive effects on human beings, it is necessary to reduce the risk of cadmium exposure so that it is not longer the cause for concern it is today.

I do not believe we can successfully reach a situation where cadmium is no longer of concern without discussions, meetings, and conferences, as well as co-operation and hard work in laboratories and in our respective businesses. As a company we can do small things. We can choose raw materials with less cadmium, we can develop products based on raw materials containing less cadmium – but this is today almost all we can do. As a farmer you can do very small things in your own farming business. As a consumer you can do almost nothing; you have to rely on the products you chose. This is our mutual challenge.

In view of these conclusions and perspectives I am very pleased that this seminar is taking place here today. Together we have the opportunity to meet the challenge of finding more efficient tools to reduce the risk of cadmium exposure for the consumers – which we all are ourselves. I believe that we have to pay attention to and improve our knowledge about the whole food chain, which today is entitled “from Plough to Plate”. Having this opportunity to meet, to share each other’s knowledge, findings, ideas and visions in this area, will I am sure enable us to move closer to our target. Cadmium in the whole food chain is pertinent to all of us. We each face the challenge of finding tools to deal with the problems in our own part of the food chain in order to reach the goals of sustainable farming, sustainable production and sustainable consumption in relation to cadmium.

Australia's National Cadmium Minimisation Strategy – from science to policy and advice to farmers

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Cadmium has been recognised in Australia as an insidious problem facing clean agricultural production systems, threatening free trade in international food commodities. Cadmium is added inadvertently to soils in phosphatic fertilizers, livestock manures, sewage biosolids and recycled organic materials. Atmospheric inputs of Cd to soils appear to be minimal in Australia. Addition of sewage sludges to soil is localised around large metropolitan centres, but the practice is increasing. The propensity of some Australian soils to allow crops to accumulate Cd to levels above or close to maximum levels has required that a strategic approach to Cd management be undertaken.

Inputs of Cd to soil in Australia are controlled by a series of regulations governing Cd concentrations in irrigation waters, fertilisers, biosolids and soil amendments. Due to rates of P application being very low in Australia (generally less than 10 kg P/ha/yr in pastures and less than 20 kg P/ha/yr for cereal crops), permissible concentrations of Cd in phosphatic fertilizers are higher (300 mg Cd/kg P) than those permitted in most European countries. Actual Cd application rates are low in cereal-growing areas due to the very low Cd fertilisers (<50 mg Cd/kg P) generally used, sourced from North America (Florida) or Australian manufacturers.

Sewage sludges are regulated according to Cd concentration (Table 1), although there is a proposal to limit Cd loading rates.

Table 1. A comparison of Australian and EU Cd regulations with regard to re-use of sewage biosolids on land.

Jurisdiction	Guideline value mg/kg dry wt
Ceiling soil concentrations	
NSW	1.0
Victoria (proposed)	1.0
	3.0 (pH ≥6)
SA	1.0
Tasmania	0.7
EU latest proposals	0.5 (5≤pH<6)
	1.0 (6≤pH<7)
	1.5 (pH≥7)

Australia has also traditionally had very stringent standards for Cd in foodstuffs, although these were revised recently to bring them into line with international standards (Table 2). However, they are still more stringent than current EU regulations for several major food commodities.

Table 2. A comparison of some ANZFA and EU food Cd regulations.

Food	Australia/NZ mg/kg fresh wt	EU mg/kg fresh wt
Chocolate	0.50	-
Kidney	2.50	1.00
Liver	1.25	0.50
Leafy vegetables	0.10	0.20
Meat	0.05	0.05 0.20 (horse)
Peanuts	0.10	-
Rice	0.10	0.20
Root and tuber vegetables	0.10	0.10 (root/tuber) 0.20 (leafy veg.) 0.05 (other veg.)
Soybean	-	0.20
Wheat	0.10	0.20
Other cereals	-	0.10

The federal Standing Committee on Agriculture and Resource Management established in July 2000 a National Cadmium Minimisation Strategy, with the aim of minimising additions of Cd to agricultural soils, and reducing accumulation of Cd by food crops. The strategy is currently: harmonising State regulations and standards controlling Cd in manufactured fertilizers; developing best management practices for growers to minimise Cd accumulation in crops; establishing national quality assurance programs for analysis of Cd in crops and foods; and providing input to international standards for Cd concentrations in traded food commodities through Codex.

In the short term there are many ways to minimise soil-plant transfer of Cd, and growers are already using these to ensure produce is low in Cd. It is on the long-term Cd transfer that concern and management action now needs to focus.

Accumulation of Cd in fertilized agricultural systems in Australia has certainly slowed in the last 10 years, but we do not have enough information to calculate accurate Cd balances for all systems. It is likely that many systems are still slowly accumulating Cd, but there are unanswered questions regarding the magnitude of Cd leaching from topsoils, and the degree to which Cd becomes bound into non-plant available forms over time in various soils. Research is needed to address these issues.

Plant breeding also offers a way to minimise food chain transfer of Cd, and perhaps some more effort needs to be directed to at least screening new Australian and imported germ plasm for Cd accumulation characteristics.

Risk assessment of cadmium in soil – the EU perspective

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Background

Generic risk assessments of existing chemicals are mandatory in the EU for all substances on the priority list, according to a council regulation (EEC) 793/93. There is a standard procedure for this risk assessment and this has mainly been used for organic chemicals. Risk assessment for metals was initiated about 5 years ago and proved to be very difficult with the standard procedures. The risk assessment of cadmium (Cd) and its oxide (CdO) has now been ongoing for more than 4 years and the very large file has still not been approved by the member states. The author of this paper has been appointed by the Belgian government as the expert for the environmental section. This paper reports the status of the risk assessment of Cd in soil, for which both the emission part and the effects assessment part is near a final 'last visit' discussion (RAR Cd/CdO, 2002).

Cadmium exposure

Emissions of Cd from the Cd/CdO producing industry and its downstream users (including recycling plants) have greatly decreased since estimates made about 20 years ago (Table 1). These emissions are small compared to the diffuse emissions of Cd. Diffuse emissions to air are mainly from burning of coal and fossil fuel and from steel and nonferro (excluding Cd) production. Application of P fertilizer is estimated to be the major input of Cd in soils at the EU scale.

Table 1. Estimated emissions of Cd in the EU-16 (ton Cd/year). Emissions to soil are mainly from fertilizer (230 ton) and sludge and do not include atmospheric deposition of Cd.

	Cd/CdO industry		Diffuse
	1982	1996	1990-2001
Air	28	4.7	140
Water	157	1.6	40
Soil			240

Current Cd emissions to agricultural soils have been used to predict future trends in soil Cd. Seven scenarios representing major EU agricultural scenarios were selected. The soil Cd is predicted to increase in 5 scenarios (between 2.8 and 37 %) and decrease in two scenarios (11 and 19 %) after 60 years of exposure to current inputs. At the EU scale (average), soil Cd is predicted to increase by 6 % after 60 years. Historic Cd emissions to soil (5-10 g Cd/ha/y) have been associated with increasing trends in soil Cd. Current emissions are now reduced to the 1-7 g Cd/ha/y range and may be balanced by output of Cd from soil. The uncertainty in predicting Cd losses by leaching limits the prediction of trends in soil Cd.

Effects assessment

The effects of soil Cd on the ecosystem and the human food chain have been reviewed. Toxicity studies with plants, invertebrates and soil microbial processes have shown that adverse effects start to occur at about 3-10 mg Cd/kg. A 'Predicted No Effect Concentration' (PNEC) was derived as the 5th percentile of No Observed Effect Concentration data and a safety factor 2, yielding PNEC=1.1 mg Cd/kg. The effects of soil Cd on wildlife was assessed based on predicting critical body burden (kidney) Cd. Various wildlife data were compiled and it appeared that worm-eating small mammals (mole and shrew) have the highest potential to accumulate Cd in their tissues. A model was constructed and the PNEC to protect mammalian wildlife in terrestrial system was derived as PNEC=0.9 mg Cd/kg, i.e. below the PNEC to protect plant, invertebrates and soil microbial processes. Soil Cd thresholds were finally calculated to protect the human food chain. A model was constructed to predict the relationship between soil Cd and dietary Cd for various regions in EU. Soil PNECs were calculated as those that are predicted to yield an average daily Cd intake of 35 μg Cd for adults (Table 2). Clearly, these PNECs are the lowest among all NOECs. This model accounts for dietary habits in these 4 regions and the effect of soil properties affecting crop Cd concentrations.

Table 2. The predicted no-effect concentration of Cd in soil that is calculated based on a critical dietary Cd intake of 0.5 μg Cd per kg body weight and day. The local exposure refers to a home garden scenario whereby only locally produced food (mainly vegetables) contributes to dietary Cd.

Scenario	$PNEC_{soil}$ (mg Cd kg^{-1})	
	local exposure	continental exposure
1. Scandinavian neutral soils (pH 6.8)	3.06	0.98
2. Scandinavian acid soils (pH 5.8)	1.54	0.62
3. Central western Europe	1.08	0.56
4. Mediterranean	2.08	0.66

Are current cadmium emissions to soil acceptable in the EU?

Current Cd emissions to soil have decreased more than 2-fold in the EU in about the last 20 years. The generic (average) assessment shows that the current emissions will not result in soil Cd concentrations above the PNEC to protect the food chain of the general population. Many uncertainties remain in this assessment: the predicted trends in soil Cd depend critically on the losses of Cd by leaching which are poorly validated. The relationship between soil Cd and the Cd exposure in critical groups (upper percentiles in Cd intake or upper percentiles in sensitivity to dietary Cd) is yet not quantified. It is concluded that the surveillance programmes of food Cd and body-burden Cd (Cd-U/Cd-B) should be maintained to account for this variability in the risk assessment.

Reference

- RAR Cd/CdO (2002) Risk assessment of Cd and CdO. Belgian Federal Ministry of Social Affairs, Public Health and the Environment. Belgian Federal Department of the Environment. Contact: linda.debacker@health.fgov.be

Cadmium – an agricultural issue in Poland

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Introduction

Results of various studies and of recent survey, especially monitoring programmes, clearly indicate that Cd pollution of agricultural soils and arable crops is a local problem, associated mainly with industrial regions of Poland. However, the balance calculated for Cd in soils indicates a continuous accumulation due to atmospheric and fertilizer input. The industrial emission of Cd is estimated to have been 9.8% lower in 1995 than in 1990. Soil contamination with Cd (above 1-3 mg/kg DW) is observed only in the industrial region (Silesia) of south-west Poland. Elevated content of Cd, mainly in potatoes that are grown in the industrial region, is a dietary concern.

Discussion

Superficial quaternary sediments, composed mainly of glacial till, sands and outwash cover the major part of the territory of Poland, located between the longitude 14° – 24° and latitude 49° –55°. The predominate climate of the region is marine cool temperate (atmospheric deposition ranges from 400 to 600 $mm/m^2.yr$), which stimulates leaching and podzolisation processes in soils. Over 60% of agricultural land consists light and medium sandy soils (granulometric fraction <0.02 mm - < 20%) that are acid or medium acid (pH <4.5 – 5.5).

During the recent monitoring programme (1992-1997), samples of surface soils and of selected arable crops were collected throughout the country (Terelak et al. 1997). Total Cd content was measured in air-dried samples (soil samples were digested in concentrated HCl/HNO_3; plant samples were dissolved in HCl after dry ashing at 450° C). Cd was measured using flame AAS spectroscopy, after the extraction with APD to MIBK phase. Reference material and multiple analyses were adopted for the analytical quality control. Cd geometric means for soils range from 0.17 to 0.42 mg/kg for remote (NE) and industrial (SW) regions, and from 0.15 to 0.31 mg/kg for sandy soils and heavy loams, respectively (Table 1).

Table 1. Cadmium in surface soil samples as related to selected regions and soil textural groups (mg/kg DW).

Region and soil group*	Sample number	Arithmetic mean	Geometric mean	Median
Country	48 600	0.24	0.20	0.20
NE Region	760	0.18	0.17	0.17
SW Region	1 300	0.44	0.42	0.43
LSS (<20)	3 500	0.19	0.15	0.15
MLS (20-35)	5 300	0.27	0.22	0.23
HLS (35-55)	1 000	0.36	0.31	0.31

*Symbols: LSS - light sandy soils, MLS - medium loamy soils, HLS – heavy loamy soils. Content (%) of clay fraction <0.02 mm given in parentheses.

The metal accumulation factor (MAF) calculated for various crops and different trace metals clearly indicates that Cd is much more easily taken up by most plants than other metals, and that potato tubers reveal a much higher ability to accumulate Cd that any other arable crops. Although a spatial difference in Cd contents is observed for cereal grains and potato tubers (about 30% more in industrial regions than in remote areas), the mean contents in these crops at the country level (Table 2) is similar to those reported for some other European countries (Kabata-Pendias and Pendias 2001).

Table 2. Cadmium in arable crops (mg/kg DW)[a].

Crops	Geometric mean	Range	Baseline (95%)
Cereal grains (3048)	0.06	0.01 – 1.55	0.01 –0.30
Cereal straw (2499)	0.08	0.01 – 1.86	0.01 – 0.48
Potato tubers (2083)	0.11	0.01 – 1.53	0.01 – 0.60
Grass (1432)	0.11	0.01 – 1.97	0.01 – 0.69

[a] After Terelak et al. (1997). Number of samples given in parentheses

Cd in food plants, which has recently been investigated, is relatively low and does not exceed the maximum level permitted by the Polish authority (Table 3).

Table 3. Cadmium in food plants (mg/kg FW)[a].

Plant[b]	MLP[c]	Geometric mean	Range
Strawberries	0.04	0.013	<0.001 – 0.20
Apple	0.03	0.005	<0.001 – 0.09
Cucumber	0.05	0.007	<0.001 – 0.04
Cabbage	0.05	0.007	0.001 – 0.12
Carrot	0.08	0.020	0.004 – 0.57
Wheat flour	-	0.030	0.004 – 0.077
Rye flour	-	0.015	0.003 – 0.040
Cereals – groats	-	0.028	-

[a] After: Szteke and Boguszewska (2000), Wojciechowska-Mazurek et al. (2000)
[b] n = (+/-) 500 for each plant, period 1995-1998
[c] Maximum Levels Permitted by the Polish Ministry of Health and Social Welfare

Cd in home-prepared food results in a relatively low Cd intake by adults, with in only 4% of cases the Cd intake exceeding 50% of the PTWI value, established by the FAO/WHO. However, Cd intake from hospital diets is higher than that from home-prepared diets (Table 4).

Table 4. Daily intake of Cd with various food ratios (µg/day).

Diets	Mean	Range
Home-prepared (1995-1997)[a]		
- women	20.7	8 - 44
- men	26.6	8 - 49
Hospital (1994-1996)[b]	38.9	18.5 - 74.6

[a] After Marzec (2000), [b] After Skibniewska (2000)

Concluding remarks

About 89% of cultivated soils contain Cd at a background level, and 9.5 % of soils are very slightly enriched in this metal. Less than 2% of arable land need to be excluded from the production of food plants due to elevated Cd content. These soils are located mainly in the industrial SW region of Poland. The spatial Cd distribution in soils in Poland indicates the influence of both anthropogenic factors and soil parameters. There are relationships between Cd and clay fraction content of soils as well as between Cd and Fe and Mn in soils. Soil pH does not reveal any significant impact on Cd content of soils, but has a great effect on Cd levels in potato tubers.

The main Cd issue in Poland is the effect of soil pH on the content of this metal in potato tubers, since potatoes are grown mainly on light acid soils where Cd is very easily phytoavailable. At the country level, the ML value set up by the CAC for Cd in potatoes is exceeded by only 5.2%, and this is limited to some industrial areas. An increased content of Cd in grains is observed only for winter wheat, also grown in the industrial region.

References

- Kabata-Pendias, A. and Pendias H. 2001. Trace Elements in Soils and Plants, 3 Edition, CRC Press, Boca Raton, Fl.
- Marzec, Z. 2000. Evaluation of cadmium intake with adults' daily food rations. In: Cadmium in the Environment-Ecological and Analytical Problems. Ed.: A. Kabata-Pendias and B. Szteke. PAN ZN 26, 353-358. (in Polish).
- Skibniewska, K. A. 2000. Intake of cadmium with the hospital diet. In: Cadmium in the Environment-Ecological and Analytical Problems. Ed.: A. Kabata-Pendias and B. Szteke. PAN ZN 26, 359-364. (in Polish).
- Szteke, B. and Boguszewska, M. 2000. Cadmium in edible plants of Poland – results of monitoring in 1995-1998. In: Cadmium in the Environment-Ecological and Analytical Problems. Ed.: A. Kabata-Pendias and B. Szteke. PAN ZN 26, 327-335. (in Polish).
- Terelak, H. Piotrowska, M. Motowicka-Terelak, T. et al.1997. Chemical properties and heavy metals and sulfur in soils and plants, IUNG, Pulawy (Report in Polish).
- Wojciechowska-Mazurek, M. Karłowski, K., Starska, K. and Brulińska-Ostrowska, E. 2000. Cadmium content in food – contamination levels, requirements. In: Cadmium in the Environment-Ecological and Analytical Problems. Ed.: A. Kabata-Pendias and B. Szteke. PAN ZN 26, 337-351 (in Polish).

Cadmium in Swedish arable soils and crops – regional patterns and their possible explanations

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About 75% of the dietary cadmium (Cd) intake in Sweden comes from cereals, potatoes, vegetables and root crops, wheat being the largest single source (Grawé, 1996). Thus the Cd concentrations in arable soils and the Cd input to agricultural systems are important controlling factors for human exposure to Cd in food. In this presentation we give a brief review of the results from the Swedish national surveys of Cd in arable soils and crops and discuss the regional patterns and their possible explanations. The survey of soil (0-20 and 40-60 cm depth) and crop Cd concentrations (wheat, barley, oats, grass) is included in the Swedish environmental monitoring programme for agricultural land. A rolling sampling scheme with 2000 sampling locations distributed over 2.7 million ha of agricultural land was set up, with repeated sampling of each site every 10th year. The first round was finished in 1995 and the second round started in 2001 and will continue until 2009.

The overall results from the first round show an average surface soil Cd concentration of 0.23 mg Cd kg$^{-1.}$ In 10% of the soils it exceeds 0.37 mg Cd kg^{-1} (Table 1; Eriksson et al., 1997). The highest soil concentrations are found in soils influenced by alum shale-rich parent material.

Table 1. Cadmium concentrations in Swedish arable soils and crops from national field surveys. EU limit values are given as a comparison (within brackets recalculated per kg dry weight) .

Soil/Crop	Mean mg kg^{-1} dw	Standard deviation	90th percentile[2]	Ref.	EU[3]-limit mg kg^{-1} fw (dw)
Surface soil (0-20 cm)	0.23[1] n=3067	0.17	0.37	Eriksson et al, 1997	
Subsurface soil, (40-60 cm)	0.14[1] n=1720	0.16	0.23	Eriksson et al, 1997	
Winter wheat	0.044 n=606	0.025	0.072	Eriksson et al, 2000	0.2 (0.24)
Oats	0.036 n=208	0.042	0.061	Eriksson et al, 2000	0.1 (0.12)
Barley	0.019 n=291	0.014	0.037	Eriksson et al, 2000	0.1 (0.12)
Potatoes	0.049 n=75	0.031	0.094	Grawé et al, 2001	0.1 (0.50)
Carrots	0.30 n=76	-	0.70	Jansson & Öborn, 2000	0.1 (0.91)

[1] 7 M HNO_3 extractable (Swedish Standard 02 83 11)

[2] 10% of the samples have concentrations above this level.

[3] EU limit values are set per kg fresh weight. Here they are recalculated per kg fresh weight (dw) using the following assumptions; cereals 85 % dw, potatoes 20 % dw, carrots 11 % dw.

Andersson (1991) calculated Cd input-output balances for Swedish arable land for the period 1900-1990 and estimated an increase of about 30% in the surface soil (plough layer) over that period, one third originating from atmospheric deposition and two thirds from Cd-contaminated P fertilisers. In the above-mentioned survey the surface soil Cd concentration was on average 60 % higher in the surface soil compared to the subsurface layer, which indicates a larger enrichment than was estimated by Andersson (1991). One explanation of the discrepancy between the survey and the estimate may be translocation of subsurface soil Cd to the surface soil through root uptake and intermixing of crop residues in the plough layer. Studies of Cd in deep soil profiles have shown that compared to the C-horizon, the B-horizon is depleted in Cd , indicating that a comparison between surface and subsurface (40-60 cm) Cd concentration will overestimate the anthropogenic Cd accumulation in the plough layer.

The average and 90th percentile crop Cd concentrations are given in Table 1 (Eriksson et al., 2000; Jansson & Öborn, 2000; Grawé et al., 2001). They are well below the EU limit values. The survey of winter wheat showed a large variation between the years of sampling. The crop Cd concentration was lowest in a dry year. Wheat and oats showed different regional patterns, wheat mainly reflecting the geochemistry of the parent material and oats the surface soil pH (Eriksson et al., 2000). Wheat showed the highest concentration in SW and SE Skåne (southernmost province in Sweden) and in the eastern plains of central Sweden, areas within which Cd-rich parent material is present. In addition, atmospheric deposition is and has been highest in southernmost Sweden, which is an intensive agricultural area where mineral P fertiliser is applied. Oats showed the lowest Cd concentrations in southern Sweden, whereas the highest concentrations generally were found in the north (Norrbotten County). The variation of Cd in oats mainly reflects the patterns of surface soil pH and not the soil Cd concentrations. Regional differences may also be due to local weather conditions and use of different cultivars. The carrot survey was carried out during two years with no significant differences in carrot Cd concentration between the years (Jansson & Öborn, 2000). SW Skåne showed the highest Cd concentration (average 0.48 mg Cd kg^{-1} dw) and Gotland the lowest (average 0.12 mg Cd kg^{-1} dw). In the potato survey no significant regional differences were found, but there was a difference between varieties, Bintje and Sava having significantly higher Cd concentrations than King Edward (Grawé et al, 2001).

References

- Eriksson, J., Andersson, A. & Andersson, R. 1997. Current status of Swedish arable soils. Naturvårdsverket rapport 4778. (in Swedish with English Summary). http://www-umea.slu.se/miljodata/akermark/index
- Eriksson, J., Stenberg, B, Andersson, A. & Andersson, R. 2000. Tillståndet i svensk åkermark och spannmålsgröda. Naturvårdsverket rapport 5062. (in Swedish with English Summary)
- Grawé, K.P., Öborn, I. & Gustafsson, K. Cadmium and other trace metals in Swedish food potatoes - Development project for environmental monitoring. Final Report, Swedish Environmental Protection Agency (contract 222 0006, 222 0010) (In Swedish).
- Jansson, G. & Öborn, I. 2000. Cadmium content of Swedish carrots and the influence of soil factors. Acta Agriculturæ Scandinavica Sect. B, Soil and Plant Science 50, 49-56.

Cadmium in arable crops – the influence of soil factors and liming

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Introduction

Regular liming has been suggested as a measure for decreasing the plant uptake of Cd since soil pH is one of the most important factors influencing the solubility of Cd in soils. However, the effects of liming on Cd concentrations in agricultural crops have been conflicting, with both decreases, increases as well as no effects being reported (Andersson & Simán, 1991; Sparrow et al., 1993). There are several possible explanations for these inconsistent results. An increase or zero crop response in Cd concentration could be due to (i) competition by added Ca^{2+} on the binding sites in the soil, which leads to higher or unaffected Cd solubility/availability, (ii) increased Cd solubility due to higher dissolution of DOC around lime particles above pH 7.5, and a resulting complex binding, (iii) micronutrient deficiency induced by the liming, which leads to lower crop biomass and a subsequent enrichment of crop Cd concentration, and (iv) micronutrient deficiency, which leads to plant release of root exudates and a subsequent increased solubility/availability of Cd.

The aims of this study were to investigate (i) the effects of calcite, pH and Ca^{2+} concentration on Cd solubility in soils and (ii) the effects of liming with calcite on Cd concentrations in crops.

Material and methods

Eight Swedish liming experiments, seven long-term and one newly established, were included in the study. The experimental crops were spring wheat (*Triticum aestivum* L.), winter wheat (*Triticum aestivum* L.), oats (*Avena sativa* L.), barley (*Hordeum vulgare* L.) and potatoes (*Solanum tuberosum* L.). Four liming rates were tested (unlimed, limed to 55, 70 and 100% base saturation), with four replicates of each. Samples of soil, potato tubers, cereal grain and straw were taken from each plot at harvest time.

The effects of liming, pH and Ca^{2+} concentration on Cd solubility were studied in saturation extracts and batch experiments. To obtain saturation extracts, deionized water was added to soil samples with different lime application rates until saturation was reached. In the batch experiments only surface soil from the unlimed plots was used. The pH levels were set in the soil by adding either HNO_3 or NaOH and $Ca(NO_3)_2$ to the soil.

Results and discussion

The Cd^{2+} solubility in saturation extracts and batch experiments was mainly controlled by pH. However, at high pH the total solubility of Cd increased due to an elevated dissolution of organic matter. We could not detect any increased Cd^{2+} solubility due to additions of Ca^{2+} at high pH (>7). This suggests that Ca^{2+}-Cd^{2+} competition at liming should not be any problem.

The Cd concentration in crops (potato tubers, cereal grains and straw) was significantly affected by the increased pH in most experiments (19 of 25 experiments) (Fig. 1, 2).

However, liming was not a straightforward way of decreasing crop Cd concentrations since this significant change in pH induced both a decrease (12 expts.) and an increase (7 expts.) in Cd concentrations. Generally, the crop Cd concentrations increased at sites with low Cd concentration in the control crop while it decreased at sites with high Cd concentrations in the control crop. The results are in agreement with other studies in which inconsistency in the effects of liming on crop Cd concentration was found.

At sites with low crop Cd concentrations, the concentration of Cd in soil solution and batch extracts was also low. This indicates a low availability of metals in the soil, which can lead to micronutrient deficiency and a resultant decrease in biomass or to a release of exudates and a resultant increase in metal bioavailability. There were both visible Mn-deficiency symptoms and/or yield decreases in two of the experiments. Crop Zn and Mn concentrations were significantly decreased by liming in most experiments, whereas crop Cd concentrations increased or decreased depending on sites. It is probable that both plant factors and soil factors affect the solubility and availability of Cd. The Cd concentrations in crops were different between sites and in most cases larger than the effect of liming.

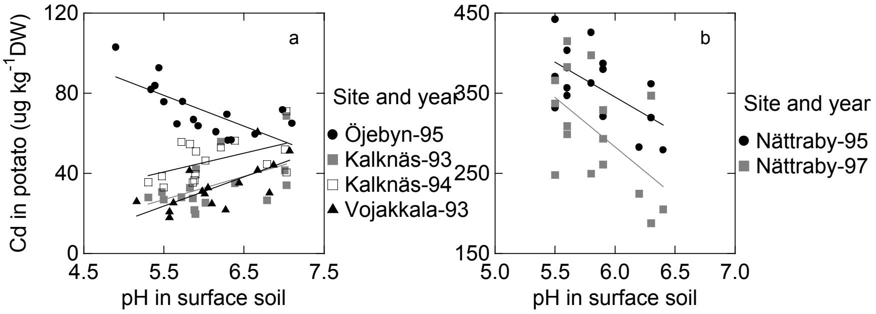

Figure 1. Correlation between pH in surface soil and cadmium concentrations in potato tubers from four experimental sites during one or two years. Only significant results are shown. *(a)* Vojakkala (-93 R^2=0.47), Öjebyn (-95 R^2=0.51) and Kalknäs (-93 R^2=0.30) (-94 R^2=0.26) *(b)* Nättraby (-95 R^2=0.35) (-97 R^2=0.31).

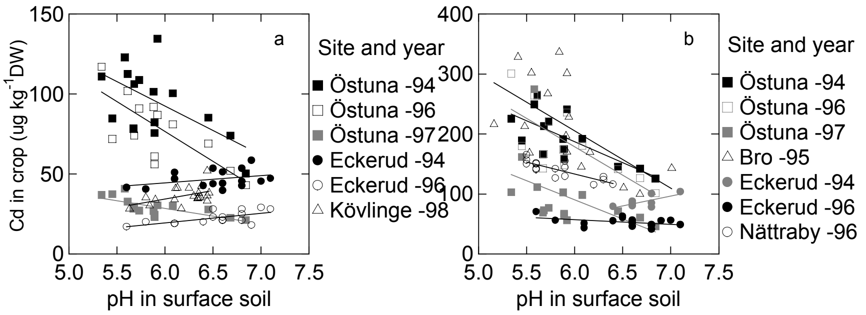

Figure 2. Correlation between pH in surface soil and cadmium concentrations in cereal from five experimental sites during one or two years. Only significant results are shown. *(a)* grain Kövlinge (-98 R^2=0.23), Eckerud (-96 R^2=0.41) and Östuna (-94 R^2=0.38) (-96 R^2=0.51) (-97 R^2= 0.52) *(b)* straw Nättraby (-96 R^2=0.68), Bro (-95 R^2=0.38) and Östuna (-94 R^2=0.56) (-96 R^2= 0.51) (-97 R^2=0.40).

Recommendations

The recommendation coming out of this study is to lime soils that have low soil pH and that are known to give high Cd concentrations in crops. Soils with low pH and low crop Cd concentrations should only be given minor or no additions of lime. The study also indicates that site selection may be more effective than liming in managing crop Cd.

References

- Andersson, A. & Simán, G. 1991. Levels of Cd and some other trace elements in soils and crops as influenced by lime and fertilizer level. *Acta Agriciculturae Scandinavica 41,* 3-11.
- Sparrow, L.A., Salardini, A.A. & Bishop, A.C. 1993. Field studies of potatoes I. Effects of lime and phosphorus on cv. Russet Burbank. *Australian Journal of Agricultural Research 44,* 845-853.

Cadmium uptake in wheat – influence of nitrogen and nitrogen supplementation

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Since about 43% of the intake of Cd via food in Sweden comes from wheat products, it is necessary to understand the mechanism behind Cd accumulation in grains and mechnisms influencing the accumulation. Field investigations have indicated that Cd in wheat grains increases with increased nitrogen supply and that wheat with a high protein level in grains often contains high Cd concentrations. The reason could be either that nitrogen application increases the bioavailable Cd in the soil or increases the plant Cd uptake from soil solution or both. The aim of this work was to test these hypotheses.

Five different cultivars of wheat (winter wheat Tarso and Kosack; spring wheat Dragon; durum wheat Grandur and Helidur) were used. The plants were cultivated either in soil or hydroponically (in a modified Hoagland solution). The soil contained 0.465 mg $Cdkg^{-1}$ while the hydroponic solution contained 0.1µM $CdCl_2$ during the whole cultivation period. Nitrogen was added as follows: to the soil, NH_4NO_3 was added at the start corresponding to either 100, 150 or 200 kg per ha; to the hydroponic solution, the Hoagland nutrient solution were modified to contain 50, 75 or 100 % N of full strength Hoagland. In parallel to these nitrogen supplies, plants were also supplied with N a second time at ear formation using KNO_3 to increase the total N supply from100->150 and from150->200. Furthermore, for one cultivar (Dragon), urea was added at ear formation to the leaves (giving N from100->150). The plants were grown to full ripening of the grains, the plants were then harvested and Cd was analysed. Also nitrogen was analysed in the grains.

The results showed that nitrogen concentration and biomass production of both grains and the whole plants increased with nitrogen addition. Nitrogen supplied at two separate periods compared to the whole application at start has no influence on the result. However, nitrogen addition to the leaves significantly increased the biomass production compared to nitrogen addition to the roots. The Cd concentration in grains decreased with increasing nitrogen concentration, both for those cultivated in soil and hydroponically. Cadmium content in the grains increased during the rain-filling period, and with increased biomass production. These parameters are known to be influenced by nitrogen. However, the cadmium concentration in grains decreased with increasing biomass production, showing that there is a dilution effect on Cd concentration caused by biomass production. The bioavailable Cd concentration in soil increased slightly with increased nitrogen addition.

The conclusion is that nitrogen decreased the Cd concentration in the grains, in all 5 wheat cultivars investigated and cultivated both in soil and nutrient medium. Results from field studies where the opposite was found might be due to both an increased bioavailable Cd concentration in the soil (caused by the nitrogen) and a longer grain-filling period, which in turn increases the Cd uptake and accumulation period in the wheat grains.

*Deceased 2001-02-01

Physiological aspects on cultivar differences in plant cadmium uptake

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In Sweden more than 75% of the human daily intake of Cadmium (Cd) derives from the vegetable part of the diet. Decreasing this source of Cd would be an important step towards decreasing the total load of Cd reaching the population. There are a few principally different means to decrease the amount of Cd reaching the edible parts of the crops. These include decreasing the emission of Cd to the environment, agricultural practice decreasing the availability of Cd to plants, and plant breeding and selection of low-accumulating cultivars.

It is known that there are cultivar differences regarding Cd accumulation in the grains of different wheat cultivars. An investigation was conducted to see if the genotypic differences in Cd accumulation of two cultivars of wheat and two cultivars of durum wheat were retained under different growing conditions. The four cultivars were grown at three locations, differing in soil Cd, during two growing seasons. The genetic differences in Cd accumulation were almost unaffected by the differences at the three locations (Fig. 1). Some variation between the two years was found, and this was probably due to variations in precipitation.

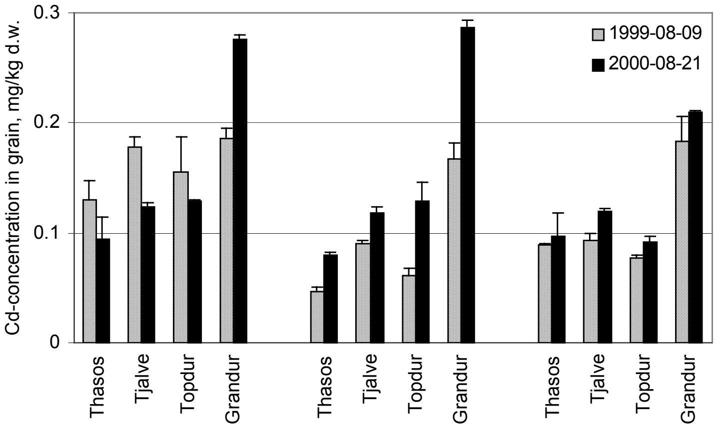

Figure 1. Concentration of cadmium in grain, at harvest, in two spring wheat cultivars Thasos and Tjalve, and two spring durum wheat cultivars Topdur and Grandur, grown at three locations during two years (1999 and 2000). Harvest dates shown in figure. Bars represent standard errors.

Already 6 weeks after sowing there were variations in Cd accumulated in the shoots that were in agreement with the variations in grain Cd levels in the different cultivars (data not shown). Due to this correlation it does not seem likely that the cultivar differences in this case were due to regulation of Cd transport from shoot to grain, but rather to root uptake or to translocation from root to shoot.

There were no easily found correlations between soil Cd and plant Cd accumulation. The middle location (see Fig.1) had the significantly highest Cd concentration in the soil irrespective of whether Cd was extracted with HNO_3, ammonium lactate or water. The soil Cd concentration at this site was almost twice as high as the lowest one. As also noted by other authors, more soil parameters, like organic matter, clay content and pH must be considered to predict Cd accumulation in plants. Not even the Cd concentration in the water extracts, which mimic the soil solution, was in agreement with Cd in the plants. However, from this study we could conclude that the cultivar differences in wheat Cd accumulation remained fairly stable when the growing conditions were changed. Thus, selection of low accumulating cultivars is a useful tool to reduce Cd in wheat grain.

Plants that hyper-accumulate Cd, for example varieties of *Thlaspi caerulescens*, often have a physiological speciality that explains the high accumulation. When it comes to variation in heavy metal uptake in commercial cultivars this is often not so pronounced, although significant. In a study with nine lettuce cultivars with significant variation in Cd accumulation, it was not possible to find a single aspect of the Cd uptake and accumulation that could explain the variation. It turned out that the final variation of Cd in the lettuce leaves was the result of variation in uptake kinetics, transport rate of Cd to the shoot and growth parameters such as total growth and shoot to root ratio. Thus, for breeders it is probably often very difficult to find just one plant physiological aspect that could be used to reduce Cd in the edible parts of the plants.

Cadmium in pig production

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Cadmium is a nephrotoxic metal with increasing levels in arable soils. The non-smoking population is exposed to cadmium mainly from vegetable food, especially cereal products. A bioindicator of cadmium in the local agricultural environment could be useful to study temporal and spatial trends and evaluate measures for reduction of pollution. The bioindicator should also be relevant for food production and human exposure to cadmium. Pig kidney could be such an indicator, as cereals are the main ingredients in feed and also a main source of cadmium exposure in humans. The cereals in pig feed are complemented with protein-rich components such as soybean and rapeseed meal, vitamins, minerals and amino acids. These complementary components can be purchased as ready-made mixtures, so-called concentrates.

To evaluate the possibility of using pig kidney as a bioindicator of cadmium availability in the local agricultural environment, we studied cadmium in the chain from soil via crops and feed to pig kidney. Furthermore, cadmium in separate feed components was analysed and the impact of feed composition, production system, pig breed, sex and age at slaughter on cadmium levels in kidney was studied.

There were significant correlations between cadmium levels in soil and wheat, between feed and kidney and between feed and faeces. Cadmium level in feed explained about 12% of the variance of cadmium level in kidney. It was found that the cadmium levels in kidneys from pigs raised on the same farm and given the same feed varied on average with a factor of 2, ranging from 1.2-3.6. Cadmium level in barley, the main ingredient in the feed, was not correlated to cadmium level in feed or kidney. However, cadmium level in concentrate was correlated to both feed and kidney.

The non-cereal feed components rapeseed and soybean meal, vitamin-mineral mixtures and beet fibre contributed to a large extent to the cadmium in feed. The cadmium levels in these ingredients were several times higher than in the cereals. Cadmium levels in concentrate were on average 12 times higher than in barley. Most cadmium in feed is excreted in faeces and cadmium from the non-locally produced feed components is an external source of cadmium to arable soils when farmyard manure is applied.

Pigs given feed with less rapeseed and soybean meal and more cereals than controls had a lower total cadmium intake, but higher cadmium levels in kidneys. This can partly be explained by different bioavailability of cadmium from different feed components. Cadmium level in kidney was positively related to age at slaughter despite a very narrow age range. No difference in cadmium level in kidney was seen between female and castrated male pigs. Cadmium level in kidney differed between breeds given the same feed.

Pigs raised outdoors organically had higher cadmium levels in kidneys and faeces than conventionally raised indoor pigs, despite a lower cadmium level in the organic feed. The organic pigs were exposed to cadmium from soil via rooting, as an additional source of exposure. Differences in feed compositions and bioavailability of cadmium from the feed components may also explain the different kidney levels of cadmium.

In conclusion, feed, breed, production system and age at slaughter influenced cadmium levels in pig kidney. Animals from the same farm raised under similar conditions had cadmium levels in kidney that could differ several times. This great variation together with the high cadmium contribution from non-locally produced feed components limits the possibilities of using cadmium in pig kidney as a bioindicator of available cadmium in the local agricultural environment.

References

- Lindén A, Olsson I.-M. and Oskarsson A. (1999) Cadmium levels in feed components and kidneys of growing/finishing pigs. *JAOAC Int.* 82:1288-1297.
- Lindén A, Andersson K. and Oskarsson A. (2001) Cadmium in organic and conventional pig production. *Arch. Environ. Contam. Toxicol* 40:425-431.
- Lindén A. (2002) Biomonitoring of cadmium in pig production. Doctoral dissertation. *Acta Universitatis Agriculturae Sueciae Veterinaria 126*. Uppsala

Low level cadmium exposure and the effects on renal functions in Swedish farmers

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The results presented here are part of a larger study that aims to follow the flow of cadmium (Cd) from soil to humans (Olsson, 2002, Olsson *et al*. 2002). The results from soil to pigs were presented by Anna Lindén in the previous presentation. Recruitment for the study was done from 800 randomly selected growing/finishing pig producers in southern Sweden. A preliminary questionnaire about the farm and the smoking and food habits of the residents was sent to the farmers. 465 questionnaires, with complete answers were returned. Of the respondents, 224 volunteered to participate in a more detailed study. From this group, 51 farms were selected. The selection criteria were: a) production of more than 50% of the pig feed on the farm, b) both the man and woman on the farm were willing to participate and c) both were non-smokers. Two farms dropped out during the sampling period.

This presentation focuses on the human part of the study, in which blood and urine samples were taken from farmers and their spouses and they answered a detailed food frequency questionnaire (FFQ). The FFQ was designed to estimate the total Cd intake, the contribution of Cd from different food sources, occurrence of occupational Cd exposure, previous smoking habits, etc (Olsson 2002). Men had a higher total intake of Cd than women. Women had a higher relative Cd contribution from vegetables, potatoes and roots than men, while the latter had a higher Cd contribution from bread than women (Fig 1.).

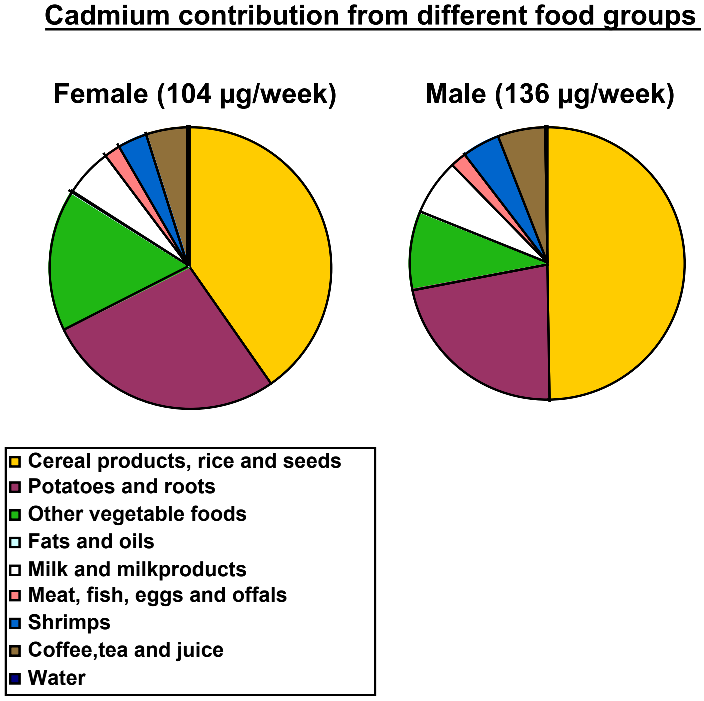

Figure 1. Estimated Cd intake from different food groups for female and male farmers in southern Sweden.

Out of the weekly consumption, the vegetable food groups contributed 83% of the total Cd intake, although constituting only 29 weight-percentage (w%) of all consumed food. Bread was the largest contributor (36%) followed by potatoes and roots (24%), and vegetables (8.4%).

The correlation between Cd intake per kg body weight per week and blood-Cd (B-Cd) or urinary-Cd (U-Cd) was not statistically significant in either the whole group or in the never-smokers. However, when a sub-group of the study population, couples (n=24) of never-smoking men and women, were compared, a lower intake per kg body weight was found in the women, although the women had a 1.8 times higher B-Cd and a 1.4 times higher U-Cd than the men.

B-Cd was 2.3 (0.66-5.7) [median (range)] nmol/L, and 1.4 (0.38-18) and U-Cd 0.26 (0.097-0.99) nmol/mmol creatinine and 0.17 (0.065-5.7), for women and men respectively. B-Cd and U-Cd both increased with age, and were higher in the ex-smokers compared to never-smokers (Fig. 2). B-Cd was inversely correlated with S-Ferritin (Fig. 3). The B-Cd and U-Cd found in this study correspond to earlier reported levels for non-smokers in the general population of Sweden (Järup *et al.* 1998).

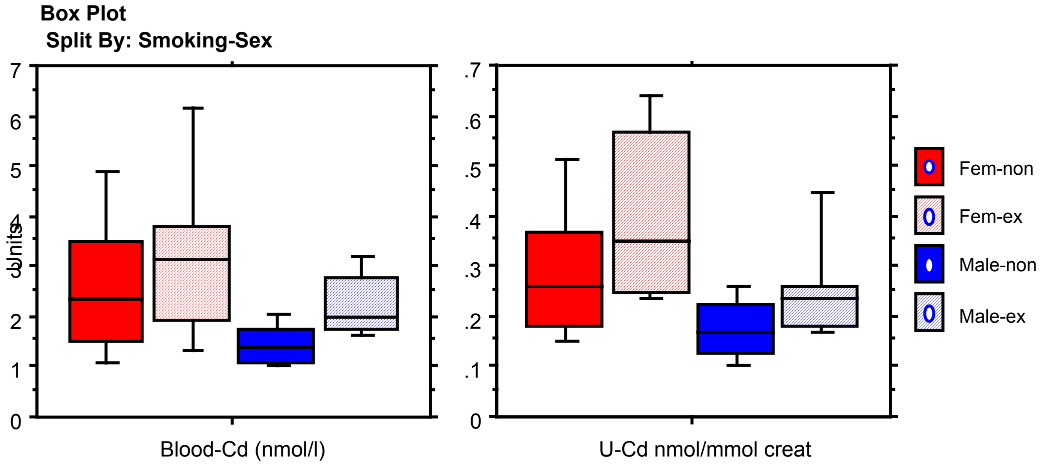

Figure 2. Blood and urinary Cd levels in women (n=48) and men (n=57).

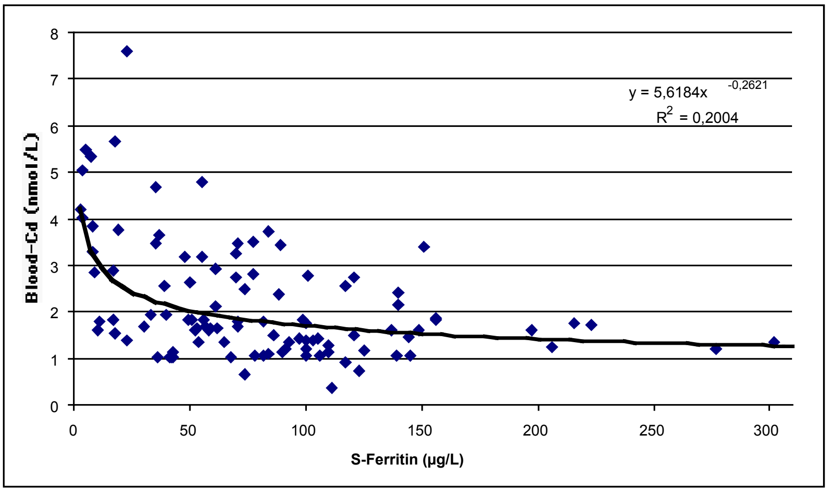

Figure 3. Blood cadmium (B-Cd) versus S-Ferritin in the study population. Data from one man (B-Cd=18 nmol/L, S-Ferritin= 45 µg/L) is not shown in the plot. An adjusted exponential line is shown.

The U-Cd in most of the individuals in the study was below 1 nmol/mmol creatinine, a level at which urinary-N-acetyl-ß-aminoglucoseaminidase (U-NAG) excretion starts to increase (Nortier et al. 1997). However, there were statistically significant correlations between U-Cd and the kidney function parameters, ß$_2$-microglobulin-creatinine-clearance, urinary-protein HC (U-pHC) and U-NAG for both sexes. When age was allowed for only ß$_2$-microglobulin-creatinine-clearance was significantly related to U-Cd. Even at the low dietary exposure levels in this study population, there was an indication of effect on biochemical markers of renal function. Hence, this may indicate an adverse health effect. Although the effect is limited, it is important for the general population that further introduction of Cd to arable soils is prevented and that measures are taken to reduce the uptake of Cd in vegetable food in order to limit the intake of Cd from staple foods.

References

- Järup L, Berglund M, Elinder CG, Nordberg G, Vahter M. 1998. Health effects of cadmium exposure--a review of the literature and a risk estimate. Scandinavian Journal of Work, Environment & Health 24:1-51.
- Nortier J, Bernard A, Roels H, Deschodt-Lanckman M, Gueuning C, Lauwerys R. 1997. Urinary neutral endopeptidase in workers exposed to cadmium: interaction with cigarette smoking. Occup Environ Med 54:432-6.
- Olsson I-M. 2002. Biomonitoring of cadmium in cattle, pigs and humans. Thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.
- Olsson I-M, Bensryd I, Lundh T, Ottosson H, Skerfving S and Oskarsson A. 2002. Environ Health perspect. Accepted

Actions: authorities and policy makers

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Kidney damage and skeletal damage (osteoporosis) may occur due to cadmium exposure at relatively low levels. As diet is the main source of cadmium exposure in the Swedish non-smoking population, these adverse effects are of relevance for the whole population. Certain groups in the population, e.g. women with low body iron stores, high consumers of cereals, are at the highest risk. A main reason for regulatory action is to minimise these risks to human health.

In Sweden, there are also environmental reasons to reduce cadmium exposure. Swedish soils and non-calcareous freshwater systems are, due to a generally poor buffering capacity, severely affected by acidification. In addition, the low salinity of the Baltic Sea results in an ecosystem of low species diversity, with some species close to their limit of physiological tolerance. Cadmium in soil is mobilised at low pH, and the availability and toxicity of cadmium in marine systems are enhanced at low salinity.

Cadmium in phosphate fertilisers is one of the main sources of the cadmium accumulation in agricultural soils. The Swedish agricultural market actors and the authorities share the same view of the need to limit the risks posed by cadmium in fertilizers. The acceptance of regulatory action is therefore high.

The intentional use of cadmium, as colouring agent, stabiliser and for surface treatment, was prohibited in Sweden in 1982. For fertilizers, a limit value of 100 g Cd/ton P and a charge (later changed into a tax) of 30 SEK per gram Cd exceeding 5 g Cd/ton P were introduced in 1994. In the Accession treaty for the new EC member states Sweden, Finland and Austria, it was agreed that the new member states should maintain their more stringent restrictions until the end of 1998 and that the EC should review the directives in these areas before the end of 1998.

With the aim of contributing to the review, The National Chemicals Inspectorate initiated various consultative studies on risks to health and the environment in Sweden (see Reference list) at this time. As the health effects are universal, the review of literature made by Järup *et al* has perhaps been the most frequently cited of these studies. Additionally, a study was made to analyse the socio-economic effects of the Swedish policy to reduce cadmium in fertilizers. The calculations done, both from top-down and bottom-up approaches, show the same picture. The costs are very small for the current measures to restrict the cadmium fluxes in Sweden, both for society and the farmers.

The conclusion from the review of the Fertilizer directive was that data were insufficient to allow a proper risk assessment of cadmium in fertilizers at the EC level and that further work was needed to continue the review. Sweden, Finland and Austria were granted another three years of exemptions. Meanwhile, member states were to fill the data gaps and make national risk assessments, in accordance with EC guidelines.

In the Swedish risk assessment, it was found that a substantial increase of total cadmium in agricultural soil as well as in dietary intake would take place if Swedish farmers were to use fertilizers with the EC average cadmium content instead of present fertilisers with a low cadmium content. Risk characterisation showed a concern for environmental effects in all agricultural soils in the EC scenario. For consumers, it was found that the margin of safety between exposure and the current value for Provisional Tolerable Weekly Intake (PTWI) is extremely small, and for risk-groups even non-existent. Thus, the overall conclusion from the assessment was a need to keep cadmium levels in soil and food as low as possible.

Eight Member States eventually submitted their risk assessments. The results were summarised, analysed and compared in a consultative study. It was noted that several Members States had reported that certain environmental compartments and/or populations are currently at risk from cadmium in fertilizers. Furthermore, it was noted that several Member States concluded that cadmium input to soil should be kept to a minimum and that any increase in fertilizer cadmium would present a risk to human health and/or the environment. Based on these results, it was decided to continue by developing options for risk reduction measures. A mandatory limit value at community level was given the highest scoring, compared to the other measures (Charges, Limit values in soil and "Regionalisation"of the different measures).

As no decision on the subject was to be taken before the end of 2001, Sweden, Austria and Finland notified the Commission that they intended to apply national provisions concerning the cadmium content in fertilizers from 1 January 2002. The Commission has recently (decision in May 2002) found that the national provisions:

- meet needs on grounds of protection of human health and the environment,
- are proportionate to the objectives pursued,
- are not a means of arbitrary discrimination, and
- do not constitute a disguised restriction on trade between Member States.

The Commission therefore considers that they can be approved. The derogations shall apply until 31 December 2005.

References

- Järup, L. (editor), Berglund, M., Elinder, CG, Nordberg, G and Vahter, M.(1998). Health effects of cadmium exposure - a review of the literature and a risk estimate. Scand J Work Environ Healh, volume 24, suppl 1.
- KemI (1997). Swedish restrictions benefit the environment. Reduced threats from cadmium, arsenic, PCP and organotin compounds. Broschure.
- KemI (1998). Cadmium exposure in the Swedish environment. KemI Report No 1/98.
- KemI (1998). The Economics of the Swedish policy to reduce cadmium in fertilisers. KemI PM No 2/98.
- KemI (2000). Assessment of the risks to health and the environment in Sweden from cadmium in fertilisers. Kemi PM No 4/00.

Swedish Seal of Quality and cadmium assured crop production

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Both environmental and quality assured crop production

Swedish Seal of Quality is a concept for environmental and quality assured crop production. In 2001 Swedish Seal consisted of around 40 000 ha of a total arable area of over 110 000 ha on 730 farms, most of them in the south and the central eastern part of Sweden. These farms produced 260 000 tonnes of their total production for Swedish Seal, which is 25 % of the Swedish market for cereals for human consumption. Crop production according to this concept mainly consists of the following rules and results:

- *Nitrogen*: A yearly field balance for input/output of nitrogen and goals depending on the production of the individual farms. At the field level the goal is a nitrogen efficiency of 80 % of input on cereal farms and 60 % of input on the most efficient livestock farms.
- *Phosphorus and Potassium*: A farm-gate balance every fifth year according to STANK, the official input/output model of the Swedish Board of Agriculture, and goals depending on soil map values. The most recent farm-gate values for the efficiency of P and K were 103 and 101 % of input.
- *Cadmium*: Threshold values for soil and plant content of cadmium (see below).
- *Plant protection products*: Rules regarding ”biobeds” and safe storage and handling are used to reduce the risk of spills and leakage. Indices based on rates of application and threshold values are carefully recorded. Usage strictly follows threshold values.
- *Biodiversity*: A certain proportion of unsprayed cereal crop margins (1 500 km in 2001), buffer zones along watercourses/ditches (1 300 km in 2001) and ”green” margins.
- *GMO:* Genetically Modified Organism varieties of seed are not used.
- *Fuel*: Only fuel of the highest environmental class in Sweden used.
- *Grain storage*: Drying by warm air and continual temperature and quality control.

The cadmium situation in Sweden

Table 1. A Swedish budget for cadmium 1985 and 1998

	Cd, g/ha and year	
	1985	1998
Fallout	0.8	0.39
Fertilizers	1.0	0.05
Feed import		0.05
Sewage sludge	0.1	0.03
Lime	0.04	0.04
Grain export		-0.03
Human consumption		-0.01
Leaching		-0.06
Net addition in 1998		0.46

Unfortunately there is usually a high soil Cd content in most of the regions where cereal crops are grown in Sweden. A national budget for Cd also shows that the soil Cd content in the average Swedish soil is still increasing (Table 1). Despite the very significant decrease of Cd addition via arable inputs there is still too high a Cd addition via fallout. The possibility of reducing the fallout further through international regulations is important for improving the Swedish Cd budget.

The Swedish Seal cadmium rules and the current situation

The Cd rules for the Swedish Seal of Quality comprise the soil, the grain and the fertilizers. The maximum soil level allowed for Swedish Seal is 0.30 mg Cd per kg DW. There has to be a soil sample for each 15 ha of land, which corresponds to an ordinary load of grain.

If the soil Cd content is above 0.30 mg per kg, a grain sample has to be analysed for each 250 tonnes of grain leaving the farm (Table 2). The maximum grain Cd level accepted is 0.08 mg per kg fresh wt (14 % water). Adaptation to customer needs sometimes means that only a very low content of Cd is acceptable, e.g. manufacture of baby food.

The maximum Cd content accepted in NP and NPK fertilizers is 15 mg Cd per kg P and the recommendation is only 5 mg Cd per kg P, such fertilizers are readily available on the Swedish market today. The current mean for the soil Cd content in the Swedish Seal programme is 0.23 mg per kg DW.

Table 2. The mean for the ”upper third” Swedish Seal of Quality that needs a grain Cd analysis due to a soil Cd content above 0.30 mg per kg.

	National Cd mean, mg/kg	Upper third Sw. Seal, mg/kg
Spring wheat	0.059	0.064
Winter wheat	0.038	0.055
Oats	0.031	0.045
Malting barley	0.016	0.029
Rye	0.014	only a few samples

The conclusion drawn from the results in the table above and from other assurance programmes is that, although weak, there is a correlation between soil Cd and grain Cd content. Soil Cd content may therefore be a possible indicator for grain Cd and thus be used to prevent grain with the highest Cd levels reaching the market.

References

- Jordbruksverket. 1999. Miljökvalitetsmål 9. Ett rikt odlingslandskap. Ett rikt odlingslandskap. Jordbruksverkets Rapport 18–1999.
- Miljönyckeltal för kväve, fosfor, kadmium, energi och markpackning, Faktablad Jordbruk 7/2001. SLU, Uppsala or www.slu.se/forskning/fakta
- Swedish Seal of Quality website: www.swedishseal.com

Summary of discussion

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Cadmium intake from food and tools for reducing cadmium intake

Cerealia has a goal of reducing cadmium levels in cereals by half within ten years (1998-2008). In 2003 there will be an evaluation of the levels in cereals halfway through the programme. For the last 5-6 years the cadmium levels in flour have been stable or have slightly decreased. In Sweden, 40-50% of the dietary cadmium intake comes from cereal products and in Poland about 40% of dietary cadmium intake originates from potatoes. By choosing plant varieties with low cadmium content and also breeding for plants with lower rates of uptake of cadmium, the intake of cadmium from these foods can be reduced. Some cadmium is eliminated by peeling the potatoes.

A study of Swedish farmers found that their cadmium intake from food was higher than the average intake in Sweden. However, the cadmium levels in blood and urine were not higher than average. The intake from water was low, about 0.1-0.2% of the total dietary intake of cadmium, even in areas where cadmium levels in soil are high.

Monitoring

When balances of cadmium input and output to arable soils are calculated, there is considerable uncertainty when it comes to estimating the leaching. The value set for leaching is often decisive for whether the balance calculation outcome is positive or negative. It was also stated that leaching is not a solution for lowering cadmium levels in soil because cadmium that has leached out will simply end up somewhere else.

There was a discussion of different measurements of soil pH. The pH can be analysed in water or in calcium chloride and the results differ depending on the method. It is important to take this into consideration when comparing different studies.

Cadmium levels in potato were not correlated to soil parameters in Sweden. But in Poland a correlation was found between cadmium levels in potatoes and pH. In Sweden, the sampling was done in many different regions with different varieties and different climates. If, however, correlations are analysed on a regional basis for which the material is more homogeneous, there is a correlation between cadmium and pH. The outcome of the statistical analyses depends on the homogeneity of the material.

Cadmium in batteries

The use of cadmium in batteries was discussed. About 100 ton cadmium is imported per year into Sweden in batteries. The use of cadmium in batteries is relatively small. However, the recycling of NiCd batteries does not work very well. Mobile phones and computers can use other batteries, but more powerful machines need NiCd batteries. Coop Forum in Sweden now requires Black & Decker not to use cadmium batteries in their machines.

Swedish Seal of Quality

Swedish Seal of Quality has a cadmium limit in cereals of 0.08 mg/kg. If this limit is exceeded, the cereal can be used for feed or be exported. The mixing of grains with high and low cadmium contents to keep cadmium levels below the limit is not permitted within the Swedish Seal programme. Financial support to the farmers taking part in the programme comes from Swedish Seal and the EU, and there is also a premium for milling wheat and malting barley.

There is frequent grain sampling and analysis of cadmium within the Swedish Seal programme. However, farms where cadmium concentrations in soil are so low that there is no risk for high cadmium concentrations in crops are said to have a ”green card”.

In the Swedish Seal action plan for reducing cadmium levels in cereals, plant breeding, reduced content in inputs to arable land (feed, lime, deposition), changes soil conditions and increased monitoring of, for example, leaching were included. There is a need for more knowledge and financial support and collaboration with universities and authorities.

Zinc

The use of zinc to reduce cadmium in crops was successful in Australia. In Sweden, cadmium levels in soil are correlated to zinc levels, and there are not many zinc deficient soils in Sweden. There have been experiments using zinc, but they have shown no effect on cadmium levels in crops except in some specific areas.

Cadmium input to soil

The major input of cadmium to soil is through deposition. There is an EC convention on the reduction of cadmium emissions in Europe and a protocol from 1998 states that if appropriate action is taken by the EC countries, the emissions to air should be reduced by 30%. There will be a new protocol for critical loads and critical limits in forests, surface water and probably agricultural land, even though this is more difficult to determine. The criteria for the limits will be mainly based on ecotoxicological effects on microorganisms and plants . Secondary effects as well as food chain effects will it is hoped be included this year. There are groups currently working to set limits for both arable and forest land.

Only a very small proportion of the emissions consists of re-emissions. Good estimations have been made of wet deposition, but it is more difficult to estimate dry deposition. However, for arable land it is the wet deposition that is most relevant. It was found that some of the stations for measuring deposition were not suitably located and they had to be removed.

Cadmium input from feed is hard to estimate. It is probably in about the same range as input from fertilizers, however it is more uncontrolled. The feed industry is currently reconsidering the cadmium levels. The limits of cadmium levels in feed are not strict and do not effect the import of feed. Mineral supplements are an unnecessary source of cadmium input.

Concluding remarks
How can we minimise the cadmium transfer into the food chain?

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Suggested action plan

Methods to minimise cadmium (Cd) in the food chain were discussed by delegates and the following action plan was suggested:

1. Plant breeding – development of low Cd-accumulating lines
2. Reduced cadmium content in arable inputs (feed, lime, fertilizers etc) and in additions of recycled materials to soils (e.g. manures, composts, biosolids).
3. Reduced inputs from atmospheric deposition achieved through reductions in emissions of Cd to the atmosphere.
4. Improved soil Cd balance models to highlight areas for priority action, achieved through better estimates of Cd leaching.
5. Improved management practices to reduce the bioavailability and crop uptake of soil Cd, e.g application of lime on acidic soils, increasing organic matter content, application of fertilizers (nitrogen and trace elements) in the best forms and with optimal timing, and avoidance of high soil salinity through good irrigation practices and choice of appropriate fertilisers.

Who is responsible for taking action?

Farmers´ organisations and the agricultural industry are dealing with plant breeding and selection and testing of different cultivars. They can also improve the quality of the arable inputs (feed, fertilizers, etc) to levels below the government regulatory standards and policies (i.e. industry codes of practice). The policy makers and authorities should strive to further reduce Cd emissions from industry and society in order to decrease the Cd contribution from atmospheric deposition to food production systems. This has to be coordinated at an international level since transboundary transport (mainly intercontinental) of Cd is an important flux pathway. Soil quality monitoring schemes should include Cd concentrations in arable soils and crops, to be carried out by the relevant authorities in collaboration with scientists and farmers. However, help is needed from the scientific community (research councils, universities etc) and the authorities both in terms of joint research efforts to get new knowledge and to prove financial support for the last two parts of the program.

What needs to be done?

For soil scientists there are several challenges concerning cadmium in the soil. A long-term measure to reduce the bioavailability can be to increase the soil organic matter content in those parts of the world where the climate and/or the cultivation have decreased soil organic matter to low levels.

A rapidly acting measure for farmers is the use of lime for decreasing the cadmium availability in acidic soils. When using lime you have to consider two aspects. Firstly you need to determine soil buffer capacity to allow the optimal rate of lime to add, and secondly you need to know the cadmium content in the lime added. Another rapid measure is zinc application, which can be effective in those parts of the world where zinc deficiency is widespread. On the other hand, in other parts of the world zinc deficiency is not widespread and its occurrence in the geological parent material is often linked to the cadmium content. This is the reason why zinc addition shows no promising results in reducing cadmium in crops in areas with soils high in Cd e.g. in Scandinavia.

Nitrogen addition and its influence on crop cadmium status were discussed. This issue is particularly important when wheat is fertilized for higher protein content. There are some convincing results showing higher Cd uptake through N fertilisation, but more research is needed on when and how the Cd content is influenced by N-fertiliser application. The importance of the form of applied N as well as application rates and times needs to be considered in future research.

For plant breeders the task is obvious. New varieties of wheat, oats etc. are needed by the market. To half the Cd content seems to be relatively easy, but the next steps are probably more difficult and also new varieties will have to be combined with good management practices to reduce the bioavailability of Cd. While waiting for those new varieties, crop and site selection have to be considered. Sensitive crops can often be successfully cultivated on the right site.

Since the goal is to lower the Cd content in the crops leaving the field, we have to take all Cd inputs into consideration. Cadmium concentrations in arable inputs can be reduced strikingly, as has been demonstrated in Sweden. Even aerial deposition has been reduced to some extent, but more work has to be done. New international agreements are needed before aerial deposition will reach an acceptable level.

APPENDIX
Seminar Programme

Cadmium – from Plough to Plate

Seminar 12 June 2002, 9-16 at SLU, Uppsala

Organised by the Food 21 – Sustainable Food Production Programme and the Swedish Cadmium Network (Kadmiumrådet)

Programme

Moderator: Agneta Oskarsson, Dept Pharmacology and Toxicology, SLU

9.30 Introduction – Challenges from industry/consumers to scientists and farmers, Ingmar Börjesson, Cerealia R&D AB
9.45 Australia's National Cadmium Minimisation Strategy - from science to policy and advice to farmers, Mike McLaughlin, CSIRO, Adelaide, Australia
10.15 Risk assessment of Cd in soil from the EU perspective
Erik Smolders, K.U. Leuven, Belgium
10.40 Break
10.55 Cadmium – an agricultural issue in Poland
Alina Kabata Pendias, Poland.
11.20 Cadmium in Swedish arable soils and crops – regional patterns and their possible explanations. Ingrid Öborn, Dept Soil Sciences, SLU
11.40 Liming as a mean to reduce cadmium in crops -when does it work?
Gunilla Jansson, Dept Soil Sciences, SLU
12-13 Lunch at Ultuna's restaurant

Moderator: Ingmar Börjesson, Cerealia R&D AB

13.00 Cadmium uptake in wheat – results from controlled experiments,
Maria Greger, Dept Botany, Stockholm University
13.20 Physiological aspects of cultivar differences in plant cadmium uptake,
Håkan Asp, Dept Crop Science, SLU
13.50 Cadmium in pig production,
Anna Lindén, Dept Pharmacology and Toxicology, SLU.
14.10 Low level cadmium exposure and effects on renal functions in Swedish farmers
Ing-Marie Olsson, Dept Pharmacology and Toxicology, SLU.
14.30 Coffee
14.40 Actions: authorities and policy makers,
Jerker Forssell, National Chemical Inspectorate.
15.00 Actions: producers and actors on the market, Experiences from the certification scheme - Swedish Seal of Quality, Kjell Ivarsson, Swedish Farmers´ Supply and Crop Marketing Association
15.30 Challenges for the future – Summary discussion
16.00 Closure of the formal session
Informal discussions. Pub in the department garden (or coffee room)

The Swedish Cadmium Network (Kadmiumrådet)

The Swedish Cadmium Network consists of representatives from the universities, the authorities and the food industry. The Swedish Cadmium Network's roles are to be:

- a forum for discussing strategies regarding cadmium in the food chain - from plough to plate.
- an organ that formulates projects and ensures that sufficient measures are implemented to achieve lower Cadmium concentrations in our food.
- an organ that works to increase the funding of research into Cadmium in the food chain; in the first place through grants for research planning with the view to widening the scope of this research. The research itself, however, remains the responsibility of the individual researcher.

For more information see www.livsmedelssverige.org/forsk/kadmiumradet.htm

This is FOOD 21

FOOD 21 is an interdisciplinary Research Programme dealing with issues of a sustainable food chain, from production to consumption. The most important goals are to provide suggestions for solutions concerning the weak links in Swedish agriculture and food production. The consumers should feel comfortable and trustful about food quality and production methods when purchasing food. A set of objectives for sustainability has been developed concerning crop production, animal husbandry, product quality, consumers and producers to encompass research and evaluation of new production methods and means. The Foundation for Strategic Environmental Research, MISTRA, is financing the Program over an eight-year period starting in 1997. Twenty-five doctoral candidates and some 75 senior researchers are involved. The Swedish University of Agricultural Sciences is the centre of activities but research is also conducted at the universities in Gothenburg, Umeå, Lund and Uppsala.

For more information see www-mat21.slu.se

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