The Economics of the Swedish Policy to Reduce Cadmium in Fertilisers

Lars Drake, the Swedish University of Agricultural Sciences and Stefan Hellstrand, the Swedish Environmental Research Group (MFG)

Exemption Substances Project
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PREFACE

The study presented in this report has been performed with the aim to contribute to the EC Commission's undertaking to review existing EC provisions on the substances for which Sweden has been granted transitional provisions*. The provisions imply that Sweden may maintain more stringent regulations until the end of 1998. Exempted substances are arsenic and organotin compounds, pentachlorophenol, cadmium (Directive 76/769/EEC), and fertilisers with regard to their cadmium content (76/116/EEC).

The study has been performed on commission by the National Chemicals Inspectorate, within the Exemption Substances Project. It is one in a series of studies dealing with the risks to human health and to the environment from the above mentioned substances, and with the experiences from the Swedish regulations.

The report aims at assessing the economic effects of the Swedish policy to reduce the cadmium exposure from fertilisers. It includes a study on the price elasticity of phosphorus fertilisers in Sweden.

The authors alone are responsible for the contents of the report.

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Lars Gustafsson
Project Manager

* Act concerning the conditions of accession and the adjustments to the Treaties on which the Union is founded (OJ 94/C241/08)
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# Content

**Summary**  
Sammanfattning  
1. Background  
2. Aim and method  
2.1. Aim  
2.2. Method  
3. Economic effects over time of fluxes of cadmium to and from soil  
3.1. Future health effects of current cadmium flows  
3.2. The current costs for the farmers of not complying with the demand of the market  
3.3. Environmental effects  
3.4. Concluding remarks  
4. Market actors  
4.1. The Swedish food-chain and food-market  
4.2. Two examples from the Swedish food-market  
4.2.1. The farmer co-operatives  
4.2.2. The supplier of the food retail stores  
4.3. Food market actors and cadmium: — results from a questionnaire  
4.4. Discussion about public attitudes to food quality and regulatory policies  
5. Economic effects of the current Swedish cadmium policy  
5.1. Policy instruments  
5.2. Calculation of costs for farmers - Bottom-up approach  
5.2.1. Regional variation in the costs  
5.2.2. Some typical crop rotations in the intensive crop production districts  
5.3. Market reactions to restrictions - Top-down approach  
5.4. Administrative costs  
6. Cadmium policy affecting large market shares  
7. Scenarios  
7.1. Four scenarios  
7.1.1. Reduced concentration in fertiliser  
7.1.2. The current concentration in fertiliser  
7.1.3. A doubling of the concentration in fertiliser  
7.1.4. Rapid increase of concentration in fertilisers  
7.2. Effects on content in soil, grain and renal dysfunctions  
8. Conclusions  
9. Discussion  
10. References  
10.1. Personal Communication  
11. Appendix 1. The questionnaire to market actors  
11.1. Hydro Agri AB  
11.2. The Swedish Farmers’ Association (LRF)  
11.3. AB Nord Mills  
11.4. AB Kungsömen  
11.5. KF 65
Summary

The aim of this report is to, 1. analyse the economic consequences of cadmium fluxes to and from agricultural soils, 2. analyse the economic effects of existing, and some potential, policies within the political, as well as the private sphere, to reduce the cadmium content in food and 3. forecast the economic effects of some scenarios concerning future fluxes of cadmium to and from agricultural land. The analysis consists mainly of cost calculations based on natural science conditions and interviews with market actors.

The long run costs of the cadmium flows in the food system concern potential environmental and health effects. Based on the estimates in a recently performed health study, it was calculated that every kilogram increase in cadmium taken in with food from the current, average level in Sweden, will increase the number of renal damages with about 2,200 cases. The fraction of the renal damages which actually poses health problems to the individual was not specified. The information about the potential environmental effects is not sufficient to support a quantitative analysis of environmental effects as a function of the cadmium flows in the agricultural system.

The short run costs of the cadmium flows in the food system concern market reactions. The net revenues to individual farms in Sweden can be substantially affected if they do not comply with the cadmium limits posed by market actors. For a 100 ha farm producing wheat, the annual loss of net revenues was calculated at 14,500 SEK if the farm did not comply with the cadmium limits posed by the trade mark Svenskt Sigill, (in translation, Swedish Seal). This loss was calculated to correspond to a reduced value of the farm of 362,500 SEK.

The cost of policies to restrict cadmium fluxes to soils concern the cost of these measures to agriculture and to the society. The cost of the current tax on cadmium in phosphorus fertilisers to the Swedish agriculture is about 10 million SEK per year. The cost to the society is ca 100,000 SEK. The revenue from the tax is redistributed from agriculture to other sectors which means it is not a net welfare cost. The cost to Swedish agriculture of the cadmium tax is 0.03% of the total revenue in the agricultural sector in 1995, and 0.43% of the total contribution to the farmer’s own work and capital in 1995.

The price elasticity for phosphorus fertilisers is low, -0.1 to -0.25, which implies a very limited reduction in demand for phosphorus fertilisers. The present tax on cadmium has the following effects, 1. application of phosphorus fertilisers is reduced by roughly 1-2%, 2. yield is reduced by less than that percentage, 3. the reduction in cadmium accumulation due to reduced phosphorus application is very limited, and 4. cadmium concentrations in phosphorus fertilisers are reduced.

The cost of decadmiation processes is calculated to range from 2 to 10 million SEK/year in Sweden. The cost to non-Swedish fertiliser producers of the Swedish governmental cadmium policy is low.

The benefits of policies to restrict cadmium flows concern, in the long run, the reduction of health and environmental effects, compared to the alternative with no reduction. In a hypothetical example, it was calculated that if the cost per renal dysfunction caused by increased levels of cadmium in wheat, exceeded 600 SEK, decadmiation would be beneficial from a societal perspective. The calculation concerned the situation after one hundred years of decadmiation compared with the alternative with no decadmiation. When the corresponding calculation was performed, for the alternative with the current governmental restrictions in Sweden, the calculated "break-even" point was 7 SEK per case of cadmium induced renal dysfunction. This estimate can be conservative, since the benefit of the restricting of the cadmium flow, probably, will continue to influence the health after one hundred years.
In the short run, the benefits of cadmium restrictions concern positive market reactions, compared to the alternative with no restrictions. In a top-down approach, it was found that Swedish agriculture can only tolerate very small relative decreases in the willingness to pay for the products, before the alternative with restrictions become beneficial. The result was confirmed by the results from a bottom-up approach.

The answers to a questionnaire to important actors in the Swedish food system, from the fertiliser producers to the actors delivering products to the retail stores, expressed a benefit of cadmium restricting policies in terms of an insurance against the possibility of negative consumer reactions. The internal cadmium policy was viewed as investments in the own trade marks, as symbols for environmental and healthy products.

All respondents, including the one representing Hydro Agri AB, viewed the official restrictions as complements to the ones of the own organisation. None argued that the restrictions should be removed. The respondent from the Federation of the Swedish Farmers (LRF) even argued that the current Swedish governmental restrictions supported the development of a sustainable agriculture. All the respondents were in favour of extending the current Swedish restrictions to a general set of rules within the EU. The second best alternative to the respondents was to at least maintain the current set of rules in Sweden.

This study support the conclusion that if Sweden and some other small markets continue to demand low cadmium phosphorus fertilisers, the world supply is sufficient. If the demand on the global level increases, decadmiation will become profitable. Thus, the supply of phosphorus fertilisers will be only marginally affected by restricting policies in, for instance, the EU. The welfare costs of the policies discussed in this study are most likely lower than the benefits. The price of phosphorus fertilisers need not be increased very much even if firm restrictions/taxes are introduced in the EU, since the cost of decadmiation sets the upper limit of the price increase.
Sammanfattning

Syftet med denna studie är, 1. att analysera ekonomiska konsevenser av kadmiumflöden till och från jordbruksmark, 2. att analysera ekonomiska effekter av existerande och potentiella, offentliga och privata, styrmedel med syfte att minska kadmiuminhållet i livsmedel, och 3. att bedömma de ekonomiska effekterna av framtidiga flöden till och från jordbruksmark. Analysen består främst av kostnadsanalyser grundade på naturvetenskapliga förhållanden och av intervjuer med marknadsaktörer.

Kostnaderna för kadmiumflöden i livsmedelskedjan kommer på lång sikt att bero av eventuella miljö- och hälsoeffekter. Grundat på skattningar i en nyligen genomförd hälsostudie, beräknades det att varje kg ökning i intaget av kadmium med födan från nuvarande genomsnittliga nivå i Sverige, skulle öka antalet fall av nedsatt njurfunktion med ca 2 200 fall. Hur många av dessa som också skulle få försämrad hälsa specificerades ej.

Informationen om möjliga miljöstörningar var ej tillräcklig för att stödja en kvantitativ analys av miljöeffekter som en funktion av kadmiumflöden i jordbruksystemet.

På kortare sikt beror kostnaderna för kadmiumflöden i livsmedelskedjan om marknadens reaktioner. Beräkningar visade att ersättningen till arbete och kapital på gårdsnivå i nuläget i betydande utsträckning påverkas av gårdens produkter ej klarar marknadens kadmiumgränser. För en veteproducerande gård på 100 ha beräknades minskningen av denna ersättning till 14 500 svenska kronor om kadmiumkraven i Svenskt Sigill (SLRs kriterier för produkter med särskild kvalitet) ej uppfylldes. Detta motsvarar enligt gjorda kalkyler ett minskat fastighetsvärde på 365 000 kronor.

Kostnader för att begränsa kadmiumflödet är dels kostnader som drabbar jordbruket, dels kostnader för samhället som helhet. Nuvarande kadmiumskatt utgör en årlig kostnad för jordbruket på ca 10 miljoner kronor. Samhällets kostnad för administration är ca 100 000 kronor. De medel som tas in till statskassan omfördelas från jordbruk till övriga samhällssektorer och innebär därför inte en välfärdsekonominettokostnad.

Priselasticiteten för fosforgödselmedel är låg, -0,1 till -0,25, vilket medför att en skatt på cadmium i gödselmedel medför en mycket begränsad minskning av efterfrågan på gödselmedel. Produktionseffekten blir därmed också ytterst liten.

Kostnaden för olika processer för dekadmiering beräknades ligga i intervallet 2 till 10 miljoner kronor.

Kadmiumskatten motsvarar 0,03% av jordbrukets totala inkomster 1995, och 0,43% av den totala ersättningen till eget arbete och kapital.

Kostnaden för utländska gödselproducenter av de svenska myndighetsåtgärderna vad gäller kadmium i handelsgodset är låg.

Intäkterna av åtgärder för att begränsa flöden av kadmium i livsmedelssystemet handlar på lång sikt om lägre nivå på hälso- och miljöeffekterna, jämfört med alternativet utan sådana åtgärder. I ett hypotetiskt exempel beräknades det att om kostnaden per njurstörning orsakad av ökad halt av kadmium i vete ökade 600 kronor skulle dekadmiering från ett samhällsperspektiv vara fördelaktigt. Beräkningen avsåg situationen efter ett hundra år med respektive utan åtgärden ifråga. Motsvarande beräkning för nuvarande myndighetsåtgärder i Sverige gav "brytpunkten" 7 kronor per fall av kadmiuminducerad njurstörning. Denna skattning kan vara i underkant, eftersom begränsningar av kadmiumflödet sannolikt även fortsättningsvis, efter 100 år, kommer att påverka hälsan.
På kort sikt rör sig fördelarna av kadmiumrestriktioner om positiva marknadsreaktioner. En ”uppifrån-ned”-analys visade att det svenska jordbruket endast tål mycket små negativa prisreaktioner i alternativ utan kadmiumrestriktioner, innan restriktioner är ekonomiskt fördelaktiga. En ”nedifrån-upp”-analys gav samma resultat.

En enkätundersökning riktades till viktiga aktörer inom det svenska livsmedelsystemet, från producenter av handelsgödsel till leverantörer till detaljhandeln. Kadmiumrestriktioner sågs som en försäkran mot risken av negativa konsumentreaktioner. Aktörernas interna kadmiumregler sågs som investeringar i egna varumärken, som symboler för god miljö och god hälsa.


Denna studie stödjer slutsatsen att om Sverige och några andra länder med små marknader fortsätter att efterfråga fosforgödselmedel med lågt kadmiuminnehåll, så är de totala tillgångarna på global nivå tillräckliga för lång tid. Om efterfrågan på global nivå ökar, kommer dekadmiering att bli lönsam. Sålunda kommer tillgången på fosforgödselmedel ej att begränsas av restriktioner inom exempelvis EU. Välfärdskostnaden av de styrmedel som diskuterats i denna studie är sannolikt lägre än nytan.
1. Background

Cadmium added to agricultural soils may either accumulate in the soils, spread to surrounding ecosystems or be transferred to feed and food. A statistically confirmed increase of Cd in a local variety of winter wheat between 1918 to 1980, grown on the same location, was found by Andersson and Bingefors (1985). The main sources of cadmium intake by humans are smoking and food. Cadmium causes negative impacts in kidneys. Earlier, the safe limit was thought to be 200 mg Cd/kg kidney cortex but recent studies show impacts from as low as 50 mg Cd/kg (quoted from Järup et al. 1997). At present, the average concentration among Swedes is 10-20 mg Cd/kg with clearly higher concentrations for some groups. The situation may become very serious already at relatively small increases in intake. According to the calculations by Järup et al (1997), an increase in average intake of cadmium with food will increase the prevalence of adverse renal effects.

Budget calculations by Andersson (1992) indicate that the average content of cadmium in Swedish topsoils increased by one third between year 1900 and 1990. Cadmium is added to agricultural soils from several sources such as atmospheric deposition (mainly from industrial emissions), phosphorus fertilisers, feed, lime and sewage sludge. Today's application of cadmium from fertilisers is roughly 1/4 of the level in the end of the 1980:s, and average application is presently 0.12-0.23 g Cd/ha and year (Hellstrand and Landner, 1997). Atmospheric deposition has been reduced by 2-3 times and is now 0.1 g/ha and year in the north and 0.35 g/ha and year in the south (Hellstrand and Landner 1997). Liming only contributes an average of 0.02 g Cd/ha and year. Cadmium added from sewage sludge is rather low but counted per unit of applied phosphorus it is higher than for commercial fertilisers. The concentration in sewage sludge has roughly been halved in 15 years (Statistics Sweden, 1995). All sources should be addressed in order to attain a cost-effective reduction of cadmium influx to agricultural land. Behind the successful reduction of cadmium application lies a set of efforts in industry, agriculture and waste management, stimulated by policy instruments and by an increased awareness among market actors about the problem. Even with these drastic reductions, cadmium is still being accumulated in agricultural soils (Hellstrand and Landner 1997).

In all listed cases, the cadmium fluxes are unintended side effects of some economic activity. In order to reduce the addition of cadmium to agricultural soils in a cost-effective way, one should compare the marginal costs in all primary activities of reducing the contribution of cadmium on agricultural soils. It is economically rational to apply policies and changes in production in an order of increasing marginal costs. In industrial production it is often possible to substitute cadmium with other substances. In the case of phosphorus fertilisers the choice is between using phosphate with low cadmium content or reducing the cadmium content by some decadmiation process. It is not possible to stop using phosphorus fertilisers as long as phosphorus is exported from the soils in the form of crops or run-off, if food production is to be sustained in the long run. Recycling should be increased but phosphate rock will most likely be extracted also in the future since it is impossible to achieve 100% recycling.

Historically, the Swedish governmental policy, and other efforts, to reduce the cadmium content in soils and crops has not been straight and simple. The Governmental investigation on environmental charges on the cadmium content in phosphorus fertilizers (SOU 1990:59) suggested environmental charges but did not receive support in the Parliament, further investigation was demanded. The threat of a charge in combination with concern for future production capacity stimulated SLR (the Swedish Farmers National Selling and Purchasing Association) to voluntarily introduce a restriction on the cadmium content at 100 g Cd/ton P in 1989/90. The cooperatives from then on only bought fertilisers with less than 100 g Cd/ton P. The effect was an instant drop in average cadmium concentration from around 80 to 60 g Cd/ton P in the following year and a further drop to 35 g Cd/ton P after three years (Lantmännen 1995). The Government made the 100 g Cd/ton P limit a mandatory standard in 1994. A charge of 30 SEK per gram of cadmium exceeding 50 g Cd/ton P (later changed to 5 g Cd/ton P) was introduced in 1994 and was changed into a tax in July 1995 (Naturvårdsverket 1997). The difference between charge and tax is that a charge is redistributed in the sector, while a tax is used in the general
state budget. In the following the term "charge" is sometimes used without this distinction. In 1994, the charge on the phosphorus content in fertilisers was abolished. The net impact was roughly an unchanged price on phosphorus fertilisers. Today the average content of cadmium is less than 25 g/ton P (Hellstrand and Landner, 1997)\(^1\). A voluntary certification scheme, "Svenskt sigill", including strict conditions for cadmium content in soils and products has recently been introduced by SLR.

\(^1\) Hydro Agri claim that their average cadmium concentration is 16 g Cd/ton P (G. Bertilsson, pers. comm).
2. Aim and method

2.1. Aim
The aim of this report is to, 1. analyse the economic consequences of Cd fluxes to and from agricultural soils, 2. analyse the economic effects of existing, and some potential, policies within the political, as well as the private sphere, to reduce the cadmium content in food and 3. forecast the economic effects of some scenarios concerning future fluxes of Cd to and from agricultural land.

2.2. Method
In welfare economic tradition it is not sufficient to know that there is an environmental problem in order to motivate governmental intervention. The following three conditions should be fulfilled; (1) an externality should be identified, i.e. a side effect on a third party of an economic activity (production, consumption, trade etc.); (2) the externality should not be easily abolished by redefinition of property rights, normally at least one of the resources involved should be characterised by either non-rivalry or non-exclusiveness, or both, otherwise the market has the capacity to allocate resources in an efficient way; and (3) the value of environmental improvements exceeds the cost of the policy, i.e. administrative costs and market disturbing costs. The impacts of cadmium contamination, resulting from atmospheric deposition is an externality from industrial activities affecting the farmers who will face reduced demand for their products and the general public who will face an increased risk of health problems and negative environmental impacts. The impacts of cadmium contamination, resulting from fertiliser application, on the quality of food products is not an externality affecting farmers as long as they are informed about the content of cadmium in fertilisers since the farmer has made a voluntary market transaction. One can, however, see the effects on food quality, and indirectly on human health, as a market imperfection if consumers are not fully informed about the content of cadmium and risks for each commodity. It is very difficult (costly) to measure the content in each commodity and for the consumers to evaluate such information. It may also be difficult to get full confidence in such information transfer. The impact on natural ecosystems, which indirectly influences people’s welfare, is an externality independent of source. The air and water that function as transport media for cadmium are characterised by non-exclusiveness.

The principal motives for governmental interventions are quite solid. There are no estimates of the health and environmental cost of spreading cadmium on soils from fertilisers and airborne pollution. There are, however, some studies that give clear indications of significant health related costs. If environmental or health effects are judged to be serious but not monetary valued cost-effectiveness analysis can be used. Then the question is which policy or effort to reduce cadmium fluxes to soils and human food to a certain level is cheapest.

We see welfare economics as the framework while some of the analysis is based on cost-effectiveness analysis. The method of welfare economics is in this report complemented by an approach of system analysis, in order to relate knowledge from different system levels and disciplines in a way that supports an evaluation and valuation of environmental and health effects of the complex of fluxes of cadmium to and from soils, different soil parameters, and resulting exposure of cadmium to (i) humans via food, and to (ii) the environment. Influxes of cadmium to soils may be stored in the soil, pass to the environment, and/or be taken up in the crops, and then eventually be eaten by humans. This may cause environmental effects, health effects, and affect the value of land and the crops produced on land.

The ambition is to, when possible, move from descriptive approaches of how different factors may influence other factors in this complex, to a predictive approach, where the main factors are ranked, and their respective contribution is quantified. The main goal parameter is the average human intake of cadmium via food in Sweden, though also the environmental load will be considered.
Economic costs can be estimated/calculated using a bottom-up or a top-down approach. In this report both approaches are used. Calculating the costs for farmers, with different production in different regions, of a certain standard or a tax on cadmium represents the bottom-up approach while using macroeconomic information and an estimate of the relevant price elasticity, in this case for phosphorus fertilisers, to calculate the cost of a tax in production represents the top-down approach. In order to analyse the costs it is necessary to know the actual reactions of all actors on relevant markets. The reactions to cadmium in agricultural soils and products and to the governmental restrictions by actors in the Swedish food system, from the manufacturer of fertilizers to the supplier to the retail stores, are studied. A questionnaire has been sent out to some major actors in the food system.

On behalf of the Chemicals Inspectorate, a health study and an environmental study have recently been performed (Järup et al., 1997; Parkman et al., 1997). Also a study concerning the fluxes of cadmium to and from agricultural land, and the time trends concerning the accumulation of cadmium in agricultural soils, as a function of different Cd-levels in P-fertilizers, and P-application rates, assuming Swedish conditions has been carried out on behalf of the Chemical Inspectorate (Hellström and Landner, 1997). A group of scientists at the Department of Soil Sciences at the Swedish University of Agricultural Sciences, has during twenty years studied the the flow of cadmium to soils, and their uptake to crops. Recently, they have summed their findings, with regard to factors influencing crop content under Swedish field conditions (Eriksson et al., 1996). The answer to the mentioned questionnaire, together with the above mentioned studies forms the basis for the evaluation of the economic effects of cadmium in soil and food and cadmium fluxes to and from soil.
3. Economic effects over time of fluxes of cadmium to and from soil

The costs associated with cadmium in agricultural soils, and/or fluxes of cadmium from the soil concern direct environmental effects, direct human health effects and indirect market reactions, affecting the price on crops and arable land.

A problem in the estimation of the economic effects of cadmium flows to and from soils is the time perspective. The doubling time for cadmium in average Swedish top soils ranged from hundreds to thousands of years in the different examples with different application rates of phosphorus fertilisers and content of cadmium in fertilisers in Hellstrand and Landner (1997).

From the balances concerning cadmium to top soils in Hellstrand and Landner (1997), and the regression coefficients concerning the impact on cadmium content in crops of increased levels of cadmium in top soils from Swedish field studies (Eriksson et al., 1996), it can be calculated that only a minor fraction of the net influx of cadmium to the top soil a certain year, will be taken up the same or the following year. This does not, however, mean that the remaining fraction in the soil is harmless. It cannot be excluded that an increase of the net influxes of cadmium, will increase the uptake of cadmium by crops, until a substantial fraction of the cadmium added actually has been taken up by crops, and been exported from the agricultural system. Thus, cadmium added one year may cause health effects far into the future.

This indicates that the following are key aspects in an evaluation of the economic effects of the cadmium flows to and from soils:

- Some of the effects concern long term effects, i.e. cause and effects can be separated by hundreds of years.
- The valuation of the effects depends on whether thresholds with regard to environmental and/or human health effects have been or will be reached.
- The economic effects of a change of a specific influx, e.g. the influx via phosphorus fertilisers, cannot be fully identified.
- The cadmium added to the soil will eventually be taken up by crops, if it is not stored in the soil for eternity, or leaches out from the soil.

There is today a strong tendency that people get more concerned with environmental and health problems and in general these concerns tend to increase with income (Randall, 1987; World Bank, 1992). Both the knowledge about health effects of cadmium in food and the possibilities to measure are increasing. This is likely to result in an increase in market demand for food that is certified to have very low cadmium concentrations, thus favouring producers with low levels of cadmium in the soil. The result would be lower profits for farmers with contaminated soils.

3.1. Future health effects of current cadmium flows

The health effects are potentially important. The terminology is important. Concerning cadmium induced renal effects, the terms "adverse tubular effect" and "tubular damage" imply an unwanted irreversible damage on the tubular function of the kidneys. This damage is by itself free from symptoms. However, the tubular damage increases the risk for renal calculus, which give symptoms, and probably the risk for negative effects on the skeleton (Elinder, 1997; personal communication).

"Impairment" implies a generally lowered renal function, so serious that it may cause contact with medical attendance, and, in the long run, in severe cases, lead to renal insufficiency with a need of dialyse treatment (ibid.).
In the health study by Järup et al. (1997) it is concluded: "the renal tubular damage is most likely the critical health effect of cadmium exposure, both in the general population and in occupationally exposed workers." "If the average daily intake of cadmium would increase to 30 µg/day, about one per cent of the general population would have a cadmium induced tubular damage. In risk groups, for example women with low iron stores, the percentage would be higher, up to five per cent." 2

In Table 1, the frequency of individuals in a population attaining cadmium induced tubular dysfunction, at an average daily cadmium intake per person of 15 and 30 µg cadmium, respectively, is shown.

Table 1. The frequency of cadmium induced tubular dysfunction in different groups in Sweden with two levels of average intake of cadmium with food, and the size of these groups

<table>
<thead>
<tr>
<th>Tubular dysfunction, %</th>
<th>15 µg Cd/day</th>
<th>30 µg Cd/day</th>
<th>Population in thousands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average population, non-smokers</td>
<td>0</td>
<td>1</td>
<td>3,050</td>
</tr>
<tr>
<td>Smokers</td>
<td>0.5</td>
<td>2</td>
<td>2,200</td>
</tr>
<tr>
<td>Increased susceptibility</td>
<td>0.2</td>
<td>2</td>
<td>?</td>
</tr>
<tr>
<td>Women, low iron-stores</td>
<td>1</td>
<td>5</td>
<td>1,000</td>
</tr>
<tr>
<td>Women, low iron-stores and smokers</td>
<td>?</td>
<td>1.6</td>
<td>250</td>
</tr>
</tbody>
</table>

Comments. The number of adult persons is assumed to be 6.25 millions. The size of the average population non-smokers (3.05 millions) equals 6.25 millions minus average population smokers (2.2 millions) minus non-smoking women with low iron-stores (1.0 million). Current and previous smokers are assumed to be 35% of 6.25 millions. The number of persons with increased susceptibility is unknown, thus here they are included in the average population non-smokers. Smoking women with low iron-stores are included in the group of smokers. The figures in the table concerning the frequency of cadmium induced tubular dysfunction interpreted from figure 10.2 in Järup et al. (1997).

According to table 1, an increase of the average individual daily intake from 15 to 30 µg cadmium, is expected to increase the number of cadmium induced tubular dysfunction with about 30,000 persons in the average non-smoking population, with 33,000 in the group smokers, and with 40,000 in the subpopulation women with low iron-stores. All together this sums to a general increase of the number of individuals with cadmium-induced tubular dysfunction with around 100,000 persons, i.e. an increase with 1.6% among adults.

2 The quotations are from a draft version. The term "renal impairment" in the last quotation ought to be replaced with "renal tubular damage" (Elinder, 1997; personal communication).
As an example of the order of magnitude of the costs of renal damages to the society, the annual costs for renal replacement therapy (RRT) in the form of dialysis and kidney transplantation, can be calculated to be 980 to 3,300 million SEK in Sweden, and 44,000 to 148,000 million SEK in the EU³

We conclude, from Järup et al. (1997), that the main effects concerning the health aspect of an increased intake of cadmium with food, is an increase in the costs for treatment, suffering, and productivity for an increase in renal diseases.

Ideally, good information about which specific renal damages, and the associated costs, that most likely will increase with increased exposure to cadmium, should be used in an evaluation of the consequences of flows of cadmium. However, this information is not easily gained, and it is beyond the scope of this study to in detail investigate this question. In section 7, the calculated number of cadmium induced renal dysfunctions for a certain amount of winter wheat with increased levels of cadmium, will be compared to the increase in the costs, due to measures restricting the cadmium flow, such as a tax or decadmiation.

There are studies that indicate that skeletal damage may be a critical effect of cadmium exposure. However, the present evidence is not sufficient to permit such a conclusion for humans (Järup et al., 1997). With respect to the human carcinogenic effect, recent studies indicate that the classification of cadmium as a "probable human carcinogen, group 2A" is appropriate (ibid.)

3.2. The current costs for the farmers of not complying with the demand of the market

Farmers will suffer economically if the prices of their products drop because of the content of cadmium. Already today some purchase organisations pay less (Sjösvärd, 1997; personal communication), or refuse to buy crops with cadmium concentrations over a certain level (Hacklou, 1997; personal communication). The significance of the effect can be visualised by the trade mark "Svenskt Sigill" (Swedish Seal). The Swedish Farmers Selling and Purchasing Associations, Lantmännen, have introduced this trade mark, which is launched as a guarantee of high quality products which have been produced while respecting some defined criteria for sustainability and environmental protection. In order to check whether or not the individual farm has the right to use the trade mark, the farmer has to comply with a certain number of criteria, set up by the association. With respect to cadmium, the test consists of a two-tiered procedure. In the first step, the cadmium content in the top-soil is analysed. If it is below 0.30 mg/kg soil (dry weight), the farmer is allowed to sell the produced wheat using the Swedish Seal trade mark, without any further analyses. If the analysed soil content of cadmium is above the limit, the farmer can still deliver the wheat, if the content in the wheat is below 0.10 mg cadmium per kg grain with a dry matter content of 86% (SLR, 1996). The amount of wheat flour currently sold under this trade mark is ca 80,000 tonnes. This corresponds to 80% of the total household consumption of wheat flour in Sweden in 1996, which was 101 000 tonnes (Eriksson, 1997; personal communication). Related to the total amount of flour used in Sweden, the delivery to Svenskt Sigill, corresponds to ca 15% (Sjösvärd, 1997a; personal communication).

A rough calculation indicates the size of possible losses of incomes with corresponding decrease in the value of arable land, due to too high cadmium levels in soils and/or products. If the winter wheat harvested, passes the criteria of Svenskt Sigill, the farmer gets a bonus of about 0.10 SEK. A common yield in Skåne in intensive crop production, the most productive agricultural district in Sweden, is 8

³ Assuming 8.5 million inhabitants in Sweden, 380 million inhabitants in the EU, one US$ is worth 7.7 SEK, one RRT costs 50,000 US$, (the current cost for hemo-dialysis in Sweden, Järup et al., 1997), and that the prevalence of RRT is 300 - 1,000 per million inhabitants (ibid.).
300 kg per ha (one of the crop levels in the production branch calculi for this area, from the Swedish University of Agricultural Science, 1995). Thus, the bonus per ha is around 830 SEK. Some of the revenue is needed to pay for analyses of soil, and, in case the content of cadmium in the soil is higher than the limit, also for analyses of the cadmium content in the crop. However, these costs are only a minor fraction of the bonus. To be sure to not underestimate the costs for the analysis, assume that these costs sum up to 250 SEK per ha. Then the net benefit to the farmer is 580 SEK per ha. Now, assume that the content of cadmium in the soil and its availability result in such a plant uptake, that the production of high quality wheat is inhibited. Furthermore, assume that the crop rotation is 4 years, with winter wheat one of the years. Then the average yearly loss of income is 145 SEK/ha. It should be noted that costs for increased levels of cadmium in the other crops in the crop rotation are not considered in this example.

If the loss of the option to produce high-quality winter wheat sustains in the long run, this loss is expressed as a decrease of the value of land, due to the capitalised value of the loss of land rent. If the real interest rate is 4% and the time horizon infinite, the value of arable land, with given assumptions, will decrease with 3 625 SEK per ha (145 SEK/0.04). For a normal sized farm in this district (100 ha), the total loss of incomes per year would sum to 14,500 SEK, which in capitalised terms correspond to a loss of capital of 362,500 SEK for the whole farm.

The calculations above overestimate the costs for analysis for many producers. The soil analysis needs not be made more than once every ten years, and one analysis can cover 15 ha (SLR, 1996). The farmer should, however, fulfil a number of criteria in order to get the bonus. Thus, it can be argued that the bonus should be allocated among the different criteria, but several of the other criteria can easily be fulfilled while the cadmium criterion can be the crucial one.

The extra revenue on the farm level in Sweden of the trade mark Svenskt Sigill is, including wheat, rye and oat, in a static perspective, 112 million kg \(4 \times 0.10 \text{ SEK per kg} = 12 \text{ million SEK}. \) In a dynamic perspective, the value can be lower or higher, dependent on how well it competes, in a world of consumers with changing preferences.

The corresponding calculation for the plain districts in Svealand, with a crop rotation of six years, with winter wheat two of the six years, and a yield of 6,700 kg winter wheat per ha, results in almost the same figures (14,000 SEK in loss of incomes, and a decreased value of the farm of 350,000 SEK, for a farm of 100 ha).

### 3.3. Environmental effects

In the report concerning cadmium and the environment (Parkman et al., 1997), it is concluded that it cannot be ruled out that the levels of cadmium in agricultural soils is a risk for the soil living organisms. However, available information concerning possible environmental effects of cadmium fluxes from agricultural soils to the environment, does not admit any quantification of these effects. This is not to say that such effects do not exist.

### 3.4. Concluding remarks

Available information supports a quantification of economic effects of cadmium flows in the food system in terms of number of cadmium induced renal dysfunctions. It is not, at this stage, possible to express the costs of renal dysfunctions in monetary terms. However, a general increase in the number of renal dysfunctions is probably associated with an increase in a number of renal diseases, each with its specific cost for treatment, suffering and loss of productivity.

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479,000 tonne wheat, 4,000 tonne rye and 29,000 tonne oat (Sjösvärd, 1997b; personal communication).
Available information does not support an quantification of the environmental impact of the current cadmium flows in the Swedish agriculture.

The current market reactions can be interpreted as expressing the valuation of expected future environmental and health effects of the consumers, discounted to the present.

The costs and benefits of measures restricting the cadmium flows can in principle be done in two ways. Either by comparing the current costs for restrictions with its possible future health effects. That is, considering the information available, the costs for restrictions is divided by the number of cadmium induced renal dysfunctions that is calculated to occur without the restrictions. This way, a break-even price per renal dysfunction is obtained, where we leave it to the reader to judge whether the real costs for renal dysfunctions are higher or lower.

The second way is to use the current market premium for products with low cadmium content on the current market, and compare it with the increase in production costs that restricting measures cause at the same time. In this case too, there is a data problem.

The actors on the market do not communicate the cadmium issue to the customer in the retail store, because of the risk that the message the customer will perceive is “They have cadmium in the product”, instead of the sent message “They have very little cadmium in the product” (see section 4.3.). Thus, the consumers willingness to pay for products with different cadmium content is not explicitly expressed on the market at present. Still, the market actors producing and distributing the products show great concern in the cadmium issue, in terms of an insurance against future negative market reactions. This indicates that high cadmium levels in products by producers is judged to be associated with a high risk for substantial future costs in terms of lost market shares.
4. Market actors

On the Swedish food market, voluntary cadmium-limits are already imposed on products through initiatives taken by producer associations as well as retailing companies. These limits, which are stricter than the legally imposed criteria, have been set as a response to the perceived consumer demands. Also the tax on cadmium reduces the profitable level of cadmium in phosphorus fertiliser substantially below the allowed limit.

First, in this section, the food-supply system in Sweden with regard to the flow of cadmium with food, and the different actors on the market will be described. Secondly, two examples of how important market actors handle the cadmium-question will be presented. The two examples are chosen so that the following categories are represented:

- the two main routes in Sweden of cadmium to humans via food, cereals and vegetables (including potatoes and carrots),
- an actor close to the producer (SLR), and another actor close to the consumer (ICA Frukt och Grönt), and
- the farmers co-operative, and a private enterprise.

The motives for the choice of strategy of the actor in question, the strategy chosen, the goal parameter, the impact on the location of production to different soils, and the experiences concerning demand of products will be discussed.

Thirdly, the results from a questionnaire to some important market actors at the different levels in the food supply system will be presented. The questionnaire treats:

- the attitude of the actors towards the cadmium-problem and to the governmental policy,
- the importance of the cadmium level in used inputs,
- the importance of the cadmium level of the products, and
- the cadmium-policy of the actors.

4.1. The Swedish food-chain and food-market

There is a need to briefly describe the food-chain and the food-market, from the perspective of their “contribution” to the human exposure to cadmium via food in Sweden. There are two dominating routes of cadmium exposure to humans with food in Sweden, of about the same size. One is cereals, where wheat and rye flour contributes around 40 and 5%, respectively, to the total intake of cadmium with food. The other route is through root crops, where potatoes and carrots contribute 40% and 5%, respectively, to the total cadmium exposure via food (Hellstrand and Landner, 1997). Thus, without loosing too much information, on average, an understanding of the flow of cadmium from the soils to human intake, can be reduced to the question of the flow of cadmium through cereals and vegetables, and further on to the flow of cadmium through the grain of wheat and rye, potatoes and carrots, since the crops represent 90% of total intake.

In Figure 1, the main structure of the market in the agricultural and the food system in Sweden with regard to cadmium and wheat flour is presented. As shown by the Figure, the market structure is complex. The purpose of this section is not to analyse the Swedish food system in detail. However, an understanding of its main features facilitates an understanding of the effects of cadmium policies.
Cadmium

1. Fertiliser manufacturer

2. Seller of fertiliser to farmer

3. Federation of Swedish Farmers (LRF)

4. Farmer

5. Swedish Farmers' Regional Selling and Purchasing Association

6. Buyer of crops

7. Swedish Farmers' National Selling and Purchasing Association (SLR)

8. Mill

9. AB Cerealia

10. Distributor of flour

11. Bakeries

12. Supplier of retail stores

13. Retail stores

14. Consumer

Within the grey line the influence of the Swedish farmers is substantial/dominating

Figure 1. The main structure of the market of the Swedish agricultural and food system with regard to the flow of cadmium to the consumer of wheat flour. The flows of cadmium between actors are shown with solid lines. Dotted lines denote owner or membership relations. The grey lines from box 5 to box 2 and 6, respectively, indicate that the Swedish Farmers’ Regional Selling and Purchasing Associations are dominant actors in box 2 and 6.

Some of the boxes in the Figure need to be explained. The Federation of Swedish Farmers (LRF; 3 in Figure 1), is oriented towards the political sphere in the society. The farmers are also associated in cooperatives, engaged in the supply of inputs to the farmers, and buying their products, and processing
them. The principal task of these co-operatives is to support the profit on the farm level. In Sweden the co-operatives in general dominates the market, with market shares between 65 and 100% (dairy co-operatives).

In order to strengthen the competitive power of the farmer, vertical integration is common. As a principle, the dominance of the farmers co-operative, or the enterprises they own, decreases with the distance from the primary production on the farm. With regard to the cadmium issue, the structure concerning the trade and processing of wheat and potatoes are of special interest. The structure concerning animal products are less interesting, as only a minor fraction of the human intake of cadmium with food, is via this path.

The co-operatives supplying the farmers with fertilisers are the Swedish Farmers' Regional Selling and Purchasing Associations (the regional Lantmän-associations, box 5 in the figure). They together constitute SLR, the Farmers National Selling and purchasing Association (box 7). The Lantmän-group has a market share of 78% of the phosphorus fertilisers in Sweden. They also buy most of the cereals produced on the farms. Thus the Lantmän-group dominates box 2 and 6 in the figure. SLR owns AB Cerealia, which in turn owns AB Nord Mills, AB Kungsörnen and AB Skogaholm. AB Nord Mills grind around 40% of the flour used for human consumption in Sweden (Crona, 1997; personal communication). They sell the flour to AB Kungsörnen, which supplies the retail stores with flour used by the households. Their market share is 60% of the Swedish flour market (Lindner, 1997; see the answers to the questionnaire from AB Kungsörnen, appendix 1) (excluding flour to bakeries). AB Nord Mills also sells flour directly to bakeries. One of the main bakeries in Sweden is AB Skogaholm. Thus, SLR, through these relations, also dominates the mill industry (box 8) and the supply of retail stores with flour (box 10). They also, through AB Skogaholm, have a substantial fraction of the market of the bakeries (box 11 in Figure 1).

To further complicate the picture, it is not only the individual farmer that is associated in LRF (box 3). The different producer co-operatives, such as the regional as well as the national Farmers’ Selling and Purchasing Associations, are also so-called organisational members in LRF (Sandberg, 1997; personal communication). The consequences, with regard to the cadmium issue and cereals, is that:

• the Swedish farmers or their enterprises operate close to the consumer, and

• they have dominating or substantial market shares at levels between the fertiliser manufacturer and the supplier of the retail stores.

This implies that dominating or, at least, important actors at most of the levels in this production chain can implement similar internal cadmium policies. The cadmium policies actually implemented are the ones that the Swedish farmers and their organisations, after different considerations, have found will support the profit on the individual farm. Expressed in another way, the internal cadmium policies in the farmers associations, and the enterprises they own, express what the Swedish farmers perceive is beneficial to themselves in this issue. One more conclusion can be drawn, the extended vertical integration implies that the farmers get information about the potential concern of the consumers, and can “press” this information backwards in the production chain. Thus, which will be shown in the following, Kungsörnen AB specify cadmium restrictions which are transferred via AB Nord Mills and the regional Lantmän-association, to demands on the production on the field level on the single farm. This gives a potential to be sensitive to the consumer preferences, and the trends in the consumer preferences, in the farming practices applied on the single field.

In the case of root crops, such as potatoes and carrots, farmers often deliver to packing enterprises, which sell to the supplier of the retail stores. Thus, the production goes directly from box no 6, in the figure, to box no 12, the supplier of the retail stores.
As already mentioned, the farmers' co-operatives dominate or play major roles on several levels in the cereal system. Producer co-operatives do not play the same dominating role in the case of vegetables. This may affect the speed and power by which internal cadmium policies are implemented in the two dominating routes for cadmium exposure.

In Sweden, there are a few consumer organisations, but they are not very strong. This is the reason why, in the section concerning the questionnaire, no consumer organisation was included.

By random, it happened that the respondents from ICA Frukt och Grönt, and from SLR, did not answer the questionnaire. By luck, it happened that in another phase of this study, and in another context, respondents from these organisations gave an extensive description of the opinion of their organisations concerning the cadmium flows in the food system, and the measures of the political and the private sphere to restrict these flows. In the following section, their opinion on this issue is presented.

When coming to the questionnaire, the close relationship between the different actors with connection to the Swedish farmers and their associations, and SLR, (see Figure 1), should be remembered. The opinion of the enterprises owned by SLR, for example, may state the attitude of SLR rather than an opinion of their own.

4.2. Two examples from the Swedish food-market

4.2.1. The farmer co-operatives

Lantmännen have introduced the trade mark "Svenskt Sigill" (Swedish Seal). This trade mark and the criteria needed to be fulfilled, was described in section 3.2. It should be noted that the limit value for cadmium in soil in Svenskt Sigill is only slightly higher than the average level in Swedish farmland top-soils (0.26 mg/kg). In some regions of Sweden, the cadmium levels in soils are, of course, much higher, as shown by the 75 percentile value being 0.30 mg/kg, and the 90 percentile value being 0.40 mg/kg (Eriksson et al., 1995).

In the major production areas in southern Sweden, the average cadmium content in soils is 0.28 mg/kg.

As a comparison, the average cadmium content in the top-soil of arable land in several European countries is shown in Table 2 (after Landner et al., 1996). The availability factors differ between soils and nations. Still, the soil contents of cadmium in different nations shown in Table 2, indicate that problems could emerge in some areas, if a corresponding trade mark, with similar cadmium criteria were to be introduced in other nations.

If the top-soil contains >0.30 mg Cd/kg, the farmer may proceed to the second step, which consists in an analysis of the cadmium content in the wheat grains. If this level is <0.10 mg Cd/kg, the crop can be sold under the trade mark Swedish Seal, otherwise not.

The amount of wheat produced under the trade mark Svenskt Sigill correspond to 10-15% of the amount used for human consumption in Sweden. For the rest of the wheat milled in Sweden, a limit of 0.10 mg cadmium per kg grain is applied. One difference, however, is that in Svenskt Sigill, the limit is applied on the delivery from the single field, while the limit used by the mills, concern much bigger deliveries. Thus, deliveries which is not accepted by Svenskt Sigill, can very well anyhow be accepted for human consumption, if it is mixed with deliveries with lower content of cadmium.
### Table 2. Average cadmium concentrations in the top-soil of arable land in various countries

<table>
<thead>
<tr>
<th>Country</th>
<th>mg Cd/kg top soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>0.22 or 0.28</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.22</td>
</tr>
<tr>
<td>Finland</td>
<td>0.06 or 0.25</td>
</tr>
<tr>
<td>France</td>
<td>0.22</td>
</tr>
<tr>
<td>Germany</td>
<td>0.26 or 0.30</td>
</tr>
<tr>
<td>Italy</td>
<td>0.40</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.39 or 0.48</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.08</td>
</tr>
<tr>
<td>Spain</td>
<td>0.11</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Note: Where two values are given, they refer to different studies. From Landner et al. (1996)

Another example comes from a regional Lantmännen association in Skåne, where a slightly different limit for cadmium in soil is used for acceptance of oats for human consumption (as müsli). No production is allowed on soils with >0.45 mg Cd/kg, and at soil concentrations between 0.35 and 0.45 mg Cd/kg, the oat grains have to be analyzed. The limit value for oat grains is 0.10 mg Cd/kg, i.e. the same as for wheat grains (Nilsson, 1997; personal communication).

It should also be mentioned that the Lantmännen associations apply a general limit for cadmium content in phosphorus fertilisers sold by the co-operatives. This limit is set at 50 mg Cd/kg phosphorus, i.e. half the official limit value established by the Swedish authorities. The average cadmium content of the phosphorus fertilisers sold by the co-operatives during the 1995/96 season was 25 mg Cd/kg phosphorus (Chrisersson, 1997; personal communication). Their market share for phosphorus fertilisers was 78% (ibid.). The current average level of cadmium in phosphorus fertilisers is probably a function of the voluntary regulations by Lantmännen, as well as of the tax on cadmium content above 5 mg/kg phosphorus fertilisers. The relative importance of the two measures, cannot easily be separated.

A number of comments to the situation described above can be made:

- The fact that the Swedish farmers’ own co-operatives, with a dominating role on the food market, have introduced and are enforcing the limits for cadmium content in soil, fertilisers and crops, indicates that these limits are considered to be beneficial to the farmers.

- The application and enforcement of the limits can be viewed as an investment in the trade mark, i.e. to build credibility and trust among consumers and to avoid negative market reactions.

- In the first place, the good-will of the trade mark will enhance the market share on the home market for high-quality food products. Later, it may also promote an increasing food export. Interest has been shown by actors on the British market (Sjösvärd, 1997a; personal communication).

- The proportion of wheat for human consumption already sold under the Swedish Seal trade mark, and the very large fraction of the total amount of phosphorus fertilisers used that had a low cadmium content, indicate that important actors on the market are concerned about the cadmium question.
• Most farmers who fail to comply with the first criterion (the cadmium content of the soil) do not proceed to the second step. One reason for this is that the cost per ha and year on average for the soil analysis is about one tenth of the costs for the grain analysis, since the soil analysis can be made once every ten years and the grain analysis must be made every year. Thus, the soil cadmium content is the main operational selection criterion. It should also be noted that this criterion is applied on the field level, i.e. the cadmium content on each particular field has to be checked.

4.2.2. The supplier of the food retail stores

The majority of food retail stores in Sweden are organised in three chains, within each of which the individual stores co-operate in the field of wholesale trade. One of these chains, ICA, has a market share of 30-35% (Hacklou, 1997; personal communication). Each ICA store is an independent, private enterprise, co-operating with the others. However, each store-keeper makes his own choice on where to purchase his goods. Within the ICA structure, the subsidiary "ICA Frukt och Grönt" is responsible for delivery of fruits and vegetables to the different ICA stores. The share of the Swedish fruit and vegetable market of ICA Frukt och Grönt is about 30-35% (ibid.).

Some years ago, ICA Frukt och Grönt initiated a quality control program for the products delivered to the retail stores. A set of quality criteria has been established, stipulating maximum allowable concentrations of some pesticides, nitrate and heavy metals, including cadmium. This set of criteria was first applied, as a test, to carrots, partly because carrots potentially is one important route for cadmium intake by humans. Current levels of cadmium in Swedish carrots for human consumption have been reported as being, on average, 276 µg Cd/kg dry weight, with maximum values up to 870 µg/kg (Öborn et al., 1995), but its fraction of the total cadmium intake in a normal diet might not be more than about 5%. However, vegetarians may take in much higher amounts of cadmium with carrots.

This voluntary regulation of the cadmium content in carrots has now been in operation for three years, and the main consequences experienced have been reported as follows (Hacklou, 1997; personal communication):

• ICA Frukt och Grönt has been able to double the quantity of carrots delivered in three years. This means that the carrot-producers delivering to the company, have also doubled their market share during the same period of time.

• Production of carrots has been diverted from soils with high content of cadmium to the benefit of carrot-growers having access to soils with lower cadmium content.

The main purpose of the quality control program launched by ICA Frukt och Grönt is to try to avoid any negative market reactions. The quality manager justifies the program as an insurance against bad reputation; he explicitly points to the need to insure the company against the possible risk of consumers associating the trade mark ICA Frukt och Grönt with something similar to the "mad cow disease". Basically, it is an investment with the aim of linking the trade mark with a perception of healthy products, good quality and good environment.

In order to follow up the present positive experiences, it is planned to extend the program to include other products, such as potatoes. This is interesting in relation to cadmium, as the relative human intake of cadmium via potatoes represents more than 40% of the total intake in the average Swedish population (Jorhem and Sundström, 1993). The average concentration of cadmium in Swedish potatoes is 53 µg Cd/kg dry weight and a maximum value of 194 µg Cd/kg dry weight has been reported (Öborn et al., 1995).

The criteria for the maximum allowable concentration of cadmium in food delivered by ICA Frukt och Grönt are not intended to stay fixed in the future, but will successively become stricter, at a rate
determined by the adaptive capacity of the producers. Thus, this quality program is a dynamic one, set up to meet the requirement of continuous improvement of the quality of the products.

It can be noted that the quality manager considers the limits for cadmium content in food items being discussed by the EU to be far too tolerant to meet the objectives set up by ICA Frukt och Grönt (Hacklou, 1997; personal communication).

4.3. Food market actors and cadmium: — results from a questionnaire

In order to track the attitudes towards cadmium in the food system, and to current governmental restrictions in Sweden, a questionnaire was sent to representatives for a number of important actors along this chain. The following organisations, representing, major actors in the supply of cereals, as well as in the supply of vegetables, were contacted.

Fertiliser manufacturer: Hydro Agri AB and Agri Kemira AB.

Seller of fertilisers to the farmers: SLR and AB Svenska Foder.

Swedish Farmers: LRF.

Buyer of crops from the farmers: SLR and AB Svenska Foder.

Mill: AB Nord Mills.

Seller of flour to retail stores: AB Kungsörnen.

Supplier of retail stores: KF = Swedish Co-operative Union, AB Dagab and AB ICA Frukt och Grönt.

Most organisations asked has answered, see Appendix 1.

It is assumed that LRF represents the opinion of the Swedish farmers, and that SLR represents the opinion of the Swedish Farmers’ Regional Selling and Purchasing Associations (there are 11 such regional associations which constitute SLR).

The questions concern both the problem of cadmium in soils and products, and the attitude to governmental restrictions, as well as to restrictions driven by the market. In Appendix 1, the questions and answers are given in extension. Here follows a summary.

Because of the importance of the restrictions of cadmium in phosphorus fertilisers to the fertiliser producers, there is a need to present some general information about Hydro Agri AB and its production of phosphorus fertilisers for the Swedish market, before the answers of the respondents are summarised.

The market share of Hydro Agri AB, with regard to phosphorus fertiliser, is around 60% in Sweden, 30% in Germany, Great Britain and France and 60-70% in Italy (see Appendix 1). The enterprise is the biggest fertiliser producer in the world, still the world market share is below 10% (ibid.). The NPK-fertiliser produced in Köping in Sweden is produced from inputs with Finnish origin, the NPK sold in Sweden, produced in Norway, is based on apatite from the Kola peninsula. Both the Finnish and the Russian apatite are low in cadmium (ibid.). The PK-fertilisers Hydro Agri AB sells, are manufactured by other companies. The origin of the inputs can shift. Thus, the level of cadmium per kg phosphorus can be higher, compared with the level in the NPK-products sold in Sweden. The price paid by Hydro Agri AB for the inputs they use, tends to increase with the restrictions on the cadmium level in the inputs (ibid.).
The most striking result is the great correspondence in views expressed by the actors in most answers. Most of them advocate general rules in Europe. The complementarity between the rules of the authorities, and the measures taken by the actors on the market is stressed. Three roles of the authority-set restrictions are mentioned. One is to put the focus on a question, and speed up the work by the actors of the market. Another one is to define the lowest acceptable level of ambition in the environmental work, concerning for example cadmium. The third one is to set the rules, governing the competition on the market. The dynamics of the market was stressed by several actors, leading to the conclusion that the task of the authorities is to set the rules and objectives, while leaving the question of how to realise the objectives to the market.

Most respondents were in favour of the taxes. One respondent thought they are “completely right” as a principle (AB Kungsörnen), if there are environmental impacts, another respondent thought they seemed to be very low, compared to the risks of the cadmium exposure to human health (KF, which operate close to the consumer), yet another respondent (from Dagab) questioned if the limit that is valid today is put sufficiently low. This can be compared to Hacklou, the Quality Director at ICA Frukt och Grönt, who considers the limits for cadmium content in food items being discussed by the EU to be far too tolerant to meet the objectives set up by ICA Frukt och Grönt (see section 4.2.2.). These arguments in favour of limits of cadmium in phosphorus fertilisers, lower limits, or tough limits in food products by these three persons are interesting. They represents the three dominating whole sale dealers in Sweden, and, among the interviewed persons, their organisations operate closest to the customer.

Other respondents pointed out that an exclusive tax on Swedish agriculture implies a competitive disadvantage (Hydro Agri AB and LRF; which both operate close to the producers). A solution to this problem was suggested; the tax should be brought back to the agriculture (LRF), and, thus, become a charge.

The respondent from AB Kungsörnen expressed the opinion that the current tax could be to the advantage of the agriculture by supporting the development of an environmentally sound agriculture. This, according to the respondent, is and will be an increasingly important selling argument, where it is up to the enterprises to make benefit of the advantage. It should be noted that AB Kungsörnen dominates the Swedish flour-market, with regard to the supply of the retails stores, they are in the process to only sell certified products, and that the rules concerning the cadmium-aspect are vital in the certification.

It should also be noticed that Hydro Agri AB, by its own initiative proposed the possibility to develop low-cadmium fertilisers, while the representative of the potential buyers of this product (LRF), by its own initiative, asked for this product.

Hydro Agri AB talks in positive terms of the limit: “non serious marketing is prohibited“. The same opinion was expressed by the respondent from SLR. The disadvantage of the current set of rules mentioned by Hydro Agri AB and by SLR is the economic burden on Swedish agriculture (the size of this burden is analysed in section 5). The supply of phosphorus will not be a problem, even if the market for low cadmium products will grow substantially (Hydro Agri AB). Then decadmiation processes will be introduced. However, the Swedish market is to small to motivate decadmiation. The restrictions of the market and the authorities complement each others, according to Hydro Agri AB. They propose a general system of rules in the EU. SLR has by its own initiative introduced a lower limit than the authorities, 50 mg cadmium per kg phosphorus.

The respondent from LRF, in context of the governmental restrictions of cadmium in phosphorus fertilisers, talked in terms of support of the development of a sustainable agriculture. The restrictions strengthen the international work concerning the load of cadmium to arable land. They set rules, supporting a competition on the market on equal terms. The tax, the respondent argued, steers the
market to the current content of cadmium in fertilisers. He also stressed the acceptance for the cadmium restrictions among farmers. He concluded that the measures of the authorities and the ones of his own organisation are complementary. He stressed that the measures of the authorities are needed in order to prohibit cheap, contaminated fertilisers. However, he suggested some change in the restrictions: either that the rules are applied in other nations, or that the current tax is changed to a charge, implying that the fee is returned to the agriculture instead of going into the state budget.

The answers from SLR, were in line with the others.

The organisations operating closer to the consumer stress the consumer perspective harder, expressing a deep concern on the cadmium issue. They talk in terms of insurance against possible fast, deep and negative consumer reactions.

4.4. Discussion about public attitudes to food quality and regulatory policies

The previous presentation and discussion, together with the calculations of the current cadmium balances in agricultural soils in Sweden (Hellstrand and Landner, 1997) stress the complexity of the situation. A paradox can be pointed out. On one hand, the load of cadmium to arable land in Sweden has been substantially reduced (Hellstrand and Landner, 1997). On the other hand, a substantial part of the producers delivering wheat and carrots do not pass the cadmium limits established by the market. In “Svenskt Sigill”, the limit where grain analysis is needed is 0.30 mg Cd/kg top soil. 25% of the soils in Sweden exceed this limit (Eriksson et al. 1995). The limit for grain, is based on the maximum permissible level of cadmium in wheat grains, 0.1 mg Cd/kg, proposed by the FAO/WHO. Most farmers who fail the soil test, choose to not produce for the high quality trade mark “Svenskt Sigill”. Thus, the limits applied by the actors on the Swedish food market already influences the location of high quality wheat and carrot production, excluding the soils with the highest cadmium contents.

Furthermore, the cadmium content in phosphorus fertilisers is already subject to a voluntary restriction, which is stricter than the regulation imposed by the authorities.

This paradox can reflect that the content of cadmium in crops is a function of the cumulative net influx of cadmium to the soil, and the availability factors. Thus, an effective policy to reduce the human intake of cadmium with food, may be constituted by measures addressing the influxes of cadmium to the soil, the availability factors concerning the plant uptake of cadmium in the soil, and the level of cadmium in food. In this study, we focus on some measures of the first type. In addition to this, there is an ongoing reappraisal of the toxicological effects of long-term, low human exposure to cadmium, which possibly may result in a decrease of the recommended tolerable daily intake of cadmium (see, e.g., Järup et al., 1997).

Environmental awareness and concern among the general public tend to increase with the improvement of the standard of living (Randall, 1987; World Bank, 1992). Thus, one can assume that there will be an increasing public pressure for stricter regulation of the cadmium content in food. The market reaction mentioned above, on the low-cadmium carrots offered by ICA Frukt och Grönt, indicates that environmental concern is already a significant market force. If the environmental and health concerns among consumers will become even more important as a criterion for the choice of a certain product or a specific trade mark, we can expect that the pressure on farmers to produce safe and healthy food will increase in strength.

An important question is to what extent political decisions on regulations of, for example, food safety should lag behind spontaneous, consumer-driven regulations coming up, or to what extent the political sphere should respond to public concerns or – perhaps even – try to take initiatives and lead the development towards sustainable agriculture and improved food safety. The answer to this question may have important implications for the public perception of the legitimacy and authority of the political sphere and its institutions, both at the national and the EU level. In Sweden, the measures concerning cadmium within the political and private sphere complement and reinforce each other.
5. Economic effects of the current Swedish cadmium policy

5.1. Policy instruments

The market analysis of cadmium spreading is complicated by the fact that cadmium is not normally the traded commodity a policy instrument can be targeted on. Cadmium is normally contained in other substances without a positive role in the use of that substance. The reactions on a standard and a tax on cadmium contents of fertilisers are largely indirect. The farmers cannot choose a phosphorus fertiliser which they think is optimal given any price including the tax on cadmium. The sellers of agricultural inputs can only sell a very limited number of phosphorus fertilisers with varying cadmium content and they adapt to the new conditions by selling phosphorus fertilisers with less cadmium content. The types with more than 100 g/ton P have disappeared from the Swedish market and the market share for phosphorus fertilisers with very low content of cadmium has increased. The farmer can only choose among the marketed fertilisers and, of course, the quantity demanded.

It is practically impossible for individual consumers to measure the cadmium content in the food they buy so the consumers are left with two possibilities, either a certification system or a national policy that protects them, or a combination. If we depend on only certification, part of the market will be using fertilisers with a high content of cadmium and hence part of the soils will have high cadmium concentrations. There is also a distributional issue involved, some people can afford to pay for high quality while some people with less purchasing power will tend to buy the cheaper food with high cadmium concentration. This, in combination with the risk of severe health threats, should be enough to motivate a national, or EU, policy to reduce accumulation of cadmium in agricultural soils. Full economic liability for producers/sellers for damage caused by their products is not possible due to the large number of producers/sellers and the fact that damage will be caused by total intake from many sources, not by a single overload.

It is easier to achieve exactly a specified maximum concentration with a standard than with a tax. A tax implies an incentive to reduce cadmium content at all concentration levels for which the tax applies, while there is only an incentive to fulfil the standard and do no more in the case of a standard. The two policy instruments have equal and rather low costs for control, it can be done by random checks of a few percent of the deliveries. A tax has a higher chance of being cost-effective than a standard. A system with tradeable permits is an alternative with performance similar to that of a tax, but in this case the point in substituting the tax with tradeable permits is limited, since the total burden of a tax is rather small.

What is the risk that a firm cadmium policy would cause unfair trade barriers and monopolisation of the Swedish market? A firm policy would, of course, in principle disfavour suppliers of phosphorus fertilisers, whether Swedish or non-Swedish, with high cadmium contents. Since Sweden is such a small part of the total market this effect is, however, insignificant (see Chapter 6). It is also not possible for Swedish farmers to increase product prices to compensate for extra costs of standards or the tax since Sweden is part of the common market in the EU, unless the products are sold on a niche market and in that case it could be done also without legal restrictions or taxes. The policy, of course, does not favour export of agricultural commodities since production costs increase.

Consumers’ demand for food with very low cadmium content would favour farmers in countries with firm standards, because they can sell a commodity with the demanded quality. But farmers in other countries who voluntarily reduce their application of phosphorus fertilisers and participate in a certification system can sell on the same market. A firm policy in one country does not prevent producers in other countries from selling on the high quality (high price) market.

Monopolisation might occur if there were only one domestic producer/seller of phosphorus fertilisers that fulfilled the standard. But even then the market conditions would be competitive as long as there are international competitors with access to the domestic market. In the Swedish case consumption of
fertilisers are based on imports⁵ and there are several importers and distributors in the country so the risk for monopoly in Sweden is very limited. It may, on one hand, be difficult for non-Swedish distributors to establish themselves on the Swedish market because of the cooperatives’ domination. There is, on the other hand, no limitation in competition for non-Swedish producers to sell to the Swedish distributors, caused by the Swedish cadmium policy other than the intended effect of keeping out fertilisers with too high cadmium content.

In the following, market reactions and costs of policies to reduce cadmium in phosphorus fertilisers will be analysed. It is not possible to fully separate the effects of each effort to reduce the cadmium content in phosphorus fertilisers. It seems, however, very likely that, directly and indirectly, the 50 g Cd/ton P standard, implemented by farmers cooperatives, the 100 g Cd/ton P standard implemented by the state, and the 30 SEK/g Cd tax have had a considerable influence on decreasing application of cadmium on Swedish agricultural land.

5.2. Calculation of costs for farmers - Bottom-up approach

5.2.1. Regional variation in the costs

The calculated cost of the tax on cadmium in phosphorus fertiliser for Swedish farmers in different regions is calculated in Table 3. The regional variation in application of commercial phosphorus fertilisers is multiplied by price-increasing effect on phosphorus fertilisers of the cadmium tax. The price-increasing effect is the product of the current tax of 30 SEK/g cadmium for levels above 5 g Cd/ton P and the current average level of cadmium in phosphorus fertiliser, i.e. 25 g/tonne P. The price of phosphorus fertilisers is increased by 0.60 SEK per kg if the cadmium tax has a full effect on the fertiliser price, i.e. if the profits of fertiliser suppliers are not reduced.

In table 4, the results from the calculation of the costs for the agriculture of one method for removal of cadmium in commercial fertilisers are presented. The method in question is precipitation with anhydrite residue treatment (see Landner et al., 1996). This is our low cost alternative, the cost in SEK per kg P is calculated from an average level of 7.5 US$ per tonne P₂O₅ decadmiated (ibid.).

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⁵ Sweden has some non-sedimentary phosphate resources, in the form of iron ore, that are not currently being extracted.
Table 3. Regional variation in yearly costs of taxes on cadmium in phosphorus fertiliser for the farmers. The calculations are based on the application rate 1994/1995 (from Statistics Sweden, 1996), the average content of cadmium in phosphorus fertiliser in the crop season 1995/96 (25 mg per kg phosphorus; Hellstrand and Landner, 1997), and the current tax on cadmium in phosphorus fertiliser (30 SEK per g cadmium above the level of 5 g cadmium per tonne phosphorus)

<table>
<thead>
<tr>
<th>Production area</th>
<th>Crop area, ha * 1,000</th>
<th>P-fertiliser kg/ha</th>
<th>Costs for tax on cadmium</th>
<th>Total cost, 1,000,000 SEK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Plain districts, S. Götaland</td>
<td>313</td>
<td>9.2</td>
<td>5.52</td>
<td>1.73</td>
</tr>
<tr>
<td>2. South east Götaland</td>
<td>297</td>
<td>6.1</td>
<td>3.66</td>
<td>1.09</td>
</tr>
<tr>
<td>3. Plain districts, N. Götaland</td>
<td>380</td>
<td>11.4</td>
<td>6.84</td>
<td>2.60</td>
</tr>
<tr>
<td>4. Plain districts, Svealand</td>
<td>502</td>
<td>9.1</td>
<td>5.46</td>
<td>2.74</td>
</tr>
<tr>
<td>5. Forest districts, Götaland</td>
<td>470</td>
<td>5.5</td>
<td>3.30</td>
<td>1.56</td>
</tr>
<tr>
<td>6. Forest districts, central</td>
<td>168</td>
<td>7.3</td>
<td>4.38</td>
<td>0.74</td>
</tr>
<tr>
<td>Sweden</td>
<td>2,384</td>
<td>7.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Lower parts of Norrland</td>
<td>148</td>
<td>4.8</td>
<td>2.88</td>
<td>0.43</td>
</tr>
<tr>
<td>8. Upper parts of Norrland</td>
<td>106</td>
<td>7.5</td>
<td>4.50</td>
<td>0.48</td>
</tr>
<tr>
<td>Sweden</td>
<td>2,384</td>
<td>7.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comment. The area given in the table is excluding fallow, and the categories "others", and "not used" (see Statistics Sweden, 1996).

Table 4. Regional variation in the costs for the farmers of decadmiation of phosphorus fertiliser with precipitation with anhydrite with residue treatment. The costs are calculated from the cost-level for the method (0.125 SEK per kg phosphorus, calculated from Landner et al., 1996), and table 3

<table>
<thead>
<tr>
<th>Production area</th>
<th>Costs, SEK per ha</th>
<th>Total cost, 1,000,000 SEK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Plain districts, s. Götaland</td>
<td>1.15</td>
<td>0.36</td>
</tr>
<tr>
<td>2. South east Götaland</td>
<td>0.76</td>
<td>0.22</td>
</tr>
<tr>
<td>3. Plain districts, n. Götaland</td>
<td>1.42</td>
<td>0.54</td>
</tr>
<tr>
<td>4. Plain districts, Svealand</td>
<td>1.14</td>
<td>0.58</td>
</tr>
<tr>
<td>5. Forest districts, Götaland</td>
<td>0.69</td>
<td>0.32</td>
</tr>
<tr>
<td>6. Forest districts, central</td>
<td>0.91</td>
<td>0.15</td>
</tr>
<tr>
<td>7. Lower parts of Norrland</td>
<td>0.60</td>
<td>0.09</td>
</tr>
<tr>
<td>8. Upper parts of Norrland</td>
<td>0.94</td>
<td>0.10</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.99</td>
<td>2.36</td>
</tr>
</tbody>
</table>
In Figure 2, a map with the different production areas is shown.

Figure 2. The location of the different agricultural production districts in Sweden.
The costs of decadmiation with extraction (SOU 1992:14; Landner et al., 1996) are about the same as those of the current tax in Sweden. With a cost level of 30 US$ per tonne P2O5, (ibid.), the total cost of this method for the Swedish agriculture would be 10 million SEK. Thus the costs for the farmers of this method are roughly shown by the figures concerning the costs for farmers of the tax in Table 3.

The costs of the tax and of the decadmiation through precipitation, respectively, can be compared to total revenues for the agricultural sector in Sweden, and to the net revenue. Estimated total yearly costs of the taxes for the Swedish farmers are 11.3 million SEK (Table 3). The estimate is slightly higher than the real payments in 1996, which summed to 9.7 million (see Section 5.5.). The payments is 0.03% of the total revenue in the agricultural sector in 1995 (30,113 million SEK, Statistics Sweden, 1996). The costs of the tax correspond to 0.43% of the total contribution to the farmers’ own work and capital, in 1995, measured as the difference between revenues and costs (2,652 million SEK, Statistics Sweden, 1996).

It should be noted that the cost for the farmers is not a measure of the cost to the society of the restrictions. Most of the 9.7 million SEK paid in 1996 is redistributed within the society, and is thus no loss of real resources to the society. However, the tax is a cost to the agricultural sector, as long as it is not returned to the agricultural sector. If the tax is returned, it becomes a charge.

The calculated total costs to the Swedish agriculture for decadmiation through precipitation correspond to 0.008% of total incomes to the Swedish agriculture in 1995, and to 0.09% of the contribution to farmers own work and capital, respectively.

Ideally, costs and benefits of studied measures should be weighted against each other. The benefits of the taxes and decadmiation are at least of two types: These measures will decrease the load of cadmium to agricultural land. This will decrease the exposure of the population to cadmium through food, with benefits in terms of human health, and with possible positive environmental effects. These effects will, to some extent, be reflected in the consumers’ willingness to pay for agricultural commodities produced with less input of cadmium.

If we knew the difference in the consumers’ willingness to pay for food produced with different levels of influx of cadmium, it would be easy to judge if it is reasonable to apply a tax on cadmium in phosphorus fertiliser, and/or restrictions on allowed levels, in order to stimulate the development of decadmiation technology. We do not have full information about this. An indication of the market value of products with a guaranteed and low level of cadmium, is the introduction of the trade mark Svenskt Sigill. The cadmium-aspect is one of many conditions the farmer has to fulfil. He/she gets a 10% higher price on wheat (Sjösvärd, 1997a; personal communication, if all the conditions are met. This implies 500-1 000 SEK per ha more, depending on the yield. In case the cadmium-condition is the only one which fails, one can say that too high cadmium-levels in the crop would cost the farmer about 10% of the revenue (if not considering different acreage-based subsidies).

Another possibility to deal with this problem is to estimate the break even point, where the costs for restricting flows of cadmium, e.g. by taxes and/or decadmiation, precisely balance the benefit through the higher value of products with lower cadmium content, due to (at least by the consumers assumed) positive environmental and health effects. The total value of produced crops in Sweden in 1995 was 5,675 million SEK (Statistics Sweden, 1996). The willingness to pay for Swedish agricultural products need to increase with 0.17% (9.7 million divided with 5,675 million), in order to balance the current taxes. The value of produced winter wheat for food, spring wheat, and potatoes for food, in 1995, was 2,132 million SEK (ibid.). If the taxes are compared only to these products, the break even point is where the consumers willingness to pay due to applying these taxes, increases with 0.006 to 0.007 SEK per kg of these products. The prices on these products to the farmer vary between 1.15 and 1.30 SEK per kg (Swedish University of Agricultural Sciences, 1995). Thus, if the price premium for crops with low cadmium concentrations exceeds 0.5%, the tax is beneficial to the farmers.
The real cost of the tax to society can be estimated to around 100,000 SEK, as most of the about 10 million are redistributed within the society (see section 5.5.). Thus, from the society level, the break even point is where the willingness to pay differs 0.002% (=0.1 million/5,575 million) in favour of agricultural crops produced, when applying the current tax. If the real costs for the tax are related only to the yields of the commercial crops winter wheat for food, spring wheat, and potatoes for food, an increase in the willingness to pay with 0.00006-0.00007 SEK per kg, balances this cost, that is an increase with 0.005% (=0.1/2132).

The cost of decadmiation through precipitation is estimated at 2.36 million SEK (Table 4). Thus, an increase in the willingness to pay for agricultural crops by 0.04% (2.36/5675) balances this cost. Related to the commercial crops mentioned above, an increase in the willingness to pay by 0.1% balances the cost for decadmiation. That is an increase of the price with slightly more than 0.001 SEK per kg.

The conclusion from this exercise is that the cost to the farmers of the taxes on cadmium in phosphorus fertilisers is very small. The net cost to the society is about 100 times smaller, as most of the tax revenue is redistributed, i.e. it is not a loss of resources. The cost of decadmiation to agriculture is estimated to about one fifth of the cost of the current tax. The very small real costs of the tax to society implies that the benefit in terms of the sum of the value of improved health, environment, and positive, foreign market reactions, also can be very small, and still outweigh the costs of the tax. The same conclusion can be drawn concerning the costs of decadmiation.

5.2.2. Some typical crop rotations in the intensive crop production districts

Although the average use of phosphorus fertilisers is quite low in all production regions in Sweden, substantially higher application rates are not uncommon in the main agricultural districts (Statistics Sweden, 1996; Hellstrand and Landner, 1997).

In the following section, the costs of taxes and decadmiation for some typical crop rotations - which include crops which substantially contribute to the human exposure - in the main farming districts will be evaluated. Thus, in this section, farms with animal production are not considered.

The main human exposure to cadmium in Sweden is due to wheat flour, potatoes, rye flour, and carrots. Typical crop rotations, including winter wheat, carrots and potatoes, for some of the main districts producing these crops, are presented in Table 5.
Table 5. The cost of taxes on cadmium in phosphorus fertiliser in relation to some biological and economic features of some crop rotations from the main crop producing regions in Sweden

<table>
<thead>
<tr>
<th>Harvest level in kg/ha</th>
<th>Plain districts, S. Götaland</th>
<th>Plain districts S. Götalan</th>
<th>Plain districts, Svealand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar beets, 55 000</td>
<td>Carrots, 30 000</td>
<td>Barley, 5 300</td>
<td></td>
</tr>
<tr>
<td>Harvest level in kg/ha</td>
<td>Barley, 5 900</td>
<td>Potatoes, 46 000</td>
<td>Oats, 5 000</td>
</tr>
<tr>
<td>Winter rape, 3 770</td>
<td>Oats, 5 200</td>
<td>Winter rape, 2 600</td>
<td></td>
</tr>
<tr>
<td>Winter wheat, 8 300</td>
<td>Barley, 5 900</td>
<td>Winter wheat, 6 700</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oats, 5 000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average per ha and year for the crop rotation

<table>
<thead>
<tr>
<th>P-fertilization, kg</th>
<th>33.9</th>
<th>37.0</th>
<th>23.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenues, SEK</td>
<td>11 389</td>
<td>28 214</td>
<td>5 642</td>
</tr>
<tr>
<td>Net revenue (revenues - incremental costs), SEK</td>
<td>5 170</td>
<td>2 196</td>
<td>2 292</td>
</tr>
<tr>
<td>Tax on cadmium, SEK</td>
<td>20</td>
<td>22</td>
<td>14</td>
</tr>
<tr>
<td>Tax as % of incomes</td>
<td>0.18</td>
<td>0.08</td>
<td>0.25</td>
</tr>
<tr>
<td>Tax as % of profit</td>
<td>0.39</td>
<td>1.0</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Comments. The source is the production branch calculi (Swedish University of Agricultural Sciences, 1995) for all crops except carrots, for which the source is the County Agricultural Board in Östergötland (1994). The price-level is for the crop-season 1995/96, except for carrots, for which it is 1994. The incremental costs include labour and special machines. In the profit, subsidies per unit of arable land are considered (cereals and winter rape).

The average phosphorus application for the crop rotations (Table 5) is substantially higher, compared with the averages for the districts. Some reasons for a higher application rate of phosphorus in Table 5, compared to the one in Table 3, are that animal production is omitted, and that the data in Table 5 concern skilful farmers, with a production above the average for the region. As an example, the average yield of winter wheat in 1995, in the plain districts in S. Götaland was 7 230 kg/ha, while it in Table 5 is assumed to be 8,300 kg. The average yield in 1995 is representative for 1990-1995 in Sweden (Statistics Sweden, 1996). The average phosphorus application in the second crop rotation for plain districts in S. Götaland is 37.0 kg. This is a crop rotation specialised in high-yielding crops such as potatoes and carrots. However, as the part of the arable land used for these crops is small, (potatoes are grown on 2% of the total area of arable land, in the plain districts in S. Götaland), the impact on the average application of phosphorus is small. Concerning the production of winter wheat, the average influx of cadmium through phosphorus fertiliser is 36% higher per ha during the crop rotation, compared to the one in the scenarios in Hellstrand and Landner (1997). In the three crop rotations in the table, the cadmium-balance is about 40-45% higher, compared to the regional average calculated in Hellstrand and Landner (1997). The explanation is that the increase in cadmium influx due to the increase in phosphorus application, is partly counterbalanced by an increase of efflux with purchased crops.

The cost of the tax on cadmium per ha for the farm is around 20 SEK in the two crop rotations in S. Götaland, and 14 SEK per ha in the example from Svealand. In relation to the average revenues per ha, the cost is, however, higher for the crop rotation from the plain districts in Svealand. In relation to average net revenue per ha, the taxes are highest for the crop rotation with potatoes and carrots, in the plain districts in S. Götaland.

The two crop rotations with the highest average incomes per ha, can be more sensitive to market reactions against products which by the consumer is assumed to have too high levels of cadmium. This is so, because the production in terms of crops and money is higher per ha.
If the decadmiation costs are applied, the cost per ha for the farmer on average during the crop rotation, is about five times lower, compared to the costs of the taxes on cadmium. In absolute terms, this implies a cost of 3-5 SEK per ha, for the examples in Table 5 of intensive crop production with, for Swedish conditions, high phosphorus application. This cost can be viewed as an insurance cost against negative market reactions, due to the cadmium-question. This can be compared to the estimate of the loss of net revenues of not complying with the specifications of Svenskt Sigill in Chapter 3, of, on average for the crop rotation, 145 SEK per ha and year.

5.3. Market reactions to restrictions - Top-down approach
The price elasticity, i.e. the proportional change in demand as a result of a proportional change in price, of phosphorus fertilisers is important in determining the impact of price changes caused by a tax on cadmium content, or by other factors. Such an analysis has been performed within the frame of this study (Appendix 2). If the absolute value of the elasticity is high, i.e. around or greater than -1, the demand for phosphorus fertilisers will be significantly reduced as a result of a tax on the cadmium content. If, on the other hand, the elasticity is low, i.e. around or less than 1, the change in demand would be very limited. The relation between the tax and the market price for phosphorus fertilisers is also important for the impact of a tax on cadmium content. The long run price elasticity is most relevant for policy analysis. It was, however, only possible to estimate the short run elasticity. The long run elasticity is probably higher, possibly 50% higher than the estimated short run elasticity. The price elasticity of phosphorus fertilisers has been estimated at between -0.1 and -0.25 (Ingelsson and Drake 1997, see Appendix 2). In a study applied to Irish conditions the elasticity was estimated at -0.6, i.e. clearly higher but less than unity (Boyle 1982). The only time series with significant relations in the Swedish study were based on phosphorus fertilisers with 9% P which is available only for 1969-86, i.e. 18 years. The independent variables were phosphorus price, nitrogen quantity, nitrogen price, grain price, wage rate, available manure, area of arable land, (Adjusted R sq. 0.995, all independent variables were significant on the 1%-level, F-ratio 515). Estimates of price elasticities are always affected by the conditions in the period analysed, and the real elasticity could differ somewhat in another period.

With the average level of cadmium of 25 g/ton P and a tax of 30 SEK/g Cd (for concentrations above 5 g/ton P) the price of phosphorus fertilisers would increase by 0.6 SEK/kg P as a result of the tax. Phosphorus fertilisers with higher cadmium content than the average could not sell for a higher price since no one wants to pay for extra cadmium in fertilisers, implying that the tax will not be fully paid by the farmers in that case. Fertilisers with lower cadmium content could sell for the same price as fertilisers with average cadmium content (or possibly for an even higher price because it is considered to be of a better quality) even if the cost for the tax does not motivate such an increase. With a price, including the tax, of 11.5 SEK/kg P (JEM 1997) the tax share of the market price is about 5%. With a price elasticity of -0.1 to -0.25 the change in demand for phosphorus will be only 0.5 to 1.25%. If the long run elasticity is 50% higher the interval would be 0.75 to 1.87%. The conclusion is that the present tax on cadmium has the following effects, 1. application of phosphorus fertilisers is reduced by roughly 1-2%, 2. yield is reduced by less than that percentage, and 3. the reduction in cadmium accumulation due to reduced phosphorus application is very limited. The primary effect of the tax is to reduce accumulation of cadmium through a reduction in cadmium concentration in fertilisers. This is achieved, but the side effects are as shown, for good and bad, very limited.

However, when interpreting the results, it should be remembered that the price elasticity is calculated during a shift from an enrichment phase in the phosphorus application, to a replacement phase. Then, a marginal change in the application rate, would affect the yield proportionally less, because the stores of phosphorus in the soil would be sufficiently large to stand a reduction in the inflow of

6 Assumption based on relation between short and long run price elasticities for nitrogen (Burrell 1989).
phosphorus, and still sustain the yield. If the stores in the soil are insufficient, phosphorus will have become more of a limiting factor for the production.

With an application of 8 kg P/ha the cost of the cadmium tax is 4.8 SEK/ha, and with a yield of 4000 kg/ha the cost of the crop in question is 0.0012 SEK/kg, or 1 SEK/ton, which can be compared with crop prices around or above 1 SEK/kg. The cost of the tax for the farmer is obviously insignificant (1/1000 of turnover). These results are in line with those from the bottom up approach. Also the production change resulting from the very limited reduction in phosphorus application must be insignificant since phosphorus application is virtually unchanged and yield reacts less than proportionally to a reduction in P-fertilisers.

5.4. Administrative costs
Administrative costs for the 100 g Cd/ton P standard and the 30 SEK per gram tax should be low due to the fact that only a limited number of distributors, 12 in 1996, need to be controlled. Gross revenue from the tax for the state was 9.7 MSEK in year 1996, the second half of year 1995 it was 4,6 MSEK (Naturvårdsverket 1997 and statistics from the Swedish tax authorities). This is not a social economic cost; it is merely a transfer of money from the importers of fertilisers to the state budget and indirectly from farmers/consumers to taxpayers. The real cost is the change in production which has been shown to be very limited and the administrative cost which has not been estimated separately. According to a Swedish study on the charge on nitrogen in fertilisers the administrative costs were 0.8% of gross revenue when it was administrated by the Swedish Board of Agriculture (Naturvårdsverket 1997; personal communication, Ola Jonsson). In general it has been found that the administrative costs of environmental taxes are around 0.5-2% of gross revenues in Sweden. It is reasonable to assume that the relative administrative costs of the cadmium tax is slightly higher than those for the nitrogen tax, since the gross revenue is higher for the nitrogen tax, even if there are fewer actors to tax in the case of cadmium. The costs can be estimated to be around 1% of the gross revenue or about 100 000 SEK/year. This is a very low cost which can be compared with the health and environmental improvements of the reduced concentrations that follow on a tax (see chapter 3).
6. Cadmium policy affecting large market shares

When a single country or a very small group of countries, like Sweden or the Nordic countries, enforce more firm standards or taxes on cadmium content in fertilisers than other countries, the main effect is that the less contaminated fertilisers would be marketed in that country, or small group of countries, and the more contaminated fertilizers would be sold in the other countries. This implies that a constant cadmium application is redistributed from countries with firm policies to countries with no, or less, firm policies. The size of the Swedish market in relation to the total world market, less than 1% (FAO, 1995), however, indicates that the increase in cadmium accumulation, as a result of the Swedish cadmium policy, is very limited in other countries. The social economic cost per unit of reduced cadmium application is very low in the countries that implement firm policies as was shown in chapter 5. The limited environmental and health costs in countries that get a larger share of total cadmium application vary due to present concentrations in soils, availability conditions and crops produced.

Demand for fertilisers with low content of cadmium would exceed supply if a large number of countries, like the EU, enforce the same strict conditions as Sweden. In this case it is not possible to reallocate today's supply of phosphorus fertilisers. The cadmium concentration has to be reduced in high cadmium content fertilisers. In that case the cost of decadmiation becomes relevant and the costs of the policy will increase, i.e. the unit cost of reduced cadmium application. The direct cost is still reasonably low. The main reason for increased marginal costs is that the area of agricultural land which gets lower cadmium applications is much greater and a market tends to use the cheaper solutions first. If decadmiation is used the negative side effects in countries with less firm cadmium policy are avoided.

Most of the commercial phosphate production in the world have a sedimentary origin with normally high concentrations of cadmium and a smaller fraction has an igneous origin and contains less cadmium. Present (1994/95) world production of phosphate rock is 32,780 ktonnes/year. The shares of igneous phosphate rock, from Russia and South Africa, make up 10-12% of world production. (Louis 1995). With the present production levels of low cadmium content phosphate rock, the reserves would last 116 years, while the corresponding figure for all phosphates is 179 years (calculated from Louis, 1993). Future extraction of course depend on future prices, and technique in agriculture and nutrients recycling, but the quotient between production and reserves for low cadmium content phosphate rock can still be seen as an indicator of relative scarcity. Also in comparison with potential reserves the low content rock would be used up at a higher speed than the average for phosphate rock, 275 and 452 years respectively (calculations based on Louis, 1995). Production of low content phosphate rock could most likely increase if demand continues to increase implying an even faster extraction of those sources at the expense of phosphate rock that contains more cadmium. In the long run this would necessitate introduction of decadmiation techniques even if a relatively small share of the word market had firm policies.

The 10-12% production based on igneous rock is less than consumption in the EU countries. Introduction of firm standards, or taxes, in the EU, would imply use of decadmiation techniques. If such a policy would be introduced in the EU the other importers, largely developing countries who could probably not afford to pay for decadmiation, would be left with the contaminated sources. It is, however, possible that decadmiation would be done directly in the producing country implying that the costs of decadmiation may be reduced in the future due to scale efficiencies and improved techniques. It must be noted that the full scale decadmiation technique is not yet developed.

These relations are explained in Diagram 1. The supply in the world is depicted as Stot and demand as Dtot. The illustration in Diagram 1 implies an assumption of perfect competition which is not correct but probably not too far from reality on the international level since there are many buyers and many sellers. It is, however, possible that monopolistic situations occur locally. The supply elasticity is probably quite high (=elastic supply) because phosphate rock is easily available and the reserves are
large in relation to annual extraction (IFA 1995). The expected market value of keeping one unit of the stock available for extraction in the future must be very low due to long discounting periods\(^7\). Supply from low cadmium content sources, SI, is likely to be less elastic than average because of the higher quotient between extraction and reserves. Demand for low cadmium content phosphates, which is affected by policy instruments in the different countries, is denoted by DI. Supply of phosphates without restrictions on cadmium content, Sh, is equal to Stot-SI. Demand for of phosphates without restrictions on cadmium content, Dh, is equal to Dtot-DI.

Diagram 1 Market for phosphates

\(^7\) The social economic value may be high but that is not reflected in market behaviour.
At first, when very few demand low content fertilisers, i.e. the DI curve would be near the p-axis, they may be able to direct their demand without any extra costs. In order to establish a separate market, the price for low content phosphates has to exceed the price on the general market (assuming zero transport cost). This will happen if supply of low content fertilizers is less than demand at the general market price. The diagram shows this case, since the intercept between DI ans SI is above the price for the whole market. One result is that the price for the smaller fraction of the total market will rise more than the price will drop on the remaining larger fraction of the market. Producers of high cadmium content phosphates would not loose very much as long as the market for low cadmium content phosphates is small in relation to total supply. Addition of cadmium to agricultural land would not rise in the world, rather the opposite, due to the division of the market, but it would be differently distributed. The price increase on the low cadmium content fertiliser submarket will lead to increased supply and thereby increased market share for low cadmium content fertilisers, i.e. those sources will be extracted at a higher speed. If the economic value, including health and environmental improvements, of reduced cadmium application exceeds the increase in production and administrative costs then a standard, or a tax, can be motivated.

An increase in demand for low cadmium content fertilisers is illustrated in Diagram 2. In this case the curves have more realistic forms and the possibility for decadmiation is included. When demand for low cadmium content phosphates shifts from DI0 to DI1 the price on that submarket increases as a result of limited supply, some of the demand would be covered by supply from decadmiated phosphates. The supply would follow the dotted path. In this case the supply curve Sh must shift inwards equal to the distance $ab$. The distance $ab$ is equal to the supply of decadmiated phosphates sold on the submarket with firm restrictions, which then is not available for the submarket with little or no restrictions. The optimal points for the two submarkets would be $l^*$ and $h^*$. 

\[ \text{Diagram 2} \]
Even if the cost of decadmiation is much higher than just selecting low cadmium fertilisers (as long as supply is sufficient) it would only imply a reduction in the use of phosphorus fertilisers of less than 2% as a result of the 10% or less price increase (based on decadmiation costs, a -0.2 price elasticity and an assumption that the increased production costs would be borne by the farmers).

What is the empirical evidence for a shift towards low cadmium content phosphates on the world market? A very small number of countries have legal standards on the concentration of cadmium in phosphorus fertilisers. The countries with limits below 100 g Cd/ton P are Finland, Norway, Sweden, and Switzerland. Total demand from these countries make up only about 2% (FAO, 1995) of world imports and the market shares of phosphate rock with different cadmium content resulting from standards in the named countries, can thus not be dramatically changed. Market demand for low content phosphorus fertilizers may also be affected by other reasons than legal standards such as consumer concern which is transformed into market segmentation. There is no empirical evidence for changes in market shares (FAO, 1987 and 1995).
7. Scenarios

In section 7.1, the consequences of four different scenarios concerning content of cadmium in fertilisers are discussed, in a perspective of 20 years. The discussion is focused on effects for farmers and on the market. In section 7.2, similar scenarios are used in order to evaluate the economic effects of cadmium flows in the food system, and measures to restrict these flows, in a perspective of 100 years.

7.1. Four scenarios

This chapter discusses consequences of possible future development of cadmium content in phosphorus fertilisers. The discussion is based on insights from the analysis in previous chapters but also, by necessity, includes some speculation.

Future cadmium concentrations in soils depend on multiple factors such as, the natural content of the soil, the concentration of cadmium in phosphorus fertilisers, atmospheric deposition, application rates, recycling, leaching and efflux through products. Future cadmium concentrations in crops also depend on availability and type of crops. Beside the cadmium concentration, these factors are assumed to remain unchanged, if nothing else is said. Four scenarios with different development for cadmium concentration in phosphorus fertilisers will be discussed. The scenarios are the following:

1. A continuation of the current declining trend in cadmium concentration to 5 g Cd/ton P in twenty years.

2. A stabilisation of the cadmium concentration around 25 g Cd/ton P.

3. A slow increase in cadmium concentration from 25 to 50 g Cd/ton P in twenty years.

4. A rather rapid increase in cadmium concentration from 25 to 140 g Cd/ton P in twenty years.

The last alternative corresponds to one of the main alternatives studied by the European Commission.

Projecting the cadmium content in soils as a function of cadmium content in fertilisers is not simple because of the many factors involved. The content in crops is even more difficult to forecast. It is important to again point out that a large part of the negative health, and other, effects will appear long after application. If these very long run effects, several hundred years, are considered, the difference between the scenarios are greater than it appears below. Some more specific calculations on costs of cadmium influx to arable land are presented in chapter 7.2.

7.1.1. Reduced concentration in fertiliser

The first scenario, with further reductions in cadmium concentrations in phosphorus fertilisers, presupposes a continuation of present governmental policy and either a strengthening of voluntary measures or an increased tax rate. The resulting cadmium concentrations in soils would continue to increase, but at a slower rate. Table 6, shows the effect of content of cadmium in the top soil and in grain of winter wheat for this scenario, for intensive crop production. Notice, that in Table 6 the time frame is increased five times.

The cadmium uptake in food will increase very slowly and in practical terms be nearly unchanged (Table 6). The current market segmentation will remain. There are no important dynamic forces that would change policy in Sweden, since costs for the policy is low and no serious health problem show up. Also, there is little need of control and monitoring since the problems are limited.
The high quality Swedish crops produced on lands with low cadmium contents could be sold on niche markets in the rest of the EU. This would put pressure on politicians in other EU countries to introduce or strengthen their cadmium policies.

7.1.2. The current concentration in fertiliser
The second scenario, with stabilised cadmium concentrations in phosphorus fertilisers, presupposes a continuation of present governmental policy and voluntary measures. The resulting cadmium concentrations in soils would continue to increase, with the current speed, as long as the policy is unchanged (Table 6).

The current segmentation of markets will remain. The cadmium uptake in food will increase slowly for those who buy the ordinary quality products, especially in the long run. There is no important dynamic force that would change policy in Sweden in the short run, but, as soil and crop concentrations increase, public pressure to enforce a firmer policy is likely to emerge. The costs for voluntary control programs will increase.

The high quality Swedish crops could be sold on niche markets in the rest of the EU. This would put pressure on politicians in other EU countries to introduce or strengthen their cadmium policies.

7.1.3. A doubling of the concentration in fertiliser
The third scenario, with a doubling of the cadmium concentrations in phosphorus fertilisers, could materialise if present governmental policy would be abandoned but most of the voluntary measures remain. The resulting cadmium concentrations in soils would continue to increase, and at a higher speed than in scenario 2 (see Table 6). According to the calculations in the following section, this can influence the content of cadmium in winter wheat, and the number of Cd induced renal dysfunctions.

The segmentation of markets will remain and the difference between the quality of the products between the two markets, i.e. the one with high and the one with low cadmium concentrations in crops would increase. The cadmium uptake in food will increase for those who buy the low quality products, especially in the long run. Farmers who use phosphorus fertilisers with a high cadmium content will loose the extra revenues that can be obtained on the market for high quality products. The costs of monitoring tend to increase as compared to scenario 2. Some land will not be suitable for production of crops that have a high uptake of cadmium. One can expect an increasing public pressure to enforce a firmer cadmium policy in Sweden as a function of increasing levels of cadmium in the soil and in the crops.

The market segment of high quality Swedish crops could be sold on niche markets in the rest of the EU. This would put pressure on politicians in other EU countries to introduce or strengthen their cadmium policies.

7.1.4. Rapid increase of concentration in fertilisers
The fourth scenario, with about 5.6 times higher cadmium content compared to the current level in phosphorus fertilisers, could materialise if both present governmental policy and the voluntary measures would be abandoned. The resulting cadmium concentrations in soils would continue to increase, and at a higher speed than in scenario 3, as long as the policy is unchanged (Table 6). This may also affect the content in grain of winter wheat and the prevalence of cadmium induced renal dysfunctions (see following section). This is the scenario with the lowest probability of being materialised since the Swedish market actors seem to be very determined in keeping down the risks of cadmium related problems.

The segmentation of markets will become even more pronounced than in scenario 3, the high quality market segment will be turned into a small niche market. This scenario will imply that some farmers
can no longer produce high quality products. Farmers who use phosphorus fertilisers with a high cadmium content will loose the extra revenues that can be obtained on the market for high quality products. The economic effects on the farm level of not complying with the demands of low cadmium products, were discussed in section 3.2. The average content of cadmium in top soil, on the farms using fertilisers with 140 g Cd/kg P and with an average application rate of 25 kg P per ha and year, will, already in 20 years, exceed the level where grain analysis in "Svenskt Sigill" is needed (0.30 mg Cd/kg top soil), in most of the major crop production areas in Sweden.8 On the farm level, this scenario implies that the content of cadmium in top soil, in areas with intensive crop production, will increase with about 10%, as well as the content of cadmium in grain of winter wheat.9 

The cadmium uptake in food will increase for most consumers. The costs of monitoring may need to be quite high.

There is a high, and over time increasing, probability for public pressure to enforce a firmer cadmium policy in Sweden.

The high quality Swedish crops could be sold on niche markets in the rest of the EU, if Swedish supply exceeds Swedish demand. If so, this would put pressure on politicians in other EU countries to introduce or strengthen their cadmium policies.

The most obvious difference among the four scenarios is the speed in which cadmium levels in soils and crops are increasing. In the two latter scenarios there are mechanisms that tend to favour a reintroduction of governmental policies due to increasing health effects, i.e. the scenarios are not stable.

### 7.2. Effects on content in soil, grain and renal dysfunctions

The economic effects of cadmium flows in the food system concern environment and health. Available information about the environmental effects does not support a quantitative analysis of their economic importance (see Parkman et al., 1997). With regard to the health effects, the available information makes it possible to come closer to such a quantification.

In Appendix 3, an effort is made to relate different levels of cadmium in commercial fertilisers to the effect on cadmium induced renal dysfunctions. Based on some assumptions, the break even point is calculated for decadmiation, where it will become beneficial to the society to apply decadmiation processes. The break even point shows the hypothetical costs per cadmium induced renal dysfunction, where the total costs for the restricting measures will equal the total costs for the extra cases of renal dysfunctions, if these measures are not taken. The break even point for the current tax system is calculated in a corresponding way.

It should be noticed that the number of renal dysfunctions does not equal the number of cases where health effects are expressed on the individual level. It is the latter category that causes costs in terms of suffering of the patiente and medical treatment. In the calculation of the break even point, the cases that will cause costs, as well as the ones that will not, are included. The reason to calculate the break even point is that we do not have the needed information to calculate the real average cost per case of cadmium induced renal dysfunction. If it seems reasonable that the real costs per case of cadmium induced renal dysfunction is higher than the break even point, the result of the calculation indicates that it is beneficial to the society to implement the measure in question, for which the break even point was calculated. We stress that the results are dependent of the assumptions, and the quality of the data used. In Appendix 3, the assumptions made, and the origin of the data, is explicitly shown. The results are summarised in Tables 6 and 7.

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8 The plain districts in South Götaland, Östergötland, Svealand and South east Götaland.
9 This follows from the calculations in the following section, after correction for the difference in time span.
With increasing levels of cadmium in the top soil, the effluxes will increase. This effect has not been considered in the calculations underpinning Table 6. It can be calculated that in the example with 140 g cadmium per kg phosphorus in Table 6, the increase in the efflux of cadmium with the wheat grain after 100 years, is about 5% of the net influx calculated. This implies that the situation after one hundred years is far from a steady state, if other effluxes have not increased substantially.

In Appendix 3, the break even points for decadmiation and for tax on cadmium are calculated, based on the results in Table 7. The results imply that, with given assumptions, if the average cost per cadmium induced renal dysfunction exceeds 600 SEK, decadmiation is beneficial to the society. If the average cost per cadmium induced renal dysfunction exceeds 7 SEK, the current tax system is beneficial.

The existing information implies that it cannot be excluded that an increase in renal damages caused by an increase of the cadmium taken in by food will increase costs such as treatment costs and suffering for the patient. The results of the performed calculations indicate that if the total costs per case of cadmium induced renal dysfunction is of the order of some tens or hundreds of SEK or higher, measures to restrict the cadmium content in phosphorus fertilisers such as taxes or decadmiation can be beneficial from a societal perspective.

Table 6. Predicted increases in content of cadmium per kg dry matter (DM) in grain of winter wheat as a function of increased levels of cadmium in top soil in 100 years at different cadmium contents in phosphorus fertilisers.

<table>
<thead>
<tr>
<th>25 kg P applied per ha</th>
<th>Increase of Cd mg/kg top soil</th>
<th>Increase of Cd Winter wheat, mg/kg DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 mg Cd/kg P</td>
<td>0.014</td>
<td>2.6</td>
</tr>
<tr>
<td>25 mg Cd/kg P</td>
<td>0.031</td>
<td>5.7</td>
</tr>
<tr>
<td>50 mg Cd/kg P</td>
<td>0.051</td>
<td>9.4</td>
</tr>
<tr>
<td>140 mg Cd/kg P</td>
<td>0.128</td>
<td>23.7</td>
</tr>
</tbody>
</table>

Comments. The increase of cadmium in top soils is from Hellstrand and Landner (1997). The increase of cadmium in grain of winter wheat is calculated from the regression coefficients between increase in grain as a function of the increase in top soil (Eriksson et al., 1996). Current average content of cadmium in grain of winter wheat in Sweden is 53 mg/kg DM (Eriksson, 1990).

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10 Ten million SEK for decadmiation with extraction divided by (19,000 minus 2,100).
11 100,000 SEK (the administrative cost for the tax) divided by (19,000 minus 4,600).
12 Strictly speaking, the results concern the increase of renal dysfunctions caused by the increase of cadmium in winter wheat. Furthermore, it is assumed that the market for decadmiated fertilisers is sufficiently large.
Table 7. Estimated increase in the number of cadmium induced renal impairments after 100 years for the alternatives with different content of cadmium in phosphorus fertilisers in Table 6, through the effect on the content of cadmium in grain of winter wheat

<table>
<thead>
<tr>
<th>25 kg P applied per ha</th>
<th>Million kg wheat flour, DM</th>
<th>Increase of Cd in grain, mg/kg DM</th>
<th>Increase of Cd in all wheat flour, kg</th>
<th>Renal dysfunctions per kg increase of Cd taken in</th>
<th>Estimated increase in total number of Cd induced renal dysfunctions</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 mg Cd/kg P</td>
<td>368</td>
<td>2.6</td>
<td>1.0</td>
<td>2,174</td>
<td>2,100</td>
</tr>
<tr>
<td>25 mg Cd/kg P</td>
<td>368</td>
<td>5.7</td>
<td>2.1</td>
<td>2,174</td>
<td>4,600</td>
</tr>
<tr>
<td>50 mg Cd/kg P</td>
<td>368</td>
<td>9.4</td>
<td>3.5</td>
<td>2,174</td>
<td>7,500</td>
</tr>
<tr>
<td>140 mg Cd/kg P</td>
<td>368</td>
<td>23.7</td>
<td>8.7</td>
<td>2,174</td>
<td>19,000</td>
</tr>
</tbody>
</table>

Comments. Assuming a dry matter (DM) content of 85% in flour, and that the increase of cadmium in grain equals the increase of cadmium in flour.
8. Conclusions

The economic effects of Cadmium fluxes to and from agricultural soils, may be of three types: environmental effects (affect citizens), health effects (consumers), and the changed value for agricultural products and land (farmers), as a function of the levels and flows of cadmium. The last type of effects can, at least partly, be viewed as a reflection of the first two types of effects: if the flows of cadmium in the food system is so high that it causes illness and environmental damage, this will with time be reflected in the price of food and land.

From a welfare economic point of view, the health effects are the most important ones. This can in turn be divided into three parts: (i) the suffering of the patient, (ii) the cost of medical care, and (iii) the loss of production in society. Thus, the potentially most important benefit of measures reducing the Cadmium fluxes in the food system is improved health.

There are, according to a recent health study, performed by Järup et al. on behalf of the Swedish Chemicals Inspectorate, increased levels of Cadmium-induced renal damages to be expected in the Swedish population, if the average daily intake of Cadmium with food increases. The results of their study imply that every kg increase in cadmium taken in by food in Sweden from the current level, will increase the number of cadmium induced renal damages in the Swedish population with about 2.2% from the current level, or around 2,200 cases.

The market actors support the need for governmental restrictions, as well as of measures taken by the actors on the market. The main opinions expressed by the respondents in a questionnaire were the following:

- The importance of the measures of the authorities could hardly be separated from the importance of the measures within the private sphere. They complement each other.
- The governmental policy set the rules which govern the market.
- The governmental policy prohibit competition on the market by high cadmium-contending products with low prices.
- The governmental policy bring the cadmium issue into focus.

The last aspect is not the least important, it implies that a possible removal of the current restrictions in Sweden could slow down the environmental work in the private sphere.

Possible restrictions of cadmium in fertilisers will, in the first place, have the strongest impact on the fertiliser manufacturer and the farmers. Thus some of the conclusions by the respondents from the fertiliser manufacturer and the Federation of Swedish Farmers (LRF) are given explicitly.

The respondent from the fertiliser manufacturer (Hydro Agri AB) was positive to the governmental restrictions: "non-serious marketing is prohibited". The problem he mentioned was the disadvantage to Swedish agriculture caused by the economic burden. However, the calculations in this study show that this burden is very small. The respondent expressed the opinion that the supply of phosphorus is no problem. If the market for low cadmium products will grow substantially, decadmiation processes will be introduced. The restrictions introduced by the market and the authorities complement each others, according to the respondent from Hydro Agri AB. He proposed a general system of rules in the EU.

The respondent from the Federation of Swedish Farmers (LRF), felt that the governmental restrictions of cadmium in phosphorus fertilisers, were in support of the development of a sustainable agriculture.
The governmental restrictions set rules, supporting a competition on the market on equal terms. The charge steers the market to the current content of cadmium in fertilisers. He also stressed the acceptance for the cadmium restrictions among farmers, and concluded that the measures of the authorities and the ones of his own organisation are complementary. The respondent stressed that the measures of the authorities are needed in order to prohibit cheap, contaminated fertilisers. However, he suggested some change in the restrictions: either that the rules are applied in other nations, or that the current tax is changed to a charge, implying that the tax revenue is returned to agriculture.

The concern that most of the respondents showed for the Cadmium-question, and the almost total lack of criticism against the current system of governmental rules, indicate that some of the most important actors in the food market system in Sweden estimate that the external effects, or potential effects, that are associated with Cadmium in food are substantial. Some of the respondents were talking in terms of an insurance against the risk that their trade marks should be associated with something similar to the mad cow disease.

The cadmium policy concerning carrots, followed by ICA Frukt och Grönt, and the magnitude of the trade mark Svenskt Sigill, supplying the retail stores with around 60% of the wheat flour sold, indicate that the cadmium issue is important for vital actors on the market, not only in words, but also in their actions. The trade mark Svenskt Sigill is administered by organisations associated with the Swedish farmers. The specifications that can be most difficult for the farmer to fulfil, concern the cadmium level in the soil and in the crop. Thus, the market share of this trade mark in combination with its specifications concerning cadmium indicate the importance the Swedish farmers put to the cadmium issue.

The performed calculations, 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 in the political, and in the private sphere. Production and fertilisation intensity change only marginally as a result of a tax on the cadmium content. The cost of phosphorus fertilisers is a small share of the total costs and the price elasticity is rather low. Since the use of fertilisers changes only marginally, production as well as net revenues are virtually unchanged. The costs for the farmers are some millions (the low cost alternative with decadmiation), or about ten million SEK (the tax, as well as the high cost alternative with decadmiation). The trade mark Svenskt Sigill is administered by organisations associated with the Swedish farmers. The specifications that can be most difficult for the farmer to fulfil, concern the cadmium level in the soil and in the crop. Thus, the market share of this trade mark in combination with its specifications concerning cadmium indicate the importance the Swedish farmers put to the cadmium issue.

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The price elasticity of phosphorus fertilisers has been found to be between -0.1 and -0.25. Estimates of price elasticities are always affected by the conditions in the period analysed, and the real elasticity could differ somewhat in another period. The low price elasticity implies that a tax on cadmium, which will increase the price of phosphorus fertilisers, has a very limited effect on the fertilisers demand. Demand will be reduced by 0.5 to 1.25% and possibly 0.75 to 1.87%. The tax on cadmium will as a consequence increase the cost of production by roughly 1 SEK/ton. Production levels will be reduced by 1 to 2%.

The costs of the current Swedish cadmium policy for phosphorus fertilisers is very small and due to Sweden’s small share of the world market the effects in other countries are very limited. In case the EU would introduce a similar policy the world market would be affected because of the size of the EU. The competition for the sources of phosphate rock with a low content of cadmium would necessitate an introduction of decadmiation techniques. The marginal costs would increase but would still remain relatively low.

The Swedish governmental policy and voluntary efforts have been successful in reducing the content of cadmium in phosphorus fertilisers. It has not, however, been possible to estimate the relative importance of the different measures. A more general analysis shows that a tax is cost-effective and that
a standard may be better in reaching the target. The specific combination implemented in Sweden seems to be very efficient. The support and backup from market actors has had an important influence. The Swedish policy on cadmium in fertilisers does not lead to any trade barriers or increased monopolisation, beside the direct intended effect of not importing fertilisers with a high cadmium content.

The scenario discussion indicate that some of the effects of increased cadmium concentrations appear in the long run. The most obvious difference among the four scenarios is the speed in which cadmium concentrations in soils are reached. In the scenarios where present governmental cadmium policy has been abandoned, there are mechanisms that tend to favour a reintroduction of governmental policies due to increasing health effects, i.e. the scenarios without a firm policy are not stable.

In some hypothetical calculations, based on

- estimates of the evolution of the cadmium content in top soil as a result of using phosphorus fertilisers with different cadmium levels for one hundred years,
- the relation between content of cadmium in top soil and content of cadmium in crops found in Swedish field studies, and
- the relation between cadmium taken in by food and renal damages found in the previously mentioned health study,

the impact on renal damages after one hundred years of different levels of cadmium in fertilisers via the increase of the cadmium level in winter wheat was estimated.

It was found that, with decadmiation, the number of renal dysfunctions after 100 years would be 16,500 cases less, compared with a hypothetical situation with no cadmium restrictions in the political and the private sphere. With the current set of Swedish governmental rules, and no decadmiation, the result was 14,100 cases less with renal damages in favour of the alternative with the governmental rules compared with no official or private cadmium restrictions.

The results indicate that if the cost per renal damage induced by cadmium in the food exceeds 600 SEK, decadmiation would be beneficial. If the costs per renal damage induced by cadmium in the food exceeds 7 SEK, the current tax is beneficial from the societal point of view.

It should be noted that the calculations are hypothetical. The results are no better than the assumptions the calculations are based on. To be able to weigh the costs of measures restricting the cadmium flow in the food system, against the benefits of these measures in health terms, the cadmium induced diseases must be specified in qualitative and quantitative terms. The made assumptions must be further scrutinised.

However, the results indicate the possibility that restrictions of cadmium flows in the food system, may have substantial long term beneficial effects.

In short:

1. The main positive economic effect of restrictions of cadmium in phosphorus fertilisers seems to be the health effects.
2. The official Swedish policy to reduce cadmium in phosphorus fertilisers appears to be efficient.
3. The costs for the actors, from farmers to consumers, in Sweden of the governmental policy to reduce cadmium in phosphorus fertilisers is very low.
4. The costs for foreign actors of the Swedish governmental policy to reduce cadmium in phosphorus fertilisers is low.

5. The actors of the market in Sweden view the Swedish governmental policy to reduce cadmium in phosphorus fertilisers as a complement to their voluntary policies, i.e. supporting the internal ambitions.

6. The actors of the market want to extend the Swedish policy to reduce cadmium in phosphorus fertilisers to the EU. The second best alternative is to maintain the current system of rules in Sweden.
9. Discussion

The economic effects of policies to reduce the Cadmium content in food, within the private and the political sphere, concern health and environmental issues. This can, for the actors in the private sphere, be reflected in effects concerning the credibility in the eyes of the consumer. For the actors in the political sphere, it can be reflected in effects concerning the credibility in the eyes of the voter/citizen. These are mechanisms through which citizens achieve influence. The costs can, in the private sphere, include costs for decadmiation, controls, analyses of Cadmium content in soils and crops, and for administration of control programs. In the political sphere, the costs mostly concern administration. On the societal level, the measures of the authorities will affect the incentive structure in the society in a way that causes dynamic effects. Whether these are positive or negative, depends on whether a real problem is addressed. The effect on the competitive power, compared to producers in other nations, should also be mentioned. Whether it is positive or negative, depends on whether the measures support the development of products which fit well to the trends of consumers preferences. In the short run there are probably net costs while in the long run the benefits of the policy dominate.

There are theoretical welfare economic motives for a governmental policy to reduce the concentration of cadmium in phosphorus fertilisers. The specific combination of tax and limit, used in Sweden, appears to be quite successful. The most important thing seems to be that the government sets firm rules and thereby gives clear signals to the market actors.

The issue of cadmium in food has a gender and a distributional implication. A doubling of cadmium taken in with food can, for women with low iron-stores, according to the calculations in Järup et al. (1997), increase the prevalence of renal damages up to 5%. The size of this population can be up to one million persons of a Swedish population of 8.5 million people. This is an up to five times higher prevalence compared with the one per cent, that can be expected in the general population.

If no restrictions are taken by the authorities, the consumer is dependent on the restrictions taken by the actors on the market. It can be assumed that some will compete with price, and some with health arguments. It is probable that proportionally more consumers with less money and less information will choose the producers focusing on low prices. This is expected if preferences for health and environment increases with incomes. Thus, a possible effect of no restrictions by the authorities is that, in the future, women and consumers with less money and access to information will carry a proportionally heavier burden of the costs of cadmium in food in terms of renal damages, compared with the alternative where the authorities restrict the level of cadmium allowed in food with effective measures.

It appears quite safe to assume that the voluntary restrictions of the Cadmium content in food, soil and fertilizers, introduced by various actors on the Swedish food market have come to stay. It is also quite possible that new and tougher restrictions will be established and enforced by the various associations involved. However, the power in the environmental work in the enterprices might be weakened, and there might be negative impact from a gender and a distributional perspective, if the cadmium policies in the private sphere are not complemented by the type of governmental policy that Sweden currently has.

Even if the current Swedish exception from the EC Directive on Fertilizers should be extended in time, or if a general limit of - say - 100 mg Cd/kg P should be included in the new EC Directive, the majority of Swedish farmers already practice a limit of 50 mg Cd/kg P. In the wake of the discussion about the consequences of the "crazy cow disease", it is quite understandable that producer associations and sales organisations also in other sectors of the food market are eager to take steps to protect their trade marks and to minimise the risk of any setback in the sales of their food products, caused by massive consumer worries, or rejection.
Thus, the most important practical impact of a politically enacted, legal regulation of the Cadmium content in P-fertilizers might be the impact on the political sphere itself, possibly through an improved co-ordination between major actors and countries and through an enhanced trust in the leadership of the political sphere. In other words, an important impact may occur on the perception of the "trade mark" European Union in Sweden and in the rest of the EU.

There is, however, another important aspect that should be considered. The characteristics of the European agriculture and the safety of food produced within the EU are important aspects when European farmers or food sales organisations compete on the world market. Therefore, the question is how the possible future trade mark "European food" should compete on the world market: on the basis of a high quality profile, where good environment and healthy products are the corner stones, or by means of advantages of scale and lowest possible production costs? Maybe a decision regarding the introduction of a limit value for Cadmium in P-fertilizers in the new EC Directive on Fertilizers might constitute a small, but important, step to support the credibility in the development of a sustainable European agriculture that is perceived as rational and keen on protection of the consumers. This in accordance with the opinion expressed by the respondent from the Federation of Swedish Farmers, in connection with the questionnaire about the importance of the current Swedish governmental restrictions.
10. References


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10.1. Personal Communication


11. Appendix 1. The questionnaire to market actors

In order to track the attitudes towards cadmium in the food system, and to current governmental restrictions in Sweden, a questionnaire was sent to representatives for a number of important actors along this chain. The following organisations, representing major actors in the supply of cereals, as well as in the supply of vegetables, were contacted.

Fertiliser manufacturer: Hydro Agri AB and Agri Kemira AB.

Seller of fertilisers to the farmers: SLR and AB Svenska Foder.

Swedish Farmers: LRF.

Buyer of crops from the farmers: SLR and AB Svenska Foder.

Mill: AB Nord Mills.

Seller of flour to retail stores: AB Kungsörnen.

Supplier of retail stores: KF = Swedish Co-operative Union, Dagab and AB ICA Frukt och Grönt.

Answers have not been obtained from Agri Kemira AB, SLR, AB ICA Frukt och Grönt and AB Svenska Foder.

It is assumed that LRF represents the opinion of the Swedish farmers, and that SLR represents the opinion of the Swedish Farmers’ Regional Selling and Purchasing Associations (there are 11 such regional associations, which together constitute SLR).

The questions concern both the problem of cadmium in soils and products, and the attitude to governmental restrictions, as well as to restrictions driven by the market.

In the main report, a summary of the answers is given. In the following questions and answers are given in extension. In the questionnaire the term charge (avgift, Sw.) was used without the distinction between charge and tax.

Two general questions were asked.

• A restriction concerning the level of cadmium in phosphorus fertilisers at 100 g cadmium per tonne phosphorus has been introduced. What are the advantages and drawbacks for Your organisation of this restriction (including the ones the organisation represents)?

• A charge on 30 SEK per g cadmium on levels above 5 g/tonne phosphorus has been introduced. What are the advantages and drawbacks of this charge for Your organisation?

The respondent was asked to answer these general questions from the perspective of the own organisation. However, in order to "trigger" the thoughts, the general questions were supported by the following, more specified questions.

• Is Your demand on inputs steered by their cadmium level?

• Is the demand for Your products influenced by their cadmium level?

• Have the measures taken by the authorities with respect to cadmium in fertilisers influenced Your demand on low-cadmium inputs?
• Have the measures taken by the authorities with respect to cadmium in fertilisers influenced the demand for low-cadmium products from Your organisation?

• How have the governmental measures affected Your economy? Positive and negative effects, and their size?

• Are there possible restrictions on future supply of inputs to Your production, as a consequence of the restrictions of the authorities?

• Is there a risk that the restrictions of the authorities may limit Your production?

• How have the measures of the authorities concerning cadmium in fertilisers affected Your awareness in environmental issues?

• Which measures have You taken in order to affect the cadmium-level in the inputs used and/or in the produced products?

• Are there conflicts between the measures of the authorities and the ones of Your own organisation? In that case, which ones? Do the measures of the authorities and Your organisation complement each others?

• How do You rank the importance of the measures taken by the authorities compared to the measures of the actors on the market in terms of restricting the intake of cadmium via food in Sweden?

How does Your organisation look upon the possibility of changed rules in the European Union, with regard to cadmium in commercial fertilisers.

• Do You want to maintain current restrictions in Sweden?

• Do You want to apply the Swedish restrictions in the European Union in general?

• Are other changes wanted? In that case which ones and by what reasons?

11.1. Hydro Agri AB

The answers of Hydro Agri AB were delivered by Göte Bertilsson, Environmental Director, in cooperation with Mogens Erlingsson, Market Director.

In general

It is not quite easy to separate the importance of the requirements of the authorities from the ones of the market. Today, the commands of the market are stronger, but there is a history behind. The measures of the authorities have affected the requirements of the market.

Furthermore, according to the respondent, the measures of his company have had the average cadmium level in the products as objective — to have as low level of cadmium as an average for all the products as possible. They have not specified the cadmium-level in specific products out to the customer. That would imply a "multiplication" of the number of products.

Answers to the questions

1. For Hydro Agri AB, there are no negative effect of the limit of 100 mg cadmium per kg phosphorus. But, it should be observed that the average content in the world supply to the fertiliser industry is 150 mg cadmium per kg phosphorus. Exclusive treatment (in order to supply the Swedish market, for
example; my comment) may function as long as the market concerned does not dominate the global market. If everyone applied the limit of 100 mg per kg phosphorus, decadmiation processes must be introduced.

The positive thing with the limit on the maximum level of cadmium allowed, is that non serious marketing is prohibited.

The charge on cadmium levels between 5 and 100 mg cadmium per kg phosphorus is a general cost on the whole phosphorus market. Thus, it is a burden on the Swedish agriculture, which agriculture in other nations does not have to bear. This is a disadvantage to Swedish agriculture. How the cost of this disadvantage is allocated between Hydro Agri AB, and their customers, is hard to specify.

The cadmium-level is a very important criterion when Hydro Agri AB choose among the inputs for the production of the fertilisers sold on the Swedish market.

The market knows that the company has a low cadmium-level. Hopefully, the customers show a preference. However, Hydro Agri AB cannot "declare" the level in single products, thus a detail-steering does not exist.

In principal all products have a lower level than 50 (mg cadmium per kg phosphorus), the former charge-level. Thus, it (the former charge-level) is expressed and is still working. The demand of the market is now more important, though.

There is no shortage of inputs to the production yet, due to the Swedish authorities' restrictions. However, there can be a potential shortage. Decadmiation processes will be introduced if the market is sufficiently large. The Swedish market is too small to motivate decadmiation processes.

The role of the different actors within the political and the private sphere, engaged in the whole cadmium-question, cannot be distinguished. Sweden is in this case somewhat special (before) (the comment in the parenthesis is made by the respondent), both with respect to the authorities and the whole society.

According to the respondent, the measures of his organisation to a high extent goes beyond the ones of the authorities. Their average level of cadmium in phosphorus fertilisers is now 15 mg (cadmium per kg phosphorus), compared to the governmental limit of 100.

In connection with the question concerning the relation between the measures of the authorities and the ones of the organisation of the respondent, his conclusion was that the restrictions and charges posed by the authorities complement the requirements of the market. However, the requirements of the market is now stronger, according to the respondent.

The respondent stressed the importance that Swedish agriculture is not treated exclusively, in the context of the rules within the European Union. A general system of rules is needed.

The respondent put an interesting proposal forward: That the marketing of "cadmium-free" products can be considered. It would be facilitated by a definition that can be communicated. For instance, if the cadmium-content is less than 5 mg/kg phosphorus, the product can be called "cadmium-free".

The written answers were complemented by an interview by telephone 1997-09-05 of the Environmental Director, Göte Bertilsson. This interview gave the following, additional information.

The market share of Hydro Agri AB, with regard to phosphorus fertiliser, is around 60% in Sweden, 30% in Germany, Great Britain and France and 60-70% in Italy (Bertilsson, 1997; personal communication). The enterprise is the biggest fertiliser producer in the world, still the world market
share is below 10% (ibid.). The NPK-fertiliser produced in Köping in Sweden is produced from inputs with Finnish origin, the NPK sold in Sweden, produced in Norway, is based on apatite from the Kola peninsula. Both the Finnish and the Russian apatite are low in cadmium (ibid.).

The PK-fertilisers Hydro Agri AB sells, are manufactured by other companies. The origin of the inputs can shift. Thus, the level of cadmium per kg phosphorus can be higher, compared with the level in the NPK-products sold in Sweden. The price paid by Hydro Agri AB for the inputs they use, tends to increase with the restrictions on the cadmium level in the inputs (ibid.).

11.2. The Swedish Farmers’ Association (LRF)

The answers was given by Jan Eksvärd, LRF.

In connection with the question about the advantages and draw-backs of the maximum allowed limit of 100 mg Cd/kg phosphorus, for the organisation of the respondent, Eksvärd answered the following. (In parenthesis, LRF represents both farmers and farmer cooperatives. The answers of Eksvärd seem to reflect that LRF both represents farmers and farmers cooperatives.)

The limit has decreased the load of cadmium to agricultural land. It is a measure which shows that Swedish agriculture takes measures which decrease the environmental impact of the agriculture. The limit supports the development of a sustainable agriculture. It contributes to a strengthening of the restrictions on other fertilisers, such as sewage sludge and other rest products from the society. It puts the focus on other metals, also in feeds and in manure, and it gives a basis to, in an international context, work with a decrease of the cadmium-load to agricultural land, also from other sources.

An (official) limit implies the same rules for everyone on the market. The Swedish Farmers’ Selling and Purchasing Association (SLR), took the limit several years before it became a law. The limit of the authorities puts the focus on the (cadmium; my comment) question and shows the fertiliser manufacturers that the market is changing. Most often, they rapidly acquire needed competence to meet the new requirements.

According to the drawbacks, the respondent answered that the governmental limit may to some extent have increased the price of phosphorus fertiliser, and that it has caused a lot of extra work for the buyers (at the Swedish Farmers’ Regional Selling and Purchasing Associations; my comment).

The buying of inputs is, clearly, affected by the limit. As no decadmiation exists, clean enough raw phosphate must be chosen. This can imply completely new deliverers and extra work.

Concerning the question if the demand for their products is steered by their cadmium content, Eksvärd answered that it depends. In cadmium rich areas the content may be more important than the price. In other areas the price can determine whether the level is below 100. The charge is put in such a way that, with the current price-relations, it is cheapest to be at the current position — with an average of about 25 mg Cd/kg phosphorus.

The respondent concluded that the measures of the authorities have had no influence on the demand for low cadmium inputs by Swedish farmers, because the Swedish Farmers’ Selling and Purchasing Associations, as an internal cadmium policy, implemented the same limit earlier.

Eksvärd concluded that the measures of the authorities have had none or a possible positive effect on the economy of the Swedish farmers. The old charge on phosphorus was replaced by the charge on cadmium, which was lower. The steering cadmium-charge is accepted by the Swedish farmers, while the previous phosphorus charge had no acceptance. As far as Eksvärd remembered, the previous phosphorus charge summed to a cost for the Swedish agriculture of 25 million SEK annually, while the cost of the cadmium-charge for the Swedish agriculture now is about the half.
Within a decade the prices on low-cadmium phosphates will probably increase more than for the other phosphates, according to the respondent. The increase depends on decreased supply. It can be noted that low-cadmium phosphates most often are mined in politically less stable areas. This is a risk by itself.

The environmental awareness among farmers may have been influenced by the governmental measures. The Swedish farmers cooperatives implemented the limit several years before the authorities. The Swedish farmers, through their federation (LRF) take part in international work in order to spread the need of decreased cadmium-fluxes from commercial fertilisers. They work for a more even distribution of manure (they have not reached so far in that issue) — which decreases the need of commercial fertilisers. The Swedish farmers, through the Selling and Purchasing Associations have performed a great number of analyses in soil and crops in order to determine the relation between content in soil and content in crops. Limits for the content in soil have been established in order to be able to deliver wheat and rye without control analysis (of the crop) concerning cadmium. A still lower limit for the cadmium level in soil is put in Skåne. AB Cerealia (owned by SLR, see figure 1 in the main report) has introduced a voluntary limit on 100 mg Cd/kg wheat since 1990 (at the same time as the Lantmännen -associations decided on the maximum allowed limit of 100 mg cadmium per kg phosphorus in phosphorus fertilisers). The Lantmännen -associations choose varieties that take up less cadmium, especially concerning oats for human consumption, and wheat. Clones of salix are tested with regard to the capacity to take up cadmium, in order for the possibility to be used to clean fields with high levels of cadmium. Trials with different treatments are performed in order to decrease the plant-uptake of cadmium.

The opinion of the respondent is that the measures of the authorities and his own organisation complement each others. A problem is, however, the increased costs for the Swedish agriculture compared to important competing nations. The Swedish farmers need the same cadmium requirements in other nations, or that the charges are brought back to the agriculture in a reasonable way.

The measures of the authorities are needed in order to prohibit that cheap and contaminated fertilisers are used in Sweden. It is also important that authorities and research councils support research which show the risks with, e.g., cadmium. With knowledge, the market can by itself drive the development specifically in order to secure the people (own limits, plant breeding, choice of varieties, internal control, and so on). The market is fast and effective but needs institutions (set of rules) that provide competition on equal terms, that prohibit bad goods. Sets of rules/limits can be used to put the focus on important questions and works above all when the awareness about the importance of the question exists among the farmers, which, then, can implement a lot of measures, which can mean very much.

According to Eksvärd, the Swedish farmers want to keep the current set of Swedish restrictions, and they want it to be a general set of rules in the European Union. The Swedish farmers also, according to the respondent, want the European Union to put demands to the fertiliser manufacturers to develop low-cadmium fertilisers for the whole of the European Union (the whole world).

11.3. AB Nord Mills

General Information

Around 40% of the flour for human consumption in Sweden is milled by AB Nord Mills (Crona, 1997; personal communication).

The answers to the questionnaire were given by Lars Pålsson, Director Cereals (Spannmålschef).

- The positive thing (for AB Nord Mills AB) with the limit of 100 mg cadmium/kg phosphorus is that it puts the focus on the problem. It stimulates activities to find alternatives. There are no negative effect this far.
The charge on cadmium for levels above 5 mg cadmium/kg phosphorus implies a stimulation to buy inputs with as low cadmium-level as possible. The cost, about one million SEK for AB Nord Mills, must be taken out.

Measures taken are positive. AB Nord Mills has, since several years, specifications concerning maximum allowed levels of cadmium and other heavy metals in the grain the company buys. For crops produced under the trade mark Svenskt Sigill (Swedish Seal in translation; see section 4.2.1. for a description of the concept), there are also specifications concerning the cadmium-level in the soil.

11.4. AB Kungsörnen

The answers were given by Britt Lindner, Environmental Management Director, via the telephone.

General information

AB Kungsörnen dominates the Swedish flour market, their market share is around 60%. Of the flour produced, 6 parts of 7 are delivered to the retail stores, and the last part is delivered to kitchens at institutions, schools, restaurants at enterprises, other enterprises, and so on. However, the main flux of flour produced in Sweden goes directly to bakeries. In rough terms, and with reservations, Lindner said that maybe 20-30% is sold to households, while 70-80% of the grain milled in Sweden, is used by bakeries. The total consumption of wheat flour by households in 1996, was 101 million kg (Eriksson, 1997; personal communication), while total consumption of wheat flour in the beginning of the 1990's was 433 million kg (Jorhem and Sundström, 1993). This agrees well with the information from Lindner.

Answers to the questions

According to Lindner, both the limit and the charge support the way AB Kungsörnen is working in this issue. A limit for maximum allowable level is needed. Increasing levels in the soil is a concern. The level of cadmium in the grain, milled to the four sold by AB Kungsörnen, is below the maximum allowable level. The maximum allowable level applied by AB Kungsörnen is 0.1 mg cadmium/kg grain. The same limit is applied on import, of e.g., durum wheat. Besides the problems with cadmium, there is a problem in the use of phosphorus by itself, being a non-renewable resource.

Lindner cannot see any negative effects of the restrictions (the limit and the charge). She believes that the cadmium-level in the future will become an argument on the market. Thus, the restrictions may support this argument on the market: Sweden has had problems from the beginning with cadmium in food, from this point of view, cannot see anything else than that the restrictions are OK.

The "following-up" questions:

AB Kungsörnen has specified demands on the inputs they use.

The demand from the customers on the products of AB Kungsörnen is not steered by the cadmium-level. The cadmium-question is not communicated to the customer. However, it gives security, to translate a Swedish expression: corpses in the wardrobe are avoided. Instead, AB Kungsörnen communicate the health aspect to the customer. It is a selling argument, important for the customer. The respondent is of the opinion that health- and environmental concern is becoming more and more important for the customer. For AB Kungsörnen, the cadmium-aspect is a part of the general health-concept.

Today the levels of cadmium in grain and flour from AB Kungsörnen are pressed down by the concept Svenskt Sigill (Swedish Seal in translation; see section 4.2.1. for a description of the concept). In Svenskt Sigill there is specification on the maximum allowable cadmium-level in the soil on the field.
level. If the analysis of the soil cadmium content gives a measure above the limit, the farmer may deliver, if an analysis of the grain content of cadmium on the field level is below the limit 0.10 mg/kg grain.

Concerning the roles of the authorities and the market, the respondent expressed the following opinion. The measures of the authorities give an acceptance to move further, the priority of the question is increased. Everything should not, however, be ruled in detail. If the reason for the concern is the environmental impact, a charge is completely right. It increases the environmental concern, and speeds up the environmental work.

Britt Lindner does not want to discuss in terms of the economic effects for AB Kungsörnen of the measures of the authorities. It is as simple as a health-problem, which needs to be solved. However, low cadmium products provide an advantage on the market in the long run, which is supported by the governmental measures.

The respondent does not see any risk for shortages of inputs. On the contrary, the development concerning use of fertilisers and the content of cadmium in phosphorus fertilisers, indicate decreasing levels of cadmium in products.

Concerning the relation between the measures of the authorities and the environmental concern in the organisation, Lindner mentioned that the organisation worked with the issue long before the measures of the authorities were introduced. An organisation working seriously, will work with the issue far before the authorities. Thus the impact of the measures of the authorities on the cadmium policy of AB Kungsörnen was limited.

Furthermore, their current policy implies a higher ambition than the one expressed by the measures of the authorities. AB Kungsörnen is engaged in Svenskt Sigill. From April 1997 all wheat flour sold under the trade mark Kungsörnen, emanates from grain and flour produced under the producers trade mark Svenskt Sigill. Svenskt Sigill will successively be introduced for other products. All AXA oat grains is, thus, produced from Svenskt Sigill-oat from May, 1997.

The respondent does not see any conflicts between the measures of the authorities, and the ones of her own organisation, on the contrary, she concludes that they complement each other.

The question of the relative importance of the measures of the authorities, and the ones of AB Kungsörnen is tricky, according to the respondent: AB Kungsörnen is so big, that the company takes responsibility for the public health aspect. The authorities except the company to take this responsibility. Hypothetically, if AB Kungsörnen did not take the expected responsibility for the public health, the authorities could, as a reaction, put straight demands to the enterprise. Thus, the importance of the measures of the authorities, cannot be distinguished from the importance of the measures of the enterprise.

Lindner continues that there is a limit to how far the market can push questions. Both the market and the authorities are important. The authorities point out the direction, and take concern about and remove the worst cases. Thereafter, the market can proceed. Many companies do not work seriously, thus, they need to be governed by the authorities. Hence, both the market and the authorities are needed and are important.

Concerning the future rules in the European Union, the respondent answered that it is always good if the rules are generally applied in the European Union. It can, however, be an advantage if Sweden goes before. It will give an advantage, which it is up to the market to make use of. However, the same basic rules should be valid in the whole of the European Union. Sweden can continue with the current set of rules, even if the European Union does not make them general, if it does not have a major
economic impact on the agriculture. The respondent does not believe that the charge is disadvantageous to Sweden, it ought to be to our benefit.

There is a general problem with the use of phosphorus, as it is a non-renewable resource. The charge on cadmium in commercial phosphorus fertiliser, should be generally applied, also on phosphorus sources to ecological agriculture, and on, for instance, sewage sludge and lime.

11.5. KF
Answers to the questionnaire was given by Per Baumann, KF Consumer & Environment.

The focus in the answer to the advantages and draw-backs of the limit on maximum allowed levels of cadmium in phosphorus fertilisers of 100 mg cadmium/kg phosphorus was the ambition level, which, according to the respondent, is to low. However, the principle of a limit was not questioned. The answer was that there is nothing positive with such a, as it appears, high limit, but, on the contrary, much negative, considering the hazards of cadmium. This, we interpret as an opinion of the respondent that the current limit is too high, implying that hazards related to cadmium is not avoided.

The answer to the question about the advantages and draw-backs of the charge also focused the ambition level. An environmental charge on a subject that everyone agrees on should be away from the biosphere, must be high to have the intended effect. A low charge, which 30 SEK appears to be, but, above all, a “free”-limit at 5 g (cadmium per tonne phosphorus) is not in agreement with the removal-discussion.

- KF shall secure the quality of food to the consumer. The more that is written that the limit of cadmium is close to the risk-level, the more attention will be paid to the problem.
- Today, the choice of goods by KF is not steered by the cadmium-level.
- KF supports the measures of the authorities to protect the consumers.
- The rules of the authorities (compared to the measures by the actors on the market, my comment) are totally determining.

Concerning the European Union.

- Above all, we would like to see a still more rigorous treatment of the cadmium-question in the whole of the European Union. It is important that Sweden drives this question in Bryssel. The reason is that the free trade with goods is not as important as the public health and the future production capacity of the soils.

11.6. DAGAB
The answers to the questionnaire was given by Lilian Fredriksson, Environment and Quality.

DAGAB is worried about that the level of cadmium in agricultural soils and in the human liver increases. Concerning humans, the limit where damages occur is not far away, as a supplier of food, Dagab does not want to contribute to a further increase. Dagab has, together with the other actors in the retail store selling, driven the replacement of cadmium in batteries and worked with the taking care of these batteries. Thus, the cadmium risk is no new question for Dagab.

Dagab is positive to the upper limit concerning the allowed level of cadmium allowed in commercial fertilisers. However, it can be questioned if the limit that is valid today is put sufficiently low. Maybe, it ought to be further decreased.
The charge on 30 SEK per g cadmium for levels above 5 g cadmium per tonne phosphorus does not affect the buying of inputs of Dagab. The price on the products at the supplier level is not affected. Other factors determine the price the supplier pays.

From the customers to Dagab, the retail stores, no signals have come that Dagab should push requirements concerning low cadmium content in, for example, cereals. This will come first when it has become an issue in the media, and the customers in the retail stores put the corresponding request. However, Dagab is aware of that this request can come very fast and that the demand for ecological products probably will increase with an increasing shortage as a consequence.

The opinion of Dagab is that it is to the advantage if the same set of rules that now operates in Sweden, can be implemented in the rest of the EU, the contrary is to the disadvantage of their future activities.

**11.7. References**


**11.7.1. Personal Communication.**


MARIA INGELSSON and LARS DRAKE

The Swedish University of Agricultural Sciences, Uppsala

12.1. Introduction

There are very few studies of the price elasticity for phosphorus, and to our knowledge there is no Swedish study in the field (Boyle 1982, Ireland based on a cost function, Roberts and Heady, 1982, USA demand functions). Demand for nitrogen has been analysed in several studies in Sweden and abroad (Burrell 19889, Ingesson and Drake 1997). The eutrophic effect of nitrogen has attracted more attention and the linkage between yearly application and production as well as leakage are stronger for nitrogen than for phosphorus. The content of cadmium in phosphates adds to the environmental interest of demand for phosphorus fertilisers. The problem that initiated this study is the relation between the price on phosphorus fertilisers and the demand for the same. This relation is important for judgements of the effectiveness of a tax on the phosphorus content in fertilisers but also in order to calculate the costs for farmers of a tax on the cadmium content.

12.2. Data

Several questions have to be considered when choosing model for the empirical analysis. The first question concerns the choice between time series and cross sectional data. In this case the availability of data has made time series data a natural choice. This choice includes an implicit assumption that farmers react systematically on price changes in nitrogen and that this relation is stable enough over time to be tested with an econometric time series model.13

How phosphorus is to be treated in the model can also be discussed. Phosphorus is in reality only a component in the fertilisers demanded. For pure phosphorus fertilisers it is not unreasonable to believe that farmers may consider themselves as buying phosphorus. Therefore, it is safe to construct a model with phosphorus content in fertilisers as the dependent variable. In this paper, in order to discuss the demand for phosphorus, an econometric model with only one equation is chosen. A model with several mutually dependent variables would make better use of the available observations. But, this would require more data than is available without dubious calculations.

The choice of variables included in the model and the calculation methods used imply several assumptions. In the following a brief summary of the most important assumptions made is given.

13 The results indicate that this assumption is reasonable.
The chosen model consists of the prices of the variable inputs, phosphorus, cereals and labour; and of the fixed inputs acreage, manure and technical progress. Due to availability of data the time period 1961-1993 has been selected and time series data given as yearly observations has been used.\textsuperscript{14}

\textbf{12.2.1. Demand for Phosphorus}

The dependent variable is the demand for phosphorus (Jordbruksstatistisk Årsbok 1974-1995). This is approximated with the sold amount of phosphorus.\textsuperscript{15} The amount phosphorus marketed increased until the mid 1970s, and has declined thereafter. The 1973/74 high sell was anticipated to be due to the purchase made by farmers who then stored a large amount for the coming seasons. The price for phosphorus increased due partly to the oil crisis. Given that the storage of phosphorus resumed its normal level in the 1974/75 season, the cost estimate considered was mainly focused on use value.\textsuperscript{16}

If data for all the years were taken into consideration, the result of the analysis would be misleading since more phosphorus was occasionally sold at times when price levels were high. Coupled with this, the emission rate would have even shown change.

\textbf{Diagram 1. Sold amount of phosphorus}\textsuperscript{17}

---

\textsuperscript{14} The data is given as yearly averages. This implies the assumption that the conditions for profit maximizing on micro level are met at the aggregated level. It also means that part of the original information is lost. This leads to a loss in parameter efficiency. Another effect of grouped data can be that the fit of the regression improves (see Greene, 1993:227-229).

\textsuperscript{15} The data refers to averages over the period june-may each year. Nitrogen used for the growing season any year can be bought during the period before, which makes calender year less relevant.

\textsuperscript{16} Jordbrukskonomiska Meddelanden 1976:1, s 18

\textsuperscript{17} In the diagram the year 1961 corresponds to the observation for 1960/61 etc.
12.2.2. Phosphorus price

In this study price of phosphorus is the main explaining variable. The concentration of phosphorus has changed twice during the 1961-1993 study period. The emission level was first 19-20%, then 9% and once again 19-20%. This has had a clear impact on the price per ton which was higher for those years when the emission level was 9%. For the 1968/69 and 1986/87 period the prices are indicated below.
12.2.3. Demand for nitrogen\textsuperscript{19}

Demand for nitrogen is estimated by the amount of nitrogen sold on the market. The diagram below shows a break in the trend in the middle of the 1970s. This could perhaps be related to the technological progress or possibly saturation of the soil. The observation for 1991/92 is extreme. This is probably due to the agricultural reform which was introduced in 1991.

\textsuperscript{18} In the diagram the year 1961 corresponds to the observation for 1960/61 etc.
\textsuperscript{19} Data från Jordbruksstatistisk Årsbok
Diagram 3. Sold amount of nitrogen

The peak in sales 1973/74 is partly due to the fact that the farmers bought and stored chemical nitrogen to protect themselves from price increases.\textsuperscript{20}

12.2.4. Nitrogen Price\textsuperscript{21}

The Nitrogen price is calculated as weighed average price based on the equation below:

\[ P_n = \frac{P_{n1} \cdot Q_{n1} + P_{n2} \cdot Q_{n2}}{Q_n} \]

\[ [Q_n = Q_{n1} \cdot N_{n1} + Q_{n2} \cdot N_{n2}] \]

where

P = price

Q = quantity

N = portion of nitrogen in fertilisers

\textsuperscript{20} Also in 1987/88 that kind of storage took place. This observation is therefore calculated as the average of 1987/88 and 1988/89 in the source.

\textsuperscript{21} Data from Jordbruksconomiska Meddelanden
$n_1 = \text{calcium nitrate}$

$n_2 = \text{ammonium nitrate}$

$n = \text{all nitrogen}$

The data over nitrogen price analysis concerns the period July-June as one year. The time series for nitrogen has been recalculated into real prices using consumers price index with year 1980 as a base year.

Diagram 4. Nitrogen price

12.2.5. Cereal Price

An assumption has to be made for how the farmers' expectations about future cereal prices are formed (Jordbruksekonomiska Meddelanden 1977-1995). In this paper the assumption of adaptive expectations has been chosen. The farmer is assumed to calculate with the price of the time the decision about production level is made. The farmer's sales price of cereals has been calculated as an average price for the quantitatively largest cereals; wheat, barley, oats and rye. Here the 1979 consumers price index is used for the 1979/80 harvest season.

Diagram 5. Cereal price
12.2.6. Acreage

Available acreage of arable land is a fixed production factor which according to theory should affect demand for fertilisers. This is complicated by the fact that farmers are paid to fallow fields. In the regression models the actually used acreage is used (Jordbruksstatistisk Årsbok 1974-1995). This implies that used acreage is treated as an exogenous variable or that the decision to fallow or not is separate from the profit maximising production decision. In the short run this seems to be a reasonable assumption.
Diagram 6. Arable land

12.2.7. Manure

The available amount of manure is calculated from the amount of manure from cattle, swine and poultry (calculated from Claesson and Steineck 1991 and Jordbruksstatistisk Årsbok 1974-1995).
Diagram 7. Manure

12.2.8. Labour Force

The price on labour as it is experienced by farmers is difficult to estimate (Statistisk Årsbok 1973-1995). For some farmers the most realistic option is to employ farm workers. For other farmers the choice may be to reduce their off-farm work. In the latter case the market price for farm workers is only an approximation of the real marginal costs. In the study the average hourly wage of farm workers is used.
12.2.9. Technical progress

Technical progress is assumed to be a linear function of time. Time is likely to be a better measure of technical progress than other alternatives such as capital stock or intensity, since it also captures quality growth.

12.3. Model estimations

The estimations of the models have been done with the statistical programme SYSTAT for Windows. Diagnostic tests for autocorrelation, heteroscedasticity, normality and model specification have been carried out for all the models. The point of departure for the analysis is based on such variables as the prices of phosphorus, nitrogen, cereals, labour force, as well as the sold quantity of nitrogen, access to acreage and manure plus change in technology as independent variables:

\[
F \text{sgP} = \alpha + \beta_1 \cdot P \text{price} + \beta_2 \cdot \text{Cerealprice} + \beta_3 \cdot F \text{sgN} + \beta_4 \cdot N \text{price} + \beta_5 \cdot \text{Acreage} + \\
+ \beta_6 \cdot \text{Manure} + \beta_7 \cdot \text{Wage} + \beta_8 \cdot \text{Year} + \epsilon
\]

Attempts to test for parameter stability have failed due to high correlation between the independent variables. The test results are shown in the appendix.

Tests of significance have been done for a 5% significance level. The first issue to consider is the choice of functional form. A basic model, with the prices of nitrogen and cereals, the cultivated acreage, the amount of manure, the wage of farm workers and time as well as dummy variables for the years 1974 and 1992, has been estimated on both linear and log-log functional form.
Often, when conducting a time series analysis, the log-log functional form gives the best result. This was also true for this particular study. Accordingly, the study has been divided into two parts, namely, the part consisting of annual data with 20% of phosphorus emission level and the part consisting of annual data with 9% of phosphorus emission level. Model estimations for the periods with 20% phosphorus fail to be significant and even show unexpected sign for the price variable. Therefore the time series study covers the period between 1968/69 and 1986/87 based on prices set for the emission. Regarding the period 1969-1986, it was possible to formulate an equation which gives the expected sign from the significant variables in the equation.

12.3.1. The log-log functional form with a 9% fertilisers

A number of calculation attempts have been tried out to arrive at an acceptable model. The basic model for calculation was:

\[
\ln FsgP = \alpha + \beta_1 \ln P_{\text{price}} + \beta_2 \ln Cereal_{\text{price}} + \beta_3 \ln FsgN + \beta_4 \ln N_{\text{price}} + \beta_5 \ln Acreage + \beta_6 \ln Manure + \beta_7 \ln Wage + \beta_8 \ln Year + \varepsilon
\]

The result of the calculation is indicated in the table below:
Table 1 Result of estimation of the log-log functional basic model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-119.282</td>
<td>381.433</td>
<td>-0.313</td>
<td>0.762</td>
</tr>
<tr>
<td>Pprice</td>
<td>0.221</td>
<td>-0.128</td>
<td>-1.720</td>
<td>0.119</td>
</tr>
<tr>
<td>Cereal price</td>
<td>0.267</td>
<td>0.422</td>
<td>0.634</td>
<td>0.542</td>
</tr>
<tr>
<td>Acreage</td>
<td>1.770</td>
<td>2.084</td>
<td>0.849</td>
<td>0.418</td>
</tr>
<tr>
<td>Manure</td>
<td>0.948</td>
<td>0.544</td>
<td>1.742</td>
<td>0.116</td>
</tr>
<tr>
<td>Labour</td>
<td>0.278</td>
<td>0.167</td>
<td>1.658</td>
<td>0.132</td>
</tr>
<tr>
<td>Time</td>
<td>10.476</td>
<td>49.369</td>
<td>0.212</td>
<td>0.837</td>
</tr>
<tr>
<td>LnFsgN</td>
<td>0.752</td>
<td>0.370</td>
<td>2.034</td>
<td>0.072</td>
</tr>
<tr>
<td>LnNprice</td>
<td>-0.260</td>
<td>0.177</td>
<td>-1.468</td>
<td>0.176</td>
</tr>
</tbody>
</table>

Source: Author's own calculation

This model has an $R^2$ of 0.971 and an adjusted $R^2$ of 0.945. All the parameters except cereal price are significant at the 5 percent significance level. Models without or with only one dummy variable have also been tested, but this model gives better results. The price elasticity for nitrogen depend on the estimated period. Calculation from the average values of sales of nitrogen and nitrogen price gives an price elasticity of -0.158. For the period 1961-74 the elasticity is -0.200 and for the period 1975-93 it is -0.135. These elasticity estimates should, however, be interpreted with caution due to the insignificant estimate of cereal price.

The F-test for general significance gives 37,574, which implies that the p-value is at 0.0000. This model does not give the expected sign for a point test estimate of the elasticity of price for phosphorus. Hence, in order to arrive at a good model we need to exclude such variables as acreage, time, and technical change; and instead include a dummy variable for the 1979/80 farming season:

$$\ln\text{FsgP} = \alpha + \beta_1 \cdot \ln\text{Pprice} + \beta_2 \cdot \ln\text{Cerealprice} + \beta_3 \cdot \ln\text{FsgN} + \beta_4 \cdot \ln\text{Nprice} +$$

$$+ \beta_5 \cdot \ln\text{Manure} + \beta_6 \cdot \ln\text{Wage} + \beta_7 \cdot \text{Dum80} + \varepsilon$$

The result of this equation is indicated below:
Table 2 The Result of estimation of the final model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>18.200</td>
<td>-2.752</td>
<td>-6.613</td>
<td>0.000</td>
</tr>
<tr>
<td>LnPprice</td>
<td>-0.178</td>
<td>0.036</td>
<td>-4.985</td>
<td>0.001</td>
</tr>
<tr>
<td>LnCerealprice</td>
<td>0.545</td>
<td>0.093</td>
<td>5.884</td>
<td>0.000</td>
</tr>
<tr>
<td>LnManure</td>
<td>0.841</td>
<td>0.158</td>
<td>5.315</td>
<td>0.000</td>
</tr>
<tr>
<td>LnWage</td>
<td>0.216</td>
<td>0.049</td>
<td>4.403</td>
<td>0.001</td>
</tr>
<tr>
<td>LnFsgN</td>
<td>1.095</td>
<td>0.083</td>
<td>13.213</td>
<td>0.000</td>
</tr>
<tr>
<td>LnNprice</td>
<td>-0.225</td>
<td>0.013</td>
<td>-17.302</td>
<td>0.000</td>
</tr>
<tr>
<td>Dum80</td>
<td>0.130</td>
<td>0.013</td>
<td>10.181</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation

This model has an $R^2$ of 0.997 (adj $R^2 = 0.995$) and all the parameters are significantly estimated at the 5 percent significance level. The log-log functional form assumes constant elasticity. This model gives an estimate of the price elasticity of phosphorus of -0.178 which means, there is 95% of confidence interval between -0.255 and -0.103.

12.4. Test of the log-log model for 1969-1986

12.4.1. Testing for autocorrelation

To fulfil the common conditions for processing the equation with the least quadrate method, a number of diagnostic tests have to be carried out. The autocorrelation test is made by using the first order of Durbin-Watson's hypothetical test which says that correlation has to be equal to nil. Accordingly, we arrive at:

Durbin-Watson D Statistic  2.467

First Order Autocorrelation  -0.271

The Durbin-Watson D is 2.467. For 18 observations and 7 identified variables the upper boundary is $(d_T) 2.461$ and the bottom boundary is $(d_L) 0.502$. If $0 < d < d_L$, then the hypothesis that there is no positive correlation can be disregarded. If $4 - d_L < d < 4$ then the hypothesis that there is no negative correlation can be disregarded. But neither of these hypotheses can be disregarded. The autocorrelation
plots at the different locations indicate that it is not possible to disregard the hypotheses and there does not occur autocorrelation.

12.4.2. Testing for heteroscedasticity

In order to test for heteroscedasticity the residuals quadrates need to be plotted against the given Y-values. The plotting implies that heteroscedasticity conditions may occur. The test results imply that there are problems with autocorrelation and heteroscedasticity for model 1.22

12.4.3. Testing for normality

The values of skewness and kurtosis for the normal distribution are nil and 3 respectively. The residual distributions tested obtained the values -0.007 and -0.768 respectively.

12.5. Conclusions

It is quite clear that the relation between application in a given year and leaching the same year is not very strong. The relation between application one year and the yield the same year is also weak. In the long run the relation is much. This can be explained by the large stock of nutrients in the soils stronger (Storesletten and Drake 1996). The policy conclusion is that a charge on nitrogen and phosphorus fertilisers will contribute to reduced eutrophication. We can also expect larger elasticities in the long run than in the short run. Unfortunately it was only possible to estimate the short run elasticity.

In order to get a significant model it was necessary to use only the part of the time series data for which the concentration is 9% phosphorus in the fertilisers, i.e. 1969-86. The estimate of the price elasticity of phosphorus in Sweden is, as expected, quite low and not sensitive to the model specification. The price elasticity of phosphorus is estimated at -17.8 percent with a 95% confidence interval between -10.3 and -25.5 percent. The price for and the quantity used of nitrogen also have heavy influence on the demand for of phosphorus. Phosphorus appear to be a complementary good to nitrogen.

The result is the expected and adj R-square, the F-test for the model and the fact that all variables in the best model are significant on the 5% level speaks in favour of the results. Only simpler tests of the conditions for the estimated model have been carried out. These test indicate that the model may have some weaknesses.

12.6. References


22 The test results for all models are presented in the appendix.


13. Appendix 3. Effects on content in soil, grain and renal dysfunctions

The economic effects of cadmium flows in the food system concern environment and health. Available information about the environmental effects does not support a quantitative analysis of their economic importance (see Parkman et al., 1997). With regard to the health effects, the available information makes it possible to come closer to such a quantification.

According to Järup et al. (1997), it can be estimated that a doubling of the average daily intake of cadmium with food from 15 to 30 mg per day and person (in Sweden), would increase the number of cadmium induced renal tubular damages from the current level of several thousands to about 100,000 individuals. In their estimation, the relationship between the intake of cadmium with food, and the prevalence of cadmium induced renal effects is close to linear in this interval.

In the study entitled "Cadmium in Fertilizers: - Risks to Human Health and the Environment" to the Finnish Ministry of Agriculture and Forestry from the Finnish Environment Institute, 30 April, 1997, it is estimated that roughly a few thousands of individuals in Finland are now at risk of adverse health effects caused by cadmium.

In the following analysis, it is assumed, based on the results of Järup et al., that a doubling of the daily intake of cadmium with food from 15 to 30 mg per day, will increase the number of cadmium induced renal dysfunctions with 100,000 cases in Sweden (see Table 3 in the main report, where the change in the prevalence of renal damages in the different subpopulations with a doubling of the average intake is explicitly shown, calculated from the results in Järup et al.). It is also assumed that the dose-response relation is linear in this interval. This implies that, if the Swedish population is 8.5 million people, the annual intake of cadmium with food will increase with 46 kg if the intake with food is doubled, causing 100,000 cases more of renal dysfunctions. Thus, for every kg cadmium more taken in, the number of cadmium induced renal dysfunctions would increase with 2,174 cases (100,000 cases/46 kg).

To avoid misunderstanding, the calculations performed are of the type "assume that, ... then the consequences will be?" The relevance of the obtained results for an understanding of real costs and benefits is determined by the relevance of the made assumptions. In the following, the calculations and assumptions, with regard to the health implications of cadmium in food, are based on the study by Järup et al. (1997), performed on behalf of the Swedish Chemicals Inspectorate.

Ideally, the costs of restricting the flows of cadmium in the food system, such as decadmiation of fertilisers, should be weighed against the benefits of such measures in terms of, for instance, health aspects. There is no estimate available of the costs associated with each case of cadmium induced renal dysfunction. This implies that the best option available is to relate a decrease in the inflow of cadmium to the food system to an estimated effect on the number of cadmium induced renal dysfunctions. To be able to execute such a calculation, the relationship between the content of cadmium in the top soil and the level of cadmium in the crop must be known. Eriksson et al. (1996) summarise information from 20 years of field studies in Sweden about the influence of different soil factors on the content of cadmium in crops. These field studies provide the needed information, based on specific Swedish conditions and farming practices actually used.

In Table 1, the change of the content of cadmium in the top soil in 100 years, as a function of different levels of cadmium in phosphorus fertiliser, is shown. The application rate is in agreement with the

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23 To be very specific, it is the effect of a slow-down of the increase in the cadmium flow in the food system that is discussed.
application in intensive wheat production in the main wheat producing districts in Sweden (see Table 5, in the main report). The change in the content of cadmium in the top soil is in accordance with assumptions and calculations in Hellstrand and Landner (1997).

### Table 1. Predicted increases in content of cadmium per kg dry matter (DM) in grain of winter wheat as a function of increased levels of cadmium in top soil in 100 years at different cadmium contents in phosphorus fertilisers

<table>
<thead>
<tr>
<th>Application rate is 25 kg P per ha</th>
<th>Increase of Cd mg/kg top soil</th>
<th>Increase of Cd Winter wheat, mg/kg DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 mg Cd per kg P</td>
<td>0.014</td>
<td>2.6</td>
</tr>
<tr>
<td>25 mg Cd per kg P</td>
<td>0.031</td>
<td>5.7</td>
</tr>
<tr>
<td>50 mg Cd per kg P</td>
<td>0.051</td>
<td>9.4</td>
</tr>
<tr>
<td>140 mg Cd per kg P</td>
<td>0.128</td>
<td>23.7</td>
</tr>
</tbody>
</table>

Comments. The increases of cadmium in top soils are from Hellstrand and Landner (1997). The increase of cadmium in grain of winter wheat is calculated from the regression coefficients between increase in grain as a function of the increase in top soil (Eriksson et al., 1996). Current average content of cadmium in grain of winter wheat in Sweden is 53 mg/kg DM (Eriksson, 1990).

Based upon the calculated increase of cadmium in the top soil, the change in cadmium content in winter wheat is predicted. The results are shown in Table 1. The prediction is based upon the change in the top soil content of cadmium, and the relation found between the top soil content of cadmium and crop content in Eriksson et al. (1996). The limits regarding how the results can be interpreted, are discussed in the original article.

The predicted increase in the content of cadmium in the grain is probably conservative. The regression coefficients used concern the relation between the average soil content of cadmium and content of cadmium in grain, while, according to Eriksson et al. (1996), "Soluble Cd in applied fertilizers or deposition will initially join the exchangeable fraction; hence this fraction will, at least temporarily, be increased relatively more than the non-soluble fraction". Eriksson and Söderström (1996), in connection with the same reasoning, propose that the uptake of the added cadmium may be proportionally higher, than from the total soil fraction, because of this reason.

With increasing levels of cadmium in the top soil, the effluxes will increase. This effect has not been considered in the calculations underpinning Table 6. It can be calculated that in the example with 140 mg cadmium per kg phosphorus in Table 6, the increase in the efflux of cadmium with the wheat grain after 100 years, is about 5% of the net influx calculated. This implies that the situation after one hundred years is far from a steady state, if not other effluxes have increased substantially.

The annual human consumption of wheat flour in Sweden is, according to Jorhem and Sundström (1993), 433 million kg. Assume that the increase of cadmium in the grain equals the increase in the flour. Then, by multiplying the amount of wheat flour consumed by the estimated increase of cadmium in winter wheat (Table 1), the total increase of cadmium taken in by wheat flour in Sweden is obtained (see Table 2). By multiplying the obtained estimate of the increase of cadmium taken in by wheat flour with the increase in the number of renal dysfunctions per kg cadmium extra taken in, an estimate of the number of cadmium induced renal dysfunctions for the different levels of cadmium in phosphorus fertilisers is obtained. The results of this exercise are shown in Table 2.
Assume that the alternative with 140 mg cadmium per kg phosphorus represents the situation when no measures restricting the cadmium flow are taken. Assume also, that the alternative with 5 mg cadmium per kg phosphorus, is the level that is achieved with decadmiation of phosphorus fertilisers. In that case, the benefit expressed after 100 years of decadmiation on the national level in Sweden, in terms of renal dysfunctions caused by the cadmium taken in by the consumption of wheat flour, is 19,000 minus 2,100 equals 16,900 cases less. It can be noticed that even with the lowest level of cadmium, there is still, with the given assumptions, an increase of the number of cadmium induced renal dysfunctions.

If the cost for decadmiation of all phosphorus fertilisers used in Sweden is 10 million SEK, this implies that decadmiation is advantageous if the total costs per renal dysfunction exceeds 600 SEK (10 million SEK/16,900 cases).

**Table 2.** Estimated increase in the number of cadmium induced renal impairments after 100 years for the alternatives with different content of cadmium in phosphorus fertilisers in Table 6, through the effect on the content of cadmium in grain of winter wheat

<table>
<thead>
<tr>
<th>25 kg P applied per ha</th>
<th>Million kg wheat flour, DM</th>
<th>Increase of Cd in grain, mg/kg DM</th>
<th>Increase of Cd in all wheat flour, kg</th>
<th>Renal dysfunctions per kg increase of Cd taken in</th>
<th>Estimated increase in total number of Cd induced renal dysfunctions</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 mg Cd per kg P</td>
<td>368</td>
<td>2.6</td>
<td>1.0</td>
<td>2,174</td>
<td>2,100</td>
</tr>
<tr>
<td>25 mg Cd per kg P</td>
<td>368</td>
<td>5.7</td>
<td>2.1</td>
<td>2,174</td>
<td>4,600</td>
</tr>
<tr>
<td>50 mg Cd per kg P</td>
<td>368</td>
<td>9.4</td>
<td>3.5</td>
<td>2,174</td>
<td>7,500</td>
</tr>
<tr>
<td>140 mg Cd per kg P</td>
<td>368</td>
<td>23.7</td>
<td>8.7</td>
<td>2,174</td>
<td>19,000</td>
</tr>
</tbody>
</table>

Comments. Assuming a dry matter (DM) content of 85% in flour, and that the increase of cadmium in grain equals the increase of cadmium in flour.

Assume that the current taxes on cadmium in phosphorus fertilisers in Sweden result in a level of 25 mg cadmium per kg phosphorus in fertilisers on average in Sweden, in the coming 100 years (this is the actual average level). Then the benefit of 100 years of taxes expressed year 100 is 19,000 minus 4,600 cases equals 14,400 cases less of renal dysfunctions, caused by the cadmium taken in by wheat. The real cost for the taxes can be estimated to about 100,000 SEK annually. Thus, if the total cost per cadmium induced renal dysfunction exceeds 7 SEK (100,000 SEK/14,100 cases), the benefit of the tax exceeds its costs, in terms of the reduction of the renal dysfunctions caused by the cadmium taken in by wheat.

A critique against the calculations is that the cumulative cost for the tax/the decadmiation in the period year 0 to year 100 is not considered, while the health effect of the cumulative net influx during the same period is considered. However, ideally, the annual costs and benefits when a steady state situation has been reached for the different alternatives, should be compared. In the steady state situation the costs for the restricting measures in a specific year can be compared to the health effects of the restrictions the same year. This, as in the steady state situation, the positive effects in health terms expressed a specific year, as a function of the cumulative effect of the preventive measures taken before this year, equals the cumulative positive health effects of the preventive measures taken the same year.
As already noticed, the situation after one hundred year is far from the steady state. This implies that the cumulative benefit of the restricting measures in a specific year is underestimated in the calculations above, while the costs for the same measures are not underestimated. Thus, in the steady state situation, the cost per case of renal dysfunction where measures restricting the cadmium flow become advantageous, is probably even less, compared to the results above, everything else being equal.

The calculations are hypothetical. The interest rate is assumed to be zero, which can be motivated from a sustainability perspective. It is assumed that there are no measures taken to restrict an increase of the level of cadmium in food. In reality, different actors in the food chain in Sweden do apply such measures. These measures rule out the fraction of, for instance, winter wheat with the highest levels. However, most cadmium policies of the market actors are not so effective against a slow increasing trend of cadmium in all fractions of the crop. The calculations behind Table 7, concern the effect on all quantities of winter wheat. If, as the results of Järup et al. (1997) indicate, the human intake of cadmium with food in Sweden already has reached a threshold level, where subpopulations of "several thousand people" "will develop adverse renal effects in the form of a tubular damage" (ibid.; quotations, p. 89), also an increase of the cadmium level in the fractions with the lowest content of cadmium, will contribute to an increase of renal dysfunctions. In fact, a general increase of the average cadmium level can be more troublesome for human health, than an increase of the fraction exceeding a limit value, since, in the latter case, it is easier to take effective protective measures.

A source of error in the calculations is that it is assumed that all the increase of cadmium in the grain is consumed by humans. However, the level of cadmium in the wheat flour is substantially lower than in the grain (Hellstrand and Landner, 1997). It has not been possible to sort out how the cadmium level in the fraction of the grain of winter wheat that is consumed by humans is affected, in the alternatives in Table 6.

The existing information implies that it cannot be excluded that an increase in renal damages caused by an increase of the cadmium taken in by food will increase costs such as treatment costs and suffering for the patient. The results of the performed calculations indicate that if the total costs per case of cadmium induced renal dysfunction is of the order of some tens or hundreds of SEK or higher, measures to restrict the cadmium content in phosphorus fertilisers such as taxes or decadmiation can be beneficial from a societal perspective.
### Förteckning över PM-serien

<table>
<thead>
<tr>
<th>PM nr</th>
<th>Titel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PM nr 1</strong></td>
<td>Flamskyddsmedelsprojektet - en förstudie</td>
</tr>
<tr>
<td><strong>PM nr 2</strong></td>
<td>Riskbilden för kreosot och kreosotliknande produkter</td>
</tr>
<tr>
<td><strong>PM nr 3</strong></td>
<td>The Flame Retardants Project - A Survey of Brominated Alternatives to Brominated Diphenylethers</td>
</tr>
<tr>
<td><strong>PM nr 4</strong></td>
<td>Flamskyddsmedelsprojektet - En metod för att uppskatta kemikalieinnehållet i elektronikprodukter</td>
</tr>
<tr>
<td><strong>PM nr 5</strong></td>
<td>Användning av metylenklorid och trikloretylen i analyser och tester</td>
</tr>
<tr>
<td><strong>PM nr 6</strong></td>
<td>Analys av konsekvenserna för kemikaliekontrollen av den ökade internationella standardiseringen och av standardiseringens delvis nya roll inom EG</td>
</tr>
<tr>
<td><strong>PM nr 7</strong></td>
<td>Plastbranschen - Struktur och verksamhet</td>
</tr>
<tr>
<td><strong>PM nr 8</strong></td>
<td>Flamskyddsmedelsprojektet - Brandtekniska krav som styr användningen av flamskyddsmedel</td>
</tr>
<tr>
<td><strong>PM nr 9</strong></td>
<td>Utvärdering av arbetet i skogsbruks plantskyddskommitté</td>
</tr>
<tr>
<td><strong>PM nr 10</strong></td>
<td>The Flame Retardants Project - Short Ecotoxicological Reviews and Hazard Analyses on Some Flame Retardants</td>
</tr>
<tr>
<td><strong>PM nr 11</strong></td>
<td>Plastadditivprojektet - Metaller i plast</td>
</tr>
<tr>
<td><strong>PM nr 12</strong></td>
<td>Riskbedömning av ftalater och andra mjukningsmedel i plast</td>
</tr>
<tr>
<td><strong>PM nr 13</strong></td>
<td>Mercury in products distribution, fluxes and environmental effects</td>
</tr>
<tr>
<td><strong>PM nr 14</strong></td>
<td>The Flame Retardants Project - Brominated Aromatics from Waste Handling and Recycling Processes</td>
</tr>
<tr>
<td><strong>PM nr 15</strong></td>
<td>Bekämpningsmedel vars godkännande har upphört</td>
</tr>
<tr>
<td><strong>PM nr 16</strong></td>
<td>Klor i USA och Kanada - Kloruppdraget, underlagsrapport 3</td>
</tr>
<tr>
<td><strong>PM nr 17</strong></td>
<td>Möjlig bildning av klorerade biprodukter vid industriella processer - Kloruppdraget, underlagsrapport 4</td>
</tr>
<tr>
<td><strong>PM nr 18</strong></td>
<td>Förekomst av PCB och PCN i varor och kemiska produkter i Sverige - Kloruppdraget, underlagsrapport 5</td>
</tr>
<tr>
<td><strong>PM nr 19</strong></td>
<td>Diskussion av eventuellt samband mellan exponering för klororganiska miljöföroreningar och bröstcancer m.m. - Kloruppdraget, underlagsrapport 6</td>
</tr>
<tr>
<td><strong>PM nr 20</strong></td>
<td>Klor Vetenskaplig workshop - Kloruppdraget, underlagsrapport 7</td>
</tr>
</tbody>
</table>
| PM nr 21 | Klorföreningar i kemiska produkter  
|          | -beskrivning och urval för vidare utredning-  
|          | - Kloruppdraget, underlagsrapport 8 |
| PM nr 22 | Synen på klor i några europeiska länder  
|          | - Kloruppdraget, underlagsrapport 9 |
| PM nr 23 | Klorerade verksamma ämnen som ingår i bekämpningsmedel  
|          | - Kloruppdraget, underlagsrapport 10 |
| PM nr 24 | The Plastic Additives Project  
|          | Stabilizers for Thermoplastics |
| PM nr 25 | Miljönämndsenkätten hösten 1999 |
| PM nr 26 | Gävleborgs län.  
|          | Regional Inspektions  
|          | Omgång  
|          | Januari-april 1993 |
| PM nr 27 | Värmelands län.  
|          | Regional Inspektions  
|          | Omgång  
|          | April-juni 1993 |
| PM nr 28 | Stockholms län.  
|          | Kommunerna Botkyrka, Haninge, Salem och Tyresö  
|          | Regional Inspektions  
|          | Omgång  
|          | April-juni 1993 |
| PM nr 29 | Hallands län  
|          | Regional Inspektions  
|          | Omgång  
|          | Mars-juni 1994 |
| PM nr 1 | Potential Formation of Chlorinated By-products in Industrial Processes |
| PM nr 2 | Stockholms län  
|          | Kommunerna Lidingö, Vaxholm och Österåker  
|          | Regional Inspektions  
|          | Omgång  
|          | November 1993-juni 1994 |
| PM nr 3 | Företagskontroll i samverkan mellan Göteborgs miljöförvaltning och Kemikalieinspektionen |
| PM nr 4 | Flamskyddade plastråvaror i Sverige  
|          | - Flamskyddsmedelsprojektet |
| PM nr 5 | Human Health Hazard Assessments of some Flame Retardants |
| PM nr 6 | A Compilation of Flame Retardants |
| PM nr 7 | Exponering av flamskyddande ämnen i textilier |
| PM nr 8 | Båtbottenfärgar och kopparhalten i den akvatiska miljön |
| PM nr 9 | Nålen i höstacken  
|          | - Hur man hittar företag som är anmälningspliktiga till produkterregistret |
| PM nr 10 | The flame retardants project  
|          | - a collection of reports on some flame retardants and an updated ecotoxicological summary for tetrabromobisphenol A |
| PM nr 1 | Efficiency test of the stark boat washer  
*Olof Holmer, Anders Johnson* |
| PM nr 2 | Kemikalier i kläder  
-från förstudie till regeringsuppdrag-  
*Barbro Gustafsson* |
| PM nr 3 | Tillsynsprojekt kadmium i varor  
-Barbro Gustafsson- |
| PM nr 4 | Avveckling av amalgam inom tandvården  
*Redovisning av ett regeringsuppdrag* |
| PM nr 5 | Substitut till amalgam - funktion och arbetsmiljö |
| PM nr 6 | Avveckling av kvicksilver  
*Rapport från ett regeringsuppdrag* |
| PM nr 7 | PVC-additiv  
*Konsekvenser för ekonomi och sysselsättning* |
| PM nr 8 | Cadmium in Fertilizers  
*Cadmium Workshop, Sweden 16-20 October 1995* |
| PM nr 9 | Kommunens miljö- och hälsoskydd på kemikalieområdet  
*Resultat av en enkät till 30 kommuner våren 1996* |

| PM nr 1 | Förändringar i kemikalievalet  
-produktutveckling från miljö- och hälsosynpunkt |
| PM nr 2 | Kartläggning av hälso- och miljöfarliga kemikalier i importerade textilier |
| PM nr 3 | The Baltic Sea environment, and its sensitivity to pollutants with emphasis on organic tin compounds |
| PM nr 4 | Experiences of the Swedish regulation concerning cadmium in stabilizers and pigments in plastics |
| PM nr 5 | Bekämpningsmedel vars godkännande har upphört  
*Registerutdrag oktober 1997* |
| PM nr 6 | Skåne 96  
*Inspektionsrapport* |
| PM nr 7 | Consequences of restricted use of organic tin compounds for the shipping in the Baltic Sea and the North Sea |
PM nr 1  Swedish Agricultural and Horticultural crops
Best.nr. 510 592