A possible EU wide charge on cadmium in phosphate fertilisers: Economic and environmental implications

Final Report to the European Commission

F.H. Oosterhuis, Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam

F.M. Brouwer, Agricultural Economics Research Institute (LEI), The Hague

H.J. Wijnants, DHV Environment and Infrastructure (DHV-MI), Amersfoort

Report number E-00/02

April 2000 (commissioned by the European Commission)

IVM

Institute for Environmental Studies
Vrije Universiteit
De Boelelaan 1115
1081 HV Amsterdam
The Netherlands

Tel. ++31-20-4449 555
Fax. ++31-20-4449 553
E-mail: secr@ivm.vu.nl

Preface

This report deals with the impacts of a possible EU-wide charge on cadmium in phosphate fertilisers, with a view to reducing their cadmium content. It has been prepared for the European Commission, DG Environment, by the Institute for Environmental Studies (IVM, Vrije Universiteit, Amsterdam), the Agricultural Economics Research Institute (LEI, The Hague) and DHV Environment and Infrastructure (DHV-MI, Amersfoort). The authors would like to thank Mr Hans Bergman (DG Environment), Mr Martin Scheele (DG Agriculture), Mr Joachim Ehrenberg (DG Enterprise), Mr Bill Watts (DG Economic and Financial Affairs), Mr Pierre Strosser (DG Environment), Mr Norbert Theihs (DG Enterprise) and Ms Anita Fokkema (DG Health and Consumer Protection) of the European Commission for their useful comments and discussions during the study. We are also very grateful for the information provided by Mr Nicholas Douthwaite, Mr Peter Botschek and Mr Hans van Balken (European Fertilizer Manufacturers' Association, EFMA), Mr Rein Coster (Dutch Association of Fertiliser Producers, VKP), Mr Kees Langeveld (Amsterdam Fertilizers B.V., Amfert), Mr J.F. Schutte (Dutch Fertiliser Federation), Mr Jerker Forssel (Swedish National Chemicals Inspectorate, KEMI), Mr Ola Jörnstedt (Swedish Environmental Protection Agency, SNV) and Mr Göte Bertilsson (Norsk Hydro).

Contents

Summary

Cadmium from phosphate fertilisers poses a potentially serious threat to soil quality and, through the food chain, to human health. The European Commission is considering the possibility of using an EU-wide charge on cadmium in fertilisers so as to improve the competitive position of the ‘low-Cd’ product *vis-à-vis* the ‘high-Cd’ one. The present study aims at evaluating the economic and environmental implications of such a charge.

The EU is presently importing almost all of its phosphate rock and a substantial part of its processed phosphate (phosphoric acid and phosphate fertilisers) from third countries. There is a tendency for phosphoric acid and fertiliser production to be relocated in phosphate rock producing countries (vertical integration). The production capacity of the phosphate fertiliser industry in the EU has been decreasing substantially in recent years.

Phosphate fertiliser consumption in the EU also shows a downward trend. Since the peaks of consumption during the1970s and 1980s, a reduction of 45% was recorded, and further decrease is expected for the future. The average share of fertilisers in total farming costs is generally around 10% or less.

Sweden is presently the only EU country which applies a charge on cadmium in phosphate fertilisers. Several other Member States pursue a cadmium reduction by means of other policy instruments. A common EU policy on the issue does not (yet) exist.

The cadmium content of phosphate fertilisers can be reduced by using low-Cd phosphate rock (usually of magmatic origin), or by decadmiation of either phosphate rock or phosphoric acid. Using low-Cd rock has been the dominant strategy in countries where cadmium reduction policies are being pursued. Decadmiation is currently too expensive and low-cost technologies are not yet fully developed. In some cases technical restrictions impede the use of either magmatic rock or decadmiation.

Designing a charge on Cd in P fertilisers implies a number of choices concerning issues such as the charge base and rate, the earmarking of revenues, degree of harmonisation and various implementation issues. This study presents six options for a possible EU wide cadmium charge, made up by combinations of three approaches and two versions:

	'Uniform' approach	**'Minimum rate' approach**	**'Divergent' approach**
	Applied in all Member States at a uniform charge rate	Applied in all Member States at charge rates equal to, or exceeding an EU wide minimum	Applied in some Member States only, with differences in charge rates
'Moderate' version	Charge rate EUR 0.25 per gramme Cd, initially applying to fertiliser with more than 60 mg Cd per kg P_2O_5. Threshold lowered to 40 mg Cd per kg P_2O_5 after 2 years and to 20 mg Cd per kg P_2O_5 after another 2 years	Minimum charge rate EUR 0.25 per gramme Cd; thresholds and phasing as in Uniform approach	Charge rates on average EUR 0.25 per gramme Cd; thresholds as in Uniform and Minimum Rate approach; phasing differing between Member States
'Stringent' version	Charge rate EUR 1.00 per gramme Cd; no threshold or phasing	Minimum charge rate EUR 1.00 per gramme Cd; no threshold or phasing	Charge rates on average EUR 1.00 per gramme Cd; no threshold or phasing

The main focus of the analysis is on the 'minimum rate, stringent' option, which is likely to have the strongest impact. In the analysis, three scenarios are distinguished:

- ***'business as usual':*** this scenario (which may prevail in the short term) implies a lack of impact from the charge on supply and demand. Obviously, this scenario has no environmental impact and leads to the highest level of charge revenues. It is unlikely to persist for a long time;
- ***'rush for low-Cd phosphate rock':*** in this scenario (which is the most likely scenario for the medium and possibly also the long term), a massive shift in the use of raw material takes place. Morocco and other African countries will be replaced by South Africa and Russia as the EU's main phosphate suppliers. Low-cadmium phosphate reserves in these countries are probably sufficient for a long period, although there may be some technical restrictions on their use. This scenario leads to reductions in cadmium flows to farmland as well as to a reduction of cadmium in waste gypsum;
- ***'decadmiation breakthrough':*** in this scenario (which may occur in the long term if certain market and technological conditions are fulfilled), decadmiation technology is assumed to be used on a large scale. In the 'stringent' version of the charge, there will still be a tendency towards the exclusion of countries producing phosphate rock with very high Cd concentrations (such as Senegal and Togo). In the 'moderate' version, most present suppliers will be able to compete. The cadmium flows to agricultural land will be reduced, but the cadmium content of waste gypsum will not be affected. Moreover, this scenario implies a flow of cadmium in decadmiation waste, which may cause environmental problems in the producing countries.

The impact of the cadmium charge on agriculture is likely to be limited in all three scenarios, as farmers face overall cost increases of less than 1%.

The environmental and economic impacts of the Cd charge are in addition to the changes which will occur as a result of other developments, e.g. the Common Agricultural Policy (CAP). Some of these developments will lead to a drop in fertiliser use, thus contributing to the decrease in cadmium load to agricultural land. This ‘autonomous’ decrease in cadmium load is, however, much smaller than the decrease that can be achieved through the charge.

It should be emphasised that, although the main conclusions are probably quite robust, quantification of the impact of a cadmium charge is only possible within relatively wide margins, given the uncertainties regarding a number of variables and assumptions.On the basis of the analysis, the following suggestions for the possible introduction of an EU wide Cd charge can be made.

First of all, the ‘ideal’ cadmium charge would have a regionally differentiated rate, because of the variety in soil quality, sensitivity and background Cd concentrations in the EU. However, such a charge would be administratively unfeasible. It is therefore suggested to introduce minimum charge rates at the EU level. Member States can choose to increase the rate depending on the severity of the cadmium problem. This ‘minimum rate’ approach is better able to reflect the differences of the problem between Member States than a uniform EU-wide charge.

The levy revenues for each Member State will be relatively low. The aggregate maximum for the EU as a whole can be roughly estimated at 175 million Euro per year in the ‘Business as usual’ scenario under the ‘stringent, uniform’ charge option. It will be much less in other options and under the two other, more likely, scenarios, where cadmium contents are effectively reduced. In principle, the net revenues of the levy could be recycled to the sector paying them: industry and the farmers. Industry could be supported by R&D funding for promising low-Cd fertiliser technologies. If these technologies include decadmiation, special attention will be needed for the problem of safe disposal of waste products containing cadmium. Farmers can receive support through awareness raising and training programmes to optimise the use of (phosphate) fertilisers. However, since the net revenues are expected to be low, due to the use of low cadmium fertilisers, it is questionable if such earmarking makes much sense from an economic point of view. Nevertheless, revenue recycling might enhance the acceptance of the charge.

Administrative costs should be minimised. In the ‘uniform’ approach, the charge can be levied from the relatively small number of producers and importers to the EU market. In the two other approaches, the number of taxpayers is higher, as the charge has to be levied (and in some cases reimbursed) on fertilisers traded between Member States as well. Thus, a compromise will have to be found between low administrative costs and differentiation between Member States.

Preferably, the introduction of a charge on cadmium should be announced well in advance. This would enable companies using high cadmium phosphate rock to switch to an alternative and in this way a situation of comparative disadvantage for these producers could be avoided. A (probably small) drawback of early announcement is the risk of traders or farmers building up stocks of untaxed high-Cd fertiliser during the intermediate period.

The impact of the charge on North- and Central-African countries mainly exporting high cadmium phosphate rock to the EU may need to be taken into account. It will be hard for at least some of these countries to remain competitive under a cadmium charge, even if profitable decadmiation technologies become available. Applying a threshold for the cadmium content (of say 20 mg Cd / kg P_2O_5) below which no charge is due could be helpful in this case (although a threshold is environmentally less advisable, because it removes the incentive for continued Cd reduction). However, under a ‘low-Cd rock’ scenario these countries will need assistance to find other export opportunities. Possible instruments are the EU association treaties (for countries like Tunisia, Jordan, and Morocco) and the Lomé Convention (for countries like Senegal, Togo and Nauru).

Finally, a cadmium charge implies the need to introduce a labelling system for P fertilisers, specifying their cadmium content. Such a system might be introduced anyway, regardless of the possible introduction of a charge. This would make farmers more aware of the amount of cadmium they put on their land, which in itself could already create a demand for low-Cd fertiliser.

The overall conclusion of the report is thus that an EU wide charge would in most options analysed have the effect of an increase in the demand for low-cadmium raw material for the production of phosphate fertilisers for the EU market. The effects on the producers of fertilisers would be limited if they were given sufficient time to prepare for the charge. The effects on EU farmers would be small. The economic effects on some raw material and fertiliser producer countries outside the EU could be significant.

The amount of cadmium put on EU soil would be considerably reduced. The cost-efficiency would be high as large reserves of low-Cd rock are probably available at limited extra cost, and this rock can in most cases be used after a limited investment in updating production facilities. In case of a breakthrough for decadmiation technologies, a waste problem in the form of cadmium would occur in the fertiliser producing countries with high Cd content in their raw material.

1. Introduction

Cadmium from phosphate fertilisers poses a potentially serious threat to soil quality and, through the food chain, to human health. The exact size of the problem is hard to determine, due to a lack of sufficient and reliable data (ERM, 1997). The risks caused by various sources of cadmium are currently subject to a comprehensive risk assessment within the framework of EU Regulation 793/93. However, it is obvious that in the long term the continuing input of cadmium to agricultural soils through fertilisers could lead to accumulation beyond acceptable levels. While there are other important sources of soil contamination with cadmium as well (e.g. manure, compost, sewage sludge and atmospheric deposition)[1], phosphate fertilisers are generally the most important one as far as farmland is concerned.

Apart from reducing fertiliser use, lowering the cadmium content in fertilisers is the only feasible way of reducing the cadmium input to farmland from this source. This can be achieved either by using raw materials (phosphate rock) with a lower cadmium content, or by eliminating the cadmium from the phosphate rock or the phosphoric acid during the production process.

Currently, no uniform EU standard for the maximum allowable cadmium content of fertilisers exists. A number of Member States apply their own limit values, which poses restrictions on the internal market for fertilisers. There is some debate on the desirability and level of a harmonised EU wide standard, given the differences in circumstances and priorities in the various Member States. Meanwhile, it is widely acknowledged that a reduction in cadmium content is in general desirable and achievable at reasonable cost.

The European Commission is considering the possibility of using an EU-wide charge on cadmium in fertilisers so as to improve the competitive position of the ‘low-Cd’ product *vis-à-vis* the ‘high-Cd’ one. Such a charge would encourage farmers to use the low-Cd alternatives, and stimulate suppliers to invest in technologies for producing them. In addition to this direct environmental impact, indirect effects may result, both positive (e.g. lower amounts of fertiliser applied in the EU due to the price increases) and negative (e.g. a relative increase in the use of high-Cd fertiliser outside the EU). Moreover, a charge on Cd in fertilisers would have a range of economic implications for supplier countries and companies and for agriculture. Therefore, the Commission initiated a study on the various aspects of a Cd charge.

The objectives of the present study are:

- to evaluate the economic and environmental implications of an EU wide charge on the content of cadmium in mineral fertilisers; and
- to evaluate the possibility and effects of an EU wide framework for charges, within which each Member State could set its own rate.

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[1] In addition to these, there are other sources of environmental pollution with cadmium, such as the disposal of batteries containing cadmium. However, these “point sources” are generally less relevant for the contamination of farmland with cadmium. Appendix II contains a comparison of the different sources of cadmium pollution, abatement costs and charge levels.

This report, which presents the key findings of the research undertaken, is structured as follows. Chapter 2 contains a survey of the EU phosphate fertiliser market. It identifies the main producers and users of phosphate rock, phosphoric acid and phosphorus fertilisers, and their relevance to the EU. Trends in production and trade are also described. In chapter 3, policies and technical options to reduce the cadmium content of P fertilisers are discussed. Chapter 4 presents some alternative options for the design of an EU wide charge on cadmium in fertilisers. The possible economic and environmental impacts of these options are analysed in chapter 5. This analysis is done by means of three scenarios, describing the possible reactions from the fertiliser industry. Chapter 6 presents conclusions and policy recommendations.

2. The phosphate fertiliser market: status and trends

2.1 Phosphate fertiliser production and trade

The production of phosphate rock, the main raw material for phosphate fertiliser, is insignificant in the EU. Presently, the only Member State producing it is Finland (about 0.2 Mtonnes P_2O_5 per year (ERM, 1997)). Phosphate rock is being imported from various sources around the world, Morocco being the single largest supplying country (see Table 2.1). Some developing countries, such as Togo, Jordan and Morocco, depend heavily (30-50%) on phosphate rock for their export earnings (ERM, 1997).

Table 2.1 Imports of phosphate rock to EU Member States by country of origin, 1995 (1000 tonnes of products)

	USA	FSU*	Morocco	Algeria	Tunisia	Jordan	Israel	Togo	RSA**	Other
Austria	-	-	65.2	4.8	12.8	20.5	10.3	-	-	48.0
Belgium	190.8	158.4	514.2	20.5	17.6	-	-	-	629.1	-
Denmark	-	67.3	6.4	11.8	-	5.5	-	-	15.5	33.0
Finland	-	91.3	-	-	-	-	-	-	-	-
France	-	16.9	212.7	110.9	196.5	-	646.3	103.3	-	199.9
Germany	78.7	22.2	66.4	-	-	67.5	14.6	-	-	-
Greece	-	-	19.3	91.4	5.3	155.4	-	75.9	-	131.1
Ireland	0.4	-	10.0	-	-	-	-	-	-	-
Italy	-	-	202.7	-	3.0	-	13.8	-	-	44.0
Netherl.	269.0	483.6	276.2	-	-	447.6	290.1	-	20.9	88.0
Portugal	-	-	6.0	-	22.9	-	-	-	-	128.0
Spain	-	-	1,624.4	13.2	18.2	-	-	54.3	-	49.0
Sweden	-	-	70.5	-	-	-	-	-	-	5.0
UK	-	11.9	8.2	10.4	-	-	-	-	-	-
Total EU	**538.9**	**851.6**	**3,082.2**	**263.0**	**273.3**	**696.5**	**975.1**	**233.5**	**665.4**	**721.0**

* Former Soviet Union ** Republic of South-Africa
Source: ERM (1997)

The EU is presently a net importer of processed P_2O_5. More than 2.5 million tonnes of phosphoric acid and phosphate fertilisers are being imported annually (the latter mainly in the form of ammonium phosphate), the major suppliers being Russia, Morocco and Tunisia (see Table 2.2). EU exports are primarily in the form of NPKs (fertilisers containing nitrogen, phosphorus and potassium), mainly to China, Thailand and the Americas (EFMA, 1997a).

Table 2.2 Imports of processed phosphate (phosphoric acid and phosphorus fertilisers) to EU Member States by country of origin, 1995 (mln tonnes P_2O_5)

	USA	FSU*	Morocco	Tunisia	Israel	Senegal	RSA**	Other	Intra-EU
Austria	-	-	1.9	-	-	-	-	-	-
Belgium	9.3	94.3	215.3	-	-	-	-	14.9	7.7
Denmark	-	14.9	-	-	-	-	-	-	41.5
Finland	-	-	-	-	-	-	-	-	-
France	39.9	87.3	230.7	177.8	38.3	1.6	17.9	31.0	119.5
Germany	36.7	97.6	27.0	-	5.8	-	48.4	15.0	112.5
Greece	-	-	-	4.4	-	-	-	2.3	-
Ireland	-	2.6	83.4	74.1	-	-	-	7.0	1.5
Italy	-	213.2	124.7	168.2	37.1	2.6	-	3.2	12.7
Netherl.	-	36.3	14.2	-	82.0	-	8.5	-	63.5
Portugal	-	12.9	27.3	-	-	-	-	-	9.2
Spain	-	52.2	83.3	24.9	10.5	-	-	12.1	12.4
Sweden	-	-	-	-	-	-	-	-	5.0
UK	-	109.3	266.8	-	53.6	-	-	3.6	68.7
Total EU	**85.9**	**720.6**	**1,074.6**	**449.4**	**227.3**	**4.2**	**74.8**	**89.1**	**454.2**

* Former Soviet Union ** Republic of South-Africa
Source: ERM (1997)

France, the Netherlands and Spain are the largest phosphate fertiliser producing countries of the EU. Together they account for almost half of total EU production capacity (EC, 1997). Table 2.3 gives the figures for production, consumption and international trade of phosphate fertilisers by EU Member State.

Figure 2.1 shows the development of the EU-15's phosphate trade over the period 1985-1995. The general decline in phosphate use is clearly reflected, as is the tendency (especially since 1990) towards less imports of raw materials and more imports of intermediate and final products.

The main competitive advantages of the EU fertiliser industry are its modern technology, high energy efficiency and skilled labour, as well as its location close to its customers in combination with a well developed system of marketing, distribution and logistics. On the other hand, the industry faces relatively high energy costs and strict health, environment and safety regulations, which also affect its cost structure negatively. Overcapacity in Central and Eastern Europe (CEE) and the former Soviet Union has led to fierce competition from those countries on the EU market. In a number of cases (all relating to nitrogen fertilisers) anti-dumping measures have been taken (EFMA, 1997a). Competition from other regions, like North Africa, the Arabian Gulf and Asia, is also growing. Tariffs on fertiliser products are to be progressively reduced: the maximum rate will decrease from 10.6% in 1995 to 6.5% in 2004. Many developing countries, and also the CEE countries can already export duty free to the EU, whereas exports to CEE countries are still subject to import levies (EC, 1997).

Table 2.3 Production, import, export and consumption of total phosphate fertiliser in EU countries, 1996 (in 1000 tonnes P_2O_5)

Country	Production	Import	Export	Consumption
Austria	52.0	22.0	16.0	56.0
Belgium	152.0	181.0	282.0	51.0
Denmark	58.0	35.0	45.0	48.0
Finland	109.0	0.0	51.0	58.0
France	558.0	511.3	58.7	1051.9
Germany	160.0	356.0	97.0	415.0
Greece	133.0	32.0	33.0	132.0
Ireland	0.0	117.0	0.0	129.0
Italy	256.0	502.0	6.0	539.0
Netherlands	363.0	109.0	411.0	61.0
Portugal	56.0	30.0	10.0	76.0
Spain	337.0	277.0	60.0	554.0
Sweden	14.0	31.0	0.0	45.0
UK	93.0	356.0	47.0	402.0
Total EU	2341.0	2559.3	1116.7	3617.9

Source: International Fertilizer Industry Association (IFA)

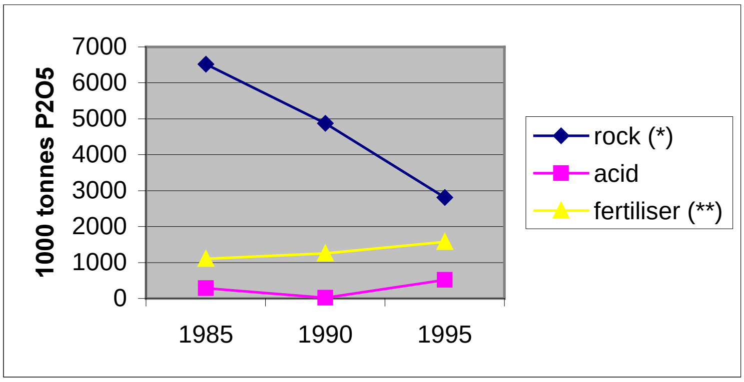

Figure 2.1. Net imports of phosphate rock, phosphoric acid and P fertilisers in the present EU-15, 1985-1995
(*) an average P_2O_5 content of 33% has been assumed.
(**) figures for 1985 relate to 1985-86 etc.
Source: Calculations based on FAO (1997).

Fertiliser manufacturing in the EU can be characterised as a capital intensive industry, which is dominated by a limited number of large companies (Norsk Hydro and Kemira being the largest ones). Having undergone major restructuring in the early 1990s, which led to a substantial reduction in production capacity and employment, the EU fertiliser industry is now regarded as viable and internationally competitive, although profitability remains modest. In some EU countries, the restructuring process is still going on.

Bartzokas and Yarime (1999) distinguish three types of corporate strategies in the restructuring process of the European fertiliser industry:

- **exit**: a strategy followed by firms like ICI, Hoechst and Enichem. They have decided that their core competence is not in the sectors based on the availability of cheap natural resources, and have chosen a strategy of moving away from bulk chemicals to fine and specialty chemicals;
- **regional orientation**: companies which are following this strategy include Agrolinz, BASF, DSM, Grande Paroisse, IFI and Fertiberia[2]. Their strategy is basically to secure their own markets in Europe. Close relationship with local farmers is very important for pursuing this strategy;
- **global expansion**: Norsk Hydro and Kemira have decided to go beyond the European markets. These firms are pursuing vertical integration and have started to make foreign direct investment in the upstream segment for the access to cheap raw materials, including phosphate rock. They are also moving to production in high-demand developing countries, such as South Asia and China.

The demand for phosphate fertiliser in the EU-15 is expected to decrease further, as a result of changes in crop (and fallow) areas (on which the CAP reform has a major influence), new crop varieties, improvements in nutrient management and application technology, environmental regulations, and substitution by manures and slurries. EFMA expects a 10% drop in P fertiliser use over the period 1999-2009 (EFMA, 1999).

On the world market, however, demand for fertilisers is expected to grow. According to the FAO, fertiliser consumption in developing countries will increase at an annual rate of 3.8% until 2010 (EC, 1997). New projects that are scheduled to start by 2003 in Australia, Canada, China, India, Jordan, and Morocco are expected to increase world phosphate rock and phosphoric acid production capacities by 10%. Expansions in phosphoric acid and fertiliser production capacity planned beyond 2003 will be located near phosphate rock mines to reduce costs and avoid transportation or other disruptions to supply (Jasinski, 1998). The trend for new phosphoric acid plants to be situated at or near the location of a phosphate rock mine is also stimulated by the complications for the production process caused by differences in phosphate rock qualities (IFA/UNEP, 1998).

2.2 Phosphate fertiliser use

The use of phosphate fertilisers in the EU and the share of fertiliser costs in the total cost of three types of farms in the 15 EU countries is discussed in this section.

Total consumption of phosphate fertilisers in Western Europe in 1996/97 is assessed at a level of some 3,600 Kt P_2O_5 (EFMA, 1997b). This is slightly more than 10% of total world consumption. Since the peaks of consumption during the1970s and 1980s, phosphate fertiliser use in the EU has been reduced dramatically by some 45% (EFMA, 1998a). An important reason for this is the transition from an ‘enrichment phase’, in which the phosphorus status of soils is improved, to a ‘replacement phase’, in which the amount of phosphorus added to the soil is about the same as the amount harvested with the crops (Bertilsson, 1996). Other factors behind the reduction in P fertiliser use are replacement by organic nutrients and the more efficient use of nutrients, which has allowed yields to increase without a corresponding increase in chemical inputs.

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[2] However, DSM and ICI do not produce phosphate fertilisers anymore.

During the past couple of years, figures on total consumption in the EU have been relatively stable. Differences across countries and crops are large (Table 2.4). Average consumption of phosphate fertilisers for growing cereals in the EU is relatively high (about 44 kg/ha) and well above that of permanent crops and permanent grassland.

Table 2.4 Phosphate application 1997/98 (kg P_2O_5 per hectare) by country and crop.

Country	Total cereals	Permanent crops	Permanent grassland
Belgium/Luxembourg	20	30	33
Denmark	19	-	14
France	47	12	26
Germany	31	28	7
Greece	25	37	-
Ireland	60	-	17
Italy	75	40	2
Netherlands	13	38	17
Portugal	51	25	2
Spain	50	20	2
United Kingdom	51	25	12
Austria	35	18	4
Finland	24	50	25
Sweden	16	-	13
EUR-15	44	26	11

Source: EFMA

The impact of a charge on cadmium in phosphate fertilisers on agriculture would largely depend on the share of the costs of such nutrients in total costs. The incentive to apply phosphate fertilisers with lower cadmium content is likely to be highest where costs of such phosphates are a considerable part of total costs of input. In light of this sensitivity we provide some figures indicating the significance of fertiliser costs in the EU. Detailed information regarding the expenses on mineral fertilisers at farm level is available from the Farm Accountancy Data Network (FADN) of the Commission of the European Communities. FADN contains farm level data on the structure of the farm level (economic size, agricultural area and livestock population), total output, intermediate consumption, a balance sheet account and a profit and loss account. The sample includes approximately 60,000 holdings, which are stratified according to region, economic size and farming type.

Figures on the costs of fertilisers[3] and soil improvers are presented for three farming types, i.e. specialist cereals, specialist horticulture, and specialist fruit and citrus fruit. Table 2.5 shows the distribution of represented holdings by share of fertilisers and soil improvers in total costs on specialist cereals. Similar figures for the two other farming types are presented in Table 2.6 (specialist horticulture) and Table 2.7 (specialist fruit and citrus fruit). Similar maps on the costs of fertilisers and soil improvers are also presented in Appendix III of this report. Map A.3.1 shows the costs of fertilisers and soil improvers per hectare of Utilised Agricultural Area (ECU) on specialist cereals in the

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[3] These figures relate to total fertiliser use, not only phosphate fertiliser.

EU. Similar figures for the two other farming types are presented in Map A.3.3 (specialist horticulture) and Map A.3.5 (specialist fruit and citrus fruit).

Map A.3.2 shows the share of fertilisers and soil improvers in total costs (%) on specialist cereals in the EU. Similar figures for the two other farming types are presented in Map A.3.4 (specialist horticulture) and Map A.3.6 (specialist fruit and citrus fruit).

Figure A.3.1 shows the share of fertilisers and soil improvers in total costs of specialist cereals. Similar figures for the two other farming types are presented in Figure A.3.2 (specialist horticulture) and Figure A.3.3 (specialist fruit and citrus fruit).

Specialist cereals

The costs of fertilisers and soil improvers on specialist cereals exceed 125 ECU per hectare of utilised agricultural area in parts of Germany, France, Italy, Sweden, Greece and Portugal. These costs on average are below 100 ECU. In contrast to the expenses of fertilisers in the horticulture sector, in specialist cereals the costs are relatively small on a per hectare basis. The expenses however are a substantial share of total costs. On average, they are 12%.

A wide variation exists across the group of holdings with lowest shares relative to the group of holdings with highest shares. Group ‘low’ is 6% in Denmark, whereas it is 15% in group ‘high’ (Table 2.5). Italy has more than 70 thousand specialist cereals holdings. In this country the share is 20% on about a third of these holdings. There the incentive to achieve a reduction on the expenses of phosphate fertilisers is likely to be highest in regions where costs of fertilisers are a considerable part of the total costs of input.

Table 2.5 Distribution [a] on specialist cereals (type 11) in EU 15 in 1995/96.

Country	Share of fertilizers and soil improvers in total costs (%)				Number of represented holdings (x 1,000)
	Low	Medium	High	Total	Total
Denmark	6	10	15	10	9.5
Germany	5	9	14	9	8.0
Greece	9	16	23	15	17.7
Spain	10	18	29	19	46.7
France	8	13	18	13	33.2
Ireland	.	.	.	19	1.2
Italy	7	12	20	13	71.2
Portugal	4	10	19	11	4.1
Finland	.	.	.	17	3.0
Sweden	4	12	20	11	6.1
United Kingdom	7	11	15	10	9.4

a) Distribution of represented holdings by share of fertilizers and soil improvers in total costs.
Source: FADN-CCE-DG Agriculture/A-3; adaptation LEI.

Specialist horticulture

The costs of fertilisers and soil improvers on specialist horticulture are far above those in specialist cereals. On average they amount to 1,400 ECU per hectare, and exceed 2,500 ECU per hectare in parts of Germany (Schleswig-Holstein, Baden-Württemberg) and France (Rhone-Alpes), Belgium and the Netherlands.

The share of fertilisers and soil improvers in total costs on average is 5%. A wide variation exists across the group of holdings with lowest shares relative to the group of holdings with highest shares. Group 'low' is 7% in Spain, whereas it is 22% in group 'high' (Table 2.6). In that country, which has more than 32 thousand specialist horticulture holdings, the share is 22% on about a third of these holdings. There the incentive to achieve a reduction on the expenses of phosphate fertilisers is likely to be highest in regions where costs of fertilisers are a considerable part of the total costs of input.

Table 2.6 Distribution a) on specialist horticulture (type 20) in EU 15 in 1995/96.

Country	Share of fertilizers and soil improvers in total costs (%)				Number of represented holdings (x 1,000)
	Low	Medium	High	Total	Total
Belgium	2	5	16	7	4.6
Denmark	3	4	8	5	1.5
Germany	0	2	5	2	9.4
Greece	4	9	15	8	7.4
Spain	7	15	22	15	32.2
France	3	6	12	6	11.0
Italy	3	9	18	10	21.3
Netherlands	1	2	12	4	14.2
Portugal	3	8	15	8	8.7
United Kingdom	1	4	8	4	4.0

a) Distribution of represented holdings by share of fertilizers and soil improvers in total costs.
Source: FADN-CCE-DG Agriculture/A-3; adaptation LEI.

Specialist fruit and citrus fruit

The costs of fertilisers and soil improvers on specialist fruit and citrus fruit are 130 ECU per hectare. They exceed 175 ECU per hectare in the southern part of France, parts of Italy and large areas of Greece.

The share of fertilisers and soil improvers in total costs on average is 6%. A wide variation exists across the group of holdings with lowest shares relative to the group of holdings with highest shares. Group 'low' is 3% in Italy, whereas it is 20% in group 'high' (Table 2.7). In that country, which has more than 125 thousand specialist fruit and citrus fruit holdings, the share is 20% on about a third of these holdings. There the incentive to achieve a reduction on the expenses of phosphate fertilisers is likely to be highest in regions where costs of fertilisers are a considerable part of the total costs of input.

Table 2.7 Distribution a) on specialist fruit and citrus fruit (type 32) in EU 15 in 1995/96.

Country	Share of fertilizers and soil improvers in total costs (%)				Number of represented holdings (x 1,000)
	Low	Medium	High	Total	Total
Belgium	.	.	2	1	1.0
Denmark	.	.	.	2	0.3
Germany	1	1	.	2	1.2
Greece	6	10	15	10	45.9
Spain	7	12	21	13	90.4
France	1	3	7	3	9.2
Italy	3	8	20	9	127.5
Netherlands	1	.	2	1	2.2
Austria	.	.	.	2	1.3
Portugal	1	5	12	6	21.8
United Kingdom	.	.	.	1	0.8

a) Distribution of represented holdings by share of fertilizers and soil improvers in total costs.

Source: FADN-CCE-DG Agriculture/A-3; adaptation LEI.

3. Reducing cadmium in phosphate fertilisers: options and costs

3.1 Cadmium reduction policies in the EU and its Member States

Cadmium in fertilisers has been a long standing concern for EU policy makers. In 1984, a research programme was started on cadmium removal from phosphate rock and phosphoric acid, which was funded successively by the World Bank and the European Commission. In 1988, the Commission adopted a resolution outlining an action programme for the EU with the aim of reducing the introduction of cadmium in soil from fertiliser (Mrabet, 1996). The EU has also issued legislation concerning other sources of cadmium inputs to agricultural soil, notably Directive 86/278/EEC, which gives limit values for the concentration of cadmium in agricultural soils of 1 to 3 mg/kg (dry matter). Sewage sludge should not be applied to soils where the cadmium concentrations exceed these limits.

As yet, however, there are no harmonised EU regulations regarding the cadmium content of fertilisers. The EU Fertiliser Directive (76/116/EEC) does not refer to cadmium, whereas the Cadmium Directive (91/338/EEC) deals only with products in which cadmium is being applied intentionally. Possible EU initiatives will depend on the outcome of studies on the risks which cadmium in fertilisers entails. These studies are part of a comprehensive risk assessment of cadmium, which takes place within the framework of EU Regulation 793/93 on the evaluation and control of the risks of existing substances. Meanwhile, an EU Directive (98/97/EC) has been adopted which allows Austria, Finland and Sweden to maintain their existing national limits on cadmium in fertilisers until the end of 2001.

In addition to these three, several Member States have national regulations and industry commitments, which limit the maximum concentration of cadmium in fertilisers, the yearly amount of cadmium input on agricultural land, and/or the cadmium concentrations in agricultural soils (see Table3.1).

The cadmium content of fertilisers can also be affected indirectly by other regulations, including those directed at reducing fertiliser use in general, regarding the maximum cadmium content of food products and the emission limits for cadmium in gypsum from phosphoric acid production[4]. The latter influence is, however, not necessarily positive: such regulations may lead to process changes which reduce the cadmium concentrations in the gypsum, but increase the cadmium content of the fertiliser. To avoid this, separate measures (such as the envisaged charge) are needed addressing the cadmium content of fertilisers.

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[4] Although EU Directive 83/513 on Cadmium (a Daughter Directive to the Framework Directive 76/464 on the discharge of dangerous substances into the aquatic environment) did not set limit values for the manufacture of phosphoric acid or fertiliser from phosphate rock, Member States do have the obligation to fix emission standards for these discharges (Bartzokas and Yarime, 1999).

Table3.1 Limit values for cadmium in fertilisers and soils in EU Member States.

Country	Max. concentration of Cd in fertiliser (mg per kg P_2O_5)	Max. amount of Cd input to agricultural soils (grammes per ha per year)	Max. conc. of Cd in agr. soils (mg/kg dry soil; guidance level)
Austria	75 (since 1994)	10 (1) / 5 (2)	1.0
Belgium/Lux.	90 (10)	150	1.0 – 3.0
Denmark	47 (since 1995)		0.5
Finland	21.5	3	0.5
France			
Germany	40 – 90 (7)	16.7 (3)	1.0
Greece			
Ireland			
Italy			
Netherlands	(8)		0.5 – 1.0
Portugal	40 – 70 (10)		
Spain			
Sweden	43 (9)	1.75 (4)	
UK		0.15 (5)	3.0 (6)

(1) arable land (20 g over a period of 2 years)
(2) grassland and vegetables (10 g over a period of 2 years)
(3) average over a period of 3 years
(4) average for 7 years; will be lowered to 0.75 g/ha/year as from 2000
(5) with sewage sludge only (average over a period of ten years)
(6) soils with a pH of 5.0 and above, treated with sewage sludge
(7) based on a voluntary agreement between government and industry: all fertilisers should comply with the 90 mg/kg level; 89% of the products with the 70 mg/kg level and 63% with the 40 mg/kg level.
(8) OECD (1994) mentions a limit of 40 mg per kg phosphorous, which would equal 17 mg per kg P_2O_5. However, according to a spokesman of the Dutch Fertiliser Producers' Association VKP, there is no legal limit to the Cd content in phosphate fertiliser in the Netherlands. Instead, a voluntary agreement is in preparation (see below).
(9) a voluntary limit of 21.5 mg/kg P_2O_5 (50 mg/kg P) has been introduced by the Swedish Farmers' Regional Selling and Purchasing Association SLR (Drake and Hellstrand, 1998).
(10) Mentioned in OECD (1994); probably not a legal limit.
Sources: OECD (1994); ERM (1997); Ehrenberg (1999); Swedish Government (1985)

The use of economic instruments to reduce the cadmium content of fertilisers is presently limited to Sweden, where a charge on cadmium in commercial fertiliser exists since 1994 (see Box 3.1). Other countries, such as France, are considering the possibility of introducing fertiliser taxes (ENDS 1999a), but cadmium is not included in the envisaged tax base.

The input of cadmium to agricultural soils can also be influenced by means of communicative instruments, for instance by information and auditing systems for farmers. Voluntary agreements are yet another option. The Dutch government, for example, is preparing an agreement with the phosphate fertiliser industry with a view to achieve a stabilisation of the cadmium input from phosphate fertiliser (Apotheker, 1999). Previous environmental agreements with two large fertiliser producers in the Netherlands already contained the stipulation that they would reduce the cadmium content of their phosphate fertilisers (Smit-Kroes and Valkier, 1988; Smit-Kroes, Pessi and Lens, 1988).

Box 3.1. Experience with the Swedish cadmium charge

Sweden has had environmental charges on nitrogen and phosphorus in commercial fertilisers since 1984. The charge on phosphorus was abolished in January 1994 and replaced by a charge on cadmium. An important reason for the introduction of the cadmium charge was that it creates an ongoing incentive to reduce the concentrations (Swedish EPA, 1991). Since November 1994, the charge rate is SEK 30 (EUR 3.3) per gramme of cadmium if the cadmium content exceeds 5 mg per kg phosphorus (about 2.2 mg Cd per kg P_2O_5) (Swedish EPA, 1997).

According to the (Swedish) Board of Agriculture the content of cadmium in fertiliser has gradually fallen from 35-40 mg Cd per kg phosphorus (before the introduction of the charge) to about 23 mg in 1994/95 and 16 mg in 1995/96. The Board concludes that the Cd charge in combination with the demand (for a low content of Cd in fertiliser) by the agricultural sector has kept Cd levels on a low level (Jörnstedt, 1998). Drake and Hellstrand (1998) conclude that the combination of governmental policy (including the charge and a standard) and voluntary efforts has been successful in reducing the content of cadmium in phosphorus fertilisers. However, it was not possible to estimate the relative importance of the different measures.

State tax gross revenues in 1996 were around 10 million SEK (1 million Euro), and the administrative costs are estimated to be around 1% of the gross revenues (Drake and Hellstrand, 1998). The tax is administrated by the National Tax Board, together with the tax on nitrogen. Importers and producers report quantities and contents every month.The only control made seems to be ‘tax audits’ (concerning the accounting of the firms involved). In 1999, 25 such audits were performed (corresponding to about one ‘man-year’). The actual cadmium content of fertilisers is not measured by the authorities. Some problems with illegal imports by small firms of fertilisers from Poland and the Baltic states (probably of Russian origin) are reported (Jörnstedt, 2000).

Section 5.4 in this report contains some information on the impact of the Swedish tax on agriculture.

3.2 Technical options for cadmium reduction and their costs

Cadmium occurs naturally as a contaminant in all phosphate rock, but the concentrations vary considerably, depending on the origin of the material. Igneous rock or apatite (found in the former Soviet Union, Finland, South Africa and South America) has low concentrations of cadmium (often less than 1 mg per kg P_2O_5). Sedimentary rock, which accounts for some 85-90% of world production, contains cadmium in concentrations ranging from less than 20 to more than 200 mg per kg P_2O_5 (see Table 3.2).

Table 3.2 Cadmium contents of main commercial phosphate rocks according to different sources.

Origin	**Cadmium content (mg per kg P_2O_5)**		
	(1)	**(2)**	**(3)**
Igneous			
Kola (Russia)	< 13	0.3	0.25
Pharlaborwa (South Africa)	< 13	0.1	0.38
Sedimentary			
Florida (USA)	23	19.8 - 32.7	24
Jordan	< 30	12.1 - 28	18
Khouribga (Morocco)	46	17 – 63	55
Syria	52	13 – 46	22
Algeria	60	42 – 62.6	
Egypt	74		
Bu-Cra (Morocco)	100	101 – 115	97
Nahal Zin (Israel)	100	81 – 112	61
Youssoufia (Morocco)	121	164.7	120
Gafsa (Tunisia)	137	94	173
Togo	162	164 – 179	147
North Carolina (USA)	166	125	120
Taiba (Senegal)	203	165 – 180.6	221
Nauru	243		

Sources: (1) Davister (1996); (2) Botschek and Van Balken (1999); (3) Demandt (1999).

In its unprocessed state, rock phosphate is not suitable for direct application, since the phosphorus it contains is insoluble. Three kinds of acids are used to process the phosphate rock (EFMA, 1997a):

- phosphoric acid, producing Triple Super Phosphate (TSP);
- nitric acid, producing Ammonium Phosphate (NP), used in the manufacture of complex fertilisers;
- sulphuric acid, producing either Single Super Phosphate (SSP) or phosphoric acid, an intermediate product in the production of TSP, Mono- and Di-Ammonium Phosphate (MAP and DAP) and complex fertilisers. This process leads to gypsum ($CaSO_4$) as a by-product. The cadmium in the phosphate rock is divided among the phosphoric acid and the gypsum; the proportions are depending on the exact process conditions.

An alternative to using sulphuric acid to produce phosphoric acid (the ‘wet’ process), is the ‘clean’ or ‘thermal’ process, in which pure phosphorus is released from the phosphate rock by heating it in a reducing environment (CBS, 1993). Phosphoric acid is then produced from the phosphorus. In this process, almost all cadmium ends up in a waste product (calcinate); the phosphoric acid will thus hardly contain any cadmium. The phosphoric acid from this process is used for the production of detergent phosphates, for metal treatment, as a cleaning agent, and in the food industry.

Substitution of low-Cd phosphate rock for high-Cd phosphate rock has taken place in some countries recently. In the Netherlands, for instance, this has happened in response to regulations concerning the maximum emission levels of cadmium in phosphorus gypsum (a waste product from the phosphoric acid production; see above). Many fertiliser industry representatives, however, argue that a large scale substitution (or blending low- and high-Cd grades) would not be a feasible strategy, given the limited production capacity and reserves of low-Cd phosphate rock (see e.g. OECD, 1996, and Appendix IV to the present report) . Despite these expert opinions, the available figures on low-Cd rock reserves (which will be presented in Chapter 5) seem to suggest otherwise.

Obviously, the flow of cadmium to agricultural soils can also be reduced by applying lower amounts of phosphate fertiliser and/or substituting fertilisers by other products containing phosphorus, e.g. manure. While this may be a feasible option in certain cases, it does not take away the need to minimise the amount of cadmium in fertilisers. Moreover, products such as manure, compost and sewage sludge may also contain substantial amounts of cadmium and/or other contaminants.

As an alternative to using low-Cd rock, a possible route towards phosphate fertiliser with a lower cadmium content is the development of commercially viable processes to remove cadmium from the phosphate rock or from the phosphoric acid. Several of such processes are currently under development, but none of them are commercially operational at the industrial level (except for food grade phosphoric acid). Table 3.3 gives an overview of the existing processes.

According to Davister (1996), the co-crystallisation (CC) option seems by far the most promising for the regular fertiliser grade phosphoric acid. Table 3.3 suggests that it is also the lowest-cost option[5]. In the early 1990s, a large R&D project has been carried out on this technology at CERPHOS (Morocco), with financial support from the European Commission. Tests on a laboratory scale have been successfully completed and a semi-industrial pilot was designed. However, in recent years there seems to be a lack of progress in the further development and application of the CC technology (Van Balken, 1999).

In 1995 it was estimated that it would take 7 to 10 years to bring the facilities for the most promising processes for removing cadmium from phosphoric acid on line (OECD, 1996). Since then, some delay has apparently occurred in Morocco. However, other producers may be ready to adopt decadmiation shortly when the need arises. For example, Hydro Agri’s Köping plant in Sweden is reported to be able to put a Cd removal process in action at reasonable cost (Bertilsson, 1999).

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[5] According to Van Balken (1999), the cost estimates in Table 3.3 are still up to date. The cost figure of 6 USD per tonne for the CC process is reasonably “hard”, but refers to the decadmiation itself only. The additional cost of treating the solid waste containing cadmium is included in the 9 USD figure, but this estimate is much more uncertain. Probably, this will also depend on the marketability of the cadmium metal which may be recovered from this waste.

Table 3.3 Decadmiation processes for phosphate rock and phosphoric acid

Process	Company / country	Stage of development	Achievable reduction level	Residual product	Cost (USD* /tonne P_2O_5)	Remarks
Cadmium removal from phosphate rock						
Calcination (thermal treatment) (only suitable for phosphate rock with high organic matter content)						
Calcination using chloride-containing additives	Hoechst, Germany	Studied	Up to 90-100%	$CdCl_2$ emissions		Need to remove remaining chlorine from phosphate concentrate
Calcination in an oxidising atmosphere	CERPHOS, Casablanca (Morocco)	Laboratory scale	> 85%	CdO emissions / solid waste	10	
Calcination in a neutral or slightly reducing atmosphere	Nauru Phosphate Corp. (Pacific)	Plant operational since 1974; now decommissioned	75% (from 80 to 20 ppm)	Solid waste (0.1 to 0.2% Cd); emissions of Cd as metallic vapour	30	Potential for Cd releases to atmosphere
Calcination in cyclone furnaces	Negev Phosphates, Israel					
Fluidized bed calcination	Dorr-Oliver, USA					
Other method						
Acidic solubilisation	Hoechst, Germany		50% (with Moroccan phosphate rock)			
Cadmium removal from phosphoric acid						
Co-crystallisation of Cd with $CaSO_4$ anhydrate (CC)	CERPHOS, Casablanca (Morocco)	Laboratory scale (started in 1994)	87% (from 75 to 10 mg Cd per kg P_2O_5)	Solid waste (0.1-0.2% Cd) / Cd metal (95%)	6 – 9	Financially supported by EC; considered by Davister (1996) to be the most promising route
Precipitation of acid with sulphide (PP)	SIAPE, Tunisia	Already used for feed phosphate	60 – 70% (to less than 13 mg Cd per kg P_2O_5)	Solid waste (<1% Cd)**	30	Adaptable to all conditions, but involves expensive process raw materials
Precipitation with sulphide	Boliden, Sweden					Process improved by predesulphurisation of phosphoric acid with a calcium or barium salt

Table 3.3 Decadmiation processes for phosphate rock and phosphoric acid (continued).

Process	Company / country	Stage of development	Achievable reduction level	Residual product	Cost (USD* /tonne P_2O_5)	Remarks
Precipitation by bubbling H_2S	CF Kalk, Germany					
Precipitation by addition of Fe powder and a specific agent	IMI, Israel					
Ion exchange	PECO, USA					
Ion exchange (RX)	Hydro Agri Rotterdam, Netherlands	Pilot	Less than 2 mg Cd per kg P_2O_5	Solid waste (5-10% Cd)**	15-25	Requires acid pre-treatment; considered by Lin and Schorr (1997) to be 'Best Available Technology' (BAT)
Ionic flotation	Pechiney, France		93% (from 70 to 5 ppm)			
Solvent extraction (SX)	Chemische Fabrik Budenheim (Germany)	Already used for food/ feed phosphate (since 1992)	Less than 2 mg Cd per kg P_2O_5	Filter cake / concentrate (30-60% Cd)**	32	Pilot plant shut down because of technical and cost problems. Technology cannot be applied in nitrophosphate plants
Solvent extraction (Adex)	Hoechst, Germany		Less than 1 ppm Cd in phosphoric acid			Removes cadmium and other heavy metals in a single stage
Solvent extraction followed by ion exchange	Simplot, USA					

* Given the uncertainty margins, the cost estimates given would probably be roughly the same when expressed in euros.

** Further treatment of the residue to obtain Cadmium-metal is possible at a cost.

Sources: OECD (1994), OECD (1996), ERM (1997), Lin and Schorr (1997).

WPA processes provide the input for about 70% of the world's P_2O_5 consumption. Other parts of the fertiliser industry, not using wet process phosphoric acid, do not currently have a technological alternative other than the use of low cadmium rock, or blending to reduce overall concentrations (OECD, 1996).

The market price of phosphoric acid is around USD 400 per tonne P_2O_5 (OECD, 1996), and the price of phosphate fertilisers (superphosphate 44-46%; diammonium phosphate) between USD 250 and 300 per tonne of product (TFI, 1999). Given the cost estimates in Table 3.3 (ranging between 6 and 32 USD per tonne), it would seem likely that the maximum cost of decadmiation could be around 10% of the fertiliser production costs. Langeveld (1999) expects decadmiation to cause an increase of 8 to 10% in the fertiliser price. Lin and Schorr (1997), however, report an estimated 20% increase in product costs due to decadmiation in fertiliser plants. Davister (1996) estimates the investment costs for the CC decadmiation process in the range of 30 per cent of the wet acid plant of the same capacity and operating costs ranging between 20 and 30 percent of the same.

4. Options for the design of a cadmium charge

4.1 Instruments used in environmental policy

Market based instruments for environmental policy are grouped in various ways. In general the following groups of instruments are distinguished:

- product charges/taxes;
- emissions charges/taxes;
- tradable permits;
- deposit refund systems;
- performance bonds; and
- tax credits / exemptions.

The product charge is used to increase the price of a less environmentally friendly product in favour of the environmentally friendly alternative (leaded gasoline) or to finance an environmentally friendly disposal scheme of the product charged (cars, refrigerators etc.). The former is therefore called an incentive charge and the latter a financing charge. The emissions charge is the most well known one: emissions charges are applied to (industrial) emissions to water and air, sometimes to noise as well (aircraft noise). Tradable permits have the economic advantage that the allocation of emission allowances is determined by market forces and their marginal abatement costs. In that way it is a much more flexible mechanism than the individual emission permit. Tradable permits have so far been used in the US under the acid rain program for trading SO_2 allowance certificates and within the EU for trading milk quota and fish quota. The deposit-refund system is used in case of collection schemes, to make sure that the product to be recycled will be returned after its use. The system is used in many countries for bottles and cans. Performance bonds are used as obligatory reserves with enterprises earmarked for potential clean up activities in the future when their commercial activities have ended at the current site (e.g. mining). If no pollution occurs, the money becomes available to the enterprise. The subsidies in terms of tax credits are used in many different kinds, such as investments credits (depreciation schemes, profit before tax credits, etc.) and more advanced ones like the Dutch green investment scheme for private investors to support environmentally friendly projects with low interest bank loans. The tax credits differ widely among member states.

The economic instruments that would apply best in the case of cadmium in fertilisers, are:

- product charges; and/or
- tax credits.

For emission levies the emissions should be easy to monitor, otherwise the transaction costs of the levy will be excessive high. In the case of cadmium it is possible to register the emissions to soil, but it requires extensive modelling with many parameters to calculate local absorption characteristics. So administrative costs mainly impede this option.

Tradable permits are used under a bubble concept, where emissions in the bubble are not allowed to exceed a certain maximum. This also requires monitoring of emissions. But more important is that emissions may vary locally, according to the marginal costs of abatement of the different entities and independent from the environmental sensitivity of the soil.

Deposit refund systems are not applicable, since there is no recyclable object to return after use[6]. Performance bonds could be used in case the fertiliser industry can be made responsible for environmental impacts of cadmium fertiliser. However, the farmer's responsibility in using the fertiliser is much greater than the industry's.

The two remaining options, product charges and tax credits could very well qualify. The product charge could be used to tax the high cadmium fertiliser and make the low cadmium fertiliser more attractive for farmers to buy. The revenues could be used for different purposes:

- to match the remaining price gap between high and low cadmium fertiliser;
- to subsidise research and use of technologies for the production of low-cadmium fertiliser (pilot or proven);
- to give tax credits on the purchase of such low-Cd fertiliser production technology.

The last option shows how the charge revenues could flow back into existing tax crediting schemes. Usually the revenues of the charge are earmarked for industry or society so that the impact of the charge is budget neutral.

When designing a levy, the following components should be considered:

- charge base and point of incidence;
- charge rate and implementation scheme;
- earmarking;
- degree of harmonisation;
- implementation criteria.

These issues will be addressed in the following section.

4.2 Issues in designing a charge

4.2.1 Charge base and point of incidence

The aim of the levy is to reduce the cadmium content of fertiliser: The most logical charge base would therefore be a gram of cadmium in fertiliser. Since cadmium appears in all phosphorus fertilisers, one could also imagine taxing the phosphorus content, but then the cadmium differentiation between low and high cadmium contents would be much more difficult to reach administratively.

Since the levy is introduced for environmental reasons, the incentive function of the levy is the most important, not the financing function. This means that there can be room to introduce an exemption or a zero tariff for fertiliser with low cadmium concentration.

The cadmium charge could be levied at various points in the 'fertiliser chain'. Levying at the end of the chain (the farmer) would make it possible to take local conditions into ac-

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[6] Huppes *et al.* (1992), however, do propose a deposit-refund system for cadmium, but there refunding takes place if materials and waste streams that contain cadmium are disposed of in an acceptable way, or if cadmium and cadmium containing products are exported.

count. However, this option would imply a very large number of taxable subjects. It seems more feasible to impose the charge at the moment when the fertiliser enters the EU market for the first time. This would involve only the producers and importers of fertiliser. Obviously, such a common approach is only possible in case of a uniform EU charge. If Member States apply different charge rates, the charge has to be levied from the producers and importers in each Member State.

Two versions of the charge will be analysed:

1. ‘stringent’: a general levy on cadmium in all fertiliser;
2. ‘moderate’: an initial levy on cadmium in fertiliser that exceeds 60 mg Cd per kg P_2O_5, over time narrowing down to 40 and in the end to 20 mg Cd per kg P_2O_5.

The first alternative is taxing each gram of Cd in fertiliser. In this alternative the producer of the lowest cadmium fertiliser is rewarded by the lowest charge. The low cadmium fertiliser will have a higher cost price because of the use of expensive low-Cd rock or decadmiation techniques, which can (partly or fully) be offset by the charge. For the producers of fertiliser there is always an incentive to improve and lower the cadmium content until the marginal costs of reducing more cadmium per kilogram fertiliser are equal to the levy.

The second alternative contains a ‘phasing in’ element and a ‘threshold’ element. The ‘threshold’ element may be attractive for industry, since it offers the possibility of avoiding the charge if the cadmium content of fertiliser is not exceeding the threshold. The ‘phasing in’ element is based on two thoughts:

- to make sure that producers will meet a certain standard, government can change the levy standard and tariff over time; and
- the Porter theory, stating that (under certain circumstances) environmental regulations do not inevitably hinder competitive advantage against foreign rivals; indeed, they often enhance it (Porter, 1996)[7].

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[7] In Tietenberg and Folmer (1998) three cases are identified by the authors under which the hypothesis is hold to be valid:
   a) Enhanced competitiveness of producers of complementary products and services. Producers that are specialised in products and services that protect the environment, will benefit from (tighter) environmental regulations;
   b) Relatively enhanced competitiveness of regulated firms, also called the "first mover effect": European companies, in the environmental protection technology sector, can create a relative advantage over other companies by developing new technologies / products. If the other countries are to accept stronger environmental regulations, this benefit can be further exploited.
   c) Absolute cost for reduction for the regulated firms. A private firm is forced to take measures, most of them being low hanging fruits, reducing the firm’s private costs as well as improving its environmental performance.

The idea of establishing a threshold is based on case a). If there is a threshold, European fertiliser companies will look for ways of avoiding the tax by producing fertiliser with a cadmium content below the threshold. They will do so as long as their marginal costs of abatement are lower than the tax that would otherwise have to be paid. Companies supplying equipment that reduces the amount of cadmium in fertiliser below the threshold, are challenged to find a technical solution for this problem, because a market demand for this technology (if reasonably priced) is shaped.

The charge starts with a relatively high threshold that is acceptable for industry. By setting deadlines and stricter thresholds industry has the opportunity to adapt to the new thresholds for the next phase. In the mean time technological innovation can support this trend.

The initial limit could be 60 mg Cd per kg P_2O_5. If tax revenues become less, the limit can be narrowed to 40 and at a later stage to 20 mg Cd per kg P_2O_5. Such a phased approach would benefit industry and would probably have a higher degree of acceptance than an immediate target of 20. Of course the phased approach should be communicated clearly to industry.

4.2.2 The charge rate

Most of the cost estimates for the various decadmiation techniques presented in Table 3.3 are around USD 30 per ton P_2O_5. The estimate for the CC process (Co-crystallisation of cadmium in $CaSO_4$ anhydrate) is lower (6 USD per tonne), but this is still in an early stage of development and the cost estimate does not include the cost of disposal of the cadmium waste. This CC process reduces the Cd content from 75 to 10 mg per kg P_2O_5. If we err on the safe side and estimate the cost of this reduction of 65 gramme Cd per tonne P_2O_5 also at USD 30, a charge rate of about USD 0.5 (or EUR 0.5) per gramme cadmium would compensate for the additional costs. The assumption here is that the cost estimate covers all relevant cost differences, including, for instance, the cost of disposing the waste product (which contains the cadmium).

The environmental impact of cadmium in fertiliser (its uptake in the food chain) depends on the soil quality where the fertiliser is used. There is a wide variation within the EU in the sensitivity of soils to cadmium accumulation, as well as in the cadmium levels in agricultural soils (cf. ERM, 1997, Tables 2.13-2.15). From an environmental point of view, the optimal tax rate would therefore differ by region. In theory farmers in sensitive areas would pay more for high cadmium content fertiliser use than farmers in other areas. However, a ‘farm-to-farm’ differentiation of the tax rate seems to be unfeasible. Differentiation by Member State is an alternative, although differences in soil sensitivity and background concentrations of cadmium within one Member State can be considerable.

4.2.3 Earmarking

The purpose of the levy is to promote the use of fertiliser with a low cadmium content. For the production of low cadmium fertiliser the lowest cost option currently is the purchase of low cadmium phosphate rock. Within the European Union, the use of low cadmium phosphate rock for fertiliser production is increasing. However, it is sometimes suggested that the available amount of directly suitable low cadmium rock is limited. If that is true, on the long term new technologies may have to be applied to reduce the cadmium content of phosphate fertilisers. Thus earmarking a possible cadmium levy could be used to support R&D activities and pilot projects to identify less expensive cadmium abatement techniques. Earmarked income can flow back to the charged producers in different ways: subsidies or tax credits are the most used forms. Subsidies could cofinance the purchase of equipment and effectively lower the price, tax credits could indirectly influence the price of equipment e.g. by lowering the company's profit before tax by a certain percentage of the investment, by allowing accelerated depreciation, etc. Such aid would of course have to fulfil Community state aid rules.

The charge revenues could also be spent in part on awareness raising activities for farmers.This has in the past turned out to be very effective in optimising fertiliser use.

4.2.4 Degree of harmonisation

Cadmium standards in EU Member States currently range from 21 to 90 mg Cd/kg P_2O_5. From the environmental point of view, the maximum level for cadmium content can differ since the quality of soil determines the absorption capacity of cadmium and the uptake by plants. In other words: from an environmental perspective it is not necessary to set an equal maximum rate for the content of cadmium in fertilisers. The most sensitive soils are located in Eastern Spain, France, Italy and Greece whereas the least sensitive soils are present in Belgium, Denmark, Northern Germany, Western Spain, Portugal, and most of UK. However, from an administrative point of view, setting different thresholds for the cadmium levy for different regions would be hard to manage and enforce. One solution could be a common minimum threshold for EU15. For very sensitive areas, governments could decide to put more stringent standards and in return the fertiliser industry could receive additional state aid for modifying its decadmiation process, although the administrative feasibility of this option remains questionable.

4.2.5 Implementation

General criteria applied to be applied to a levy would be:

- compliance with EU-policy;
- its estimated incentive impact;
- revenues of such a levy in comparison to enforcement and administrative costs;
- equity (on individual farmers and fertiliser industry);
- possibilities for fraud; and
- possible side effects of the levy.

Box 4.1.The EU's legislation excise duties

Currently a Community system of taxation (structure and minimum rates of excise taxes) applies to mineral oils, alcohol and alcoholic beverages, and manufactured tobacco. Article 3 of Directive 92/12/EEC allows Member States to introduce or maintain taxes which are levied on other products, provided, however, that those taxes do not give rise to border-crossing formalities in trade between Member States. Directive 92/12/EEC provides a framework for product taxes which are applied in all EU countries at possibly different rates. It is therefore conceivable that it might be applied to the envisaged cadmium charge as well.

Compliance with EU-policy

The levy needs to be in compliance with EU policy on cadmium and the directive on cadmium emissions to water by cadmium processing industries (Directive 83/513/EEC). The EU Fertilisers Directive (76/116/EEC) could be amended so as to harmonise the classification of fertilisers with respect to their cadmium content. An earmarking scheme would also need to comply with the rules for state aid for environmental protection.

Estimated incentive impact

The demand for phosphate fertiliser has a relatively low price elasticity, and its cadmium content has no influence on its performance in terms of crop productivity. Therefore, the price increase caused by the charge is unlikely to have much impact on the total demand for phosphate fertiliser. Some substitution between the different types (single phosphate and compound/complex fertilisers) might result from the fact that their cadmium content differs. However, the main impact of the charge will depend on its influence on the supply of low cadmium raw material and the development of decadmiation technology,. This issue will be a key element in the analysis of the impact of the charge (see Chapter 5).

Revenues in comparison with enforcement and administrative costs

The Swedish example (cf. Box 3.1) shows that revenues are low, so a combination with another, closely related levy could be a solution (e.g. general fertiliser taxes or charges).

The number of taxpayers influences strongly the complexity and costs of the levying system. If the charge is levied from the producer or importer of the fertiliser, this number will be quite low. A uniform charge in all EU countries will entail the lowest administrative costs. Nevertheless, any system will involve the need of sample-wise measuring of cadmium contents in fertilisers, which requires a careful balancing of accuracy and costs.

Impact on equity (on individual farmers and fertiliser industry)

The social and economic consequences which the introduction of the charge would have on the income of individual farmers and the profitability of fertiliser industry will be an important consideration. Preliminarily, one can expect minor impacts within the EU: for farmers, the charge adds only little to their total costs (see Section 2.2), and industry is likely to be able to pass the additional cost on to their customers. The strongest impact will probably be felt by the countries producing high-Cd phosphate rock which are presently strongly dependent on the EU for their export earnings (see below).

Possibilities for fraud and evasion

Depending on the way the charge is implemented, the possibilities for fraud can vary. For example, if producers and importers of fertiliser have to pay the cadmium charge, the number of charge payers is very limited (especially in case of an EU-wide, uniform charge) and easy to control. If distributors pay the cadmium charge, control becomes somewhat more difficult.

In frontier areas a change in consumers patterns is clearly observed when excise tax rates differ between the neighbouring countries, since consumers can opt for the cheapest alternative. An EU-wide, uniform cadmium charge would have the advantage that there are no opportunities for individual farmers (or illegal traders) to evade the charge by importing fertilisers from neigbour EU countries which do not apply the charge (or which apply a lower rate). However, this kind of tax evasion will probably be limited anyway in the case of fertilisers, given the relatively low value:weight ratio and hence the relatively high transport costs.

Possible side effects of a cadmium levy

If the effect of a cadmium charge would be to limit the import of phosphate only to rock with a low cadmium content, countries like Jordan, Morocco, Togo, Tunisia and Senegal would face quite severe economic consequences. For these countries it would be more beneficial to install decadmiation techniques with the European producers of fertiliser and keep European borders open for their phosphate ores. Moreover, as some of these countries have recently invested in their own (export oriented) phosphate fertiliser industries, any EU policy measures aiming at a reduction of cadmium in fertiliser should take the consequences for these industries into account as well.

4.3 Alternative approaches and versions of a cadmium charge

Based upon the considerations in the preceding sections, three different approaches for the cadmium charge have been distinguished ('uniform', 'minimum rate' and 'divergent'), each of which can be applied in a 'moderate' and a 'stringent' version. These six options are summarised in Table 4.1. In chapter 5, the economic and environmental consequences of these options will be analysed.

Table 4.1 Options for a charge on cadmium in fertilisers.

	'Uniform' approach	**'Minimum Rate' approach**	**'Divergent' approach**
Degree of harmonisation	Applied in all Member States at a uniform charge rate	Applied in all Member States at charge rates equal to, or exceeding an EU wide minimum	Applied in some Member States only, with differences in charge rates
'Moderate' version	Charge rate EUR 0.25 per gramme Cd, initially applying to fertiliser with more than 60 mg Cd per kg P_2O_5. Threshold lowered to 40 mg Cd per kg P_2O_5 after 2 years and to 20 mg Cd per kg P_2O_5 after another 2 years	Minimum charge rate EUR 0.25 per gramme Cd; thresholds and phasing as in Uniform approach	Charge rates on average EUR 0.25 per gramme Cd; thresholds as in Uniform and Minimum Rate approach; phasing differing between Member States
'Stringent' version	Charge rate EUR 1.00 per gramme Cd; no threshold or phasing	Minimum charge rate EUR 1.00 per gramme Cd; no threshold or phasing	Charge rates on average EUR 1.00 per gramme Cd; no threshold or phasing
Chargeable item	Amount of cadmium (by weight) in commercial fertilisers		
Chargeable event	The first time the chargeable product is sold in the EU or the import of the chargeable product from outside the EU	The first time the chargeable product is sold in a Member State applying the charge	
Refund on export	outside EU	outside Member State	
Competent authorities	Fiscal/customs authorities in the Member State where the chargeable event takes place		

5. Impacts of a cadmium charge

5.1 Analytical framework

A charge on cadmium in phosphate fertiliser can be expected to have a wide variety of (potential) impacts, which will work their way all through the complex chain of fertiliser production, trade and use. It is therefore important to concentrate on those parts of the chain where the impacts are likely to be significant. Figure 5.1 presents the main elements and relationships in the chain.

The initial impact of a charge on Cd in phosphate fertiliser **(1)** is a price difference between fertilisers with different Cd content **(2)** (assuming the producers pass the charge on to their customers). The fertiliser prices are of course also influenced by numerous other factors, including the EU's Common Agricultural Policy (CAP) **(3)**. Some of these factors may also have a differential impact on low-Cd and high-Cd fertilisers[8].

Farmers will react to the price differentiation by demanding more fertiliser with a low Cd content **(4)** as well as, to some extent, a reduction of phosphate fertiliser use and/or substitution by other fertilising products such as sludge or manure **(5)**. In response to the increase in demand for low-Cd fertiliser, producers will use more raw material (phosphate rock) with a low Cd content **(6)** (where this is technically possible), as long as this is a cheaper option than using decadmiation technology. The higher demand for low-Cd phosphate rock will cause an increase in the price of this type of raw material **(7)**. This means higher production costs for the fertiliser producer. Under certain assumptions it may become more profitable to use a decadmiation technology **(8)** (again: where technically possible). It is expected that the uptake of decadmiation technologies will increase once these technologies improve and become less expensive due to e.g. scale and learning effects **(9)**. Using charge revenues to finance R&D and pilot projects (**10**) can also enhance the profitability and feasibility of decadmiation.

The direct environmental impact is represented by the flow of cadmium to agricultural land **(11)** and the cadmium emissions/discharges from the production of phosphoric acid and fertiliser **(12)**.

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[8] An example might be the demand for feed phosphate, which must have a low cadmium content.

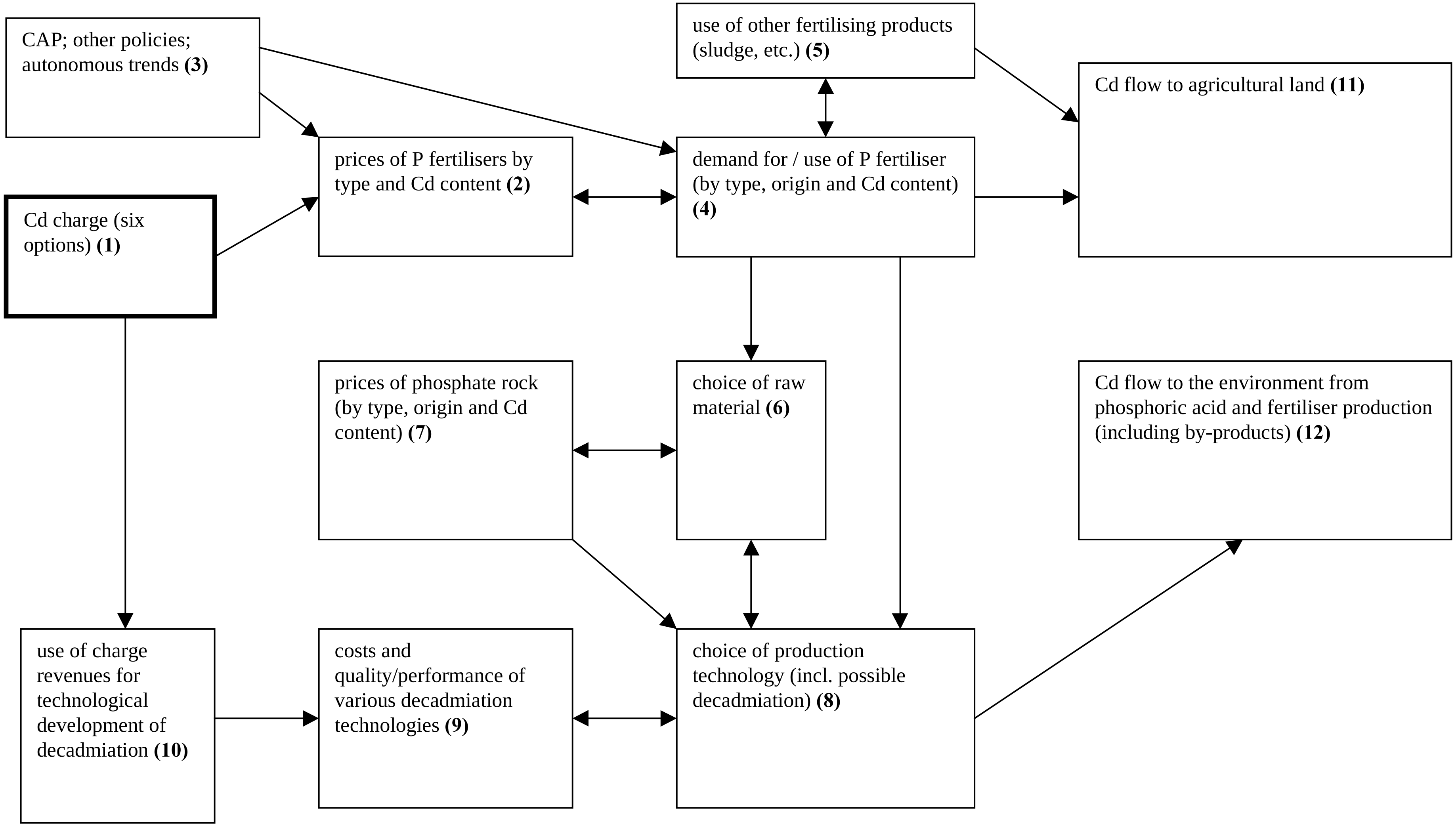

Figure 5.1. Basic relationships determining the impact of a Cd charge

In Section 4.3, three different approaches for the cadmium charge have been distinguished (‘uniform’, ‘minimum rate’ and ‘divergent’), each of which can be applied in a ‘moderate’ and a ‘stringent’ version. The analysis will be primarily based on the ‘minimum rate, stringent’ option. The other options will be dealt with only if their impact can be expected to differ significantly from this base case.

Starting from the conceptual model outlined above, three scenarios will be presented, which describe the possible impacts of the cadmium charge (Section 5.2). The economic impacts of the cadmium charge under these scenarios will be analysed for the phosphate rock and fertiliser producers (Section 5.3) and for agriculture (Section 5.4). Section 5.5 contains an assessment of the consequences for the environment. Section 5.6 deals with the costs of administration and enforcement and the revenues of the charge.

5.2 Three scenarios

5.2.1 Introduction

Because of the large uncertainties surrounding the relevant factors (such as the impact of the charge on fertiliser prices, the availability of low-Cd phosphate rock and technological developments, in particular the cost and performance of decadmiation technologies), a scenario type of analysis was chosen to assess the impact of a Cd charge. Three scenarios are distinguished, which may also be regarded as possible stages in the future development of phosphate fertiliser production (short, medium and long term):

- ‘Business as usual’ (Section 5.2.2);
- ‘Rush for low-cadmium phosphate rock’ (Section 5.2.3);
- ‘Decadmiation breakthrough’ (Section 5.2.4).

The question if and when each of these scenarios/stages will be realised, depends on numerous factors, which will be discussed in each section. One should also be aware that the chances/timing of realisation may differ between different kinds of phosphate fertiliser. Moreover, the developments in the fertiliser market outside the EU are of importance as well.

5.2.2 ‘Business as usual’

In this scenario/stage, supply and demand of phosphate fertiliser are not (or hardly) affected by the introduction of the cadmium charge. There can be several reasons for this lack of impact. Fertiliser producers often have long term contracts with their suppliers of raw materials, which can not be changed at zero cost. Farmers may tend to stick with the product and the supplier to which they are used, even if they are confronted with a price increase in the order of magnitude of 10%[9] (see also Section 5.4). It is also possible that the producers of high-Cd fertiliser reduce their sales prices by the amount of the charge rate, so that the price paid by the user shows no difference by Cd content[10]. Furthermore,

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[9] Assuming a price of 400 Euro per tonne P_2O_5, a Cd content of 40 mg per kg P_2O_5 and a charge rate of 1 Euro per gramme of cadmium.

[10] The scope for European fertiliser producers to do so seems rather limited at present, given their already low profit margins.

phosphate rock producers could reduce the prices of high-Cd phosphate rock so as to maintain their market share. Theoretically, this could go on for a long time if the lowest-cost producers of high-Cd phosphate rock could reduce their prices so as to compensate for the Cd tax, and still make a profit. However, it seems unlikely that any major phosphate rock producer can afford this strategy. The world's largest producer, Moroccan OCP, suffered net losses in 1994 and 1995. In 1996, it made a net profit of MAD 800 million (about EUR 80 million) on an output of 20.8 million tonnes of phosphate rock (roughly equivalent to 7 million tonnes P_2O_5) (Demandt, 1999). A profit margin of some 10 EUR per tonne P_2O_5 would not be sufficient to compensate for a 'stringent' Cd charge of 1 EUR per gramme Cd, given a Cd content in the order of magnitude of 50 mg/kg for Moroccan phosphate rock.

Thus, while the 'Business as usual' scenario may persist for some time (as changes in the use of raw materials and/or technologies often require substantial amounts of transition costs, investments and time[11]), it is unlikely that it can continue indefinitely. The introduction of the cadmium charge creates the opportunity to capture a 'rent' from cadmium reduction somewhere in the phosphate fertiliser chain, and it is reasonable to assume that eventually this opportunity will be seized. Given the present market situation, the primary option to do so would be a shift towards the use of raw materials with a low cadmium content.

5.2.3 'Rush for low-cadmium phosphate rock'

Using phosphate rock with a low cadmium content is likely to be the lowest-cost option to reduce the cadmium content in phosphate fertilisers[12]. Initially, it is assumed that no price difference exists between low and high Cd phosphate rock[13]. Under certain (rather simplifying) assumptions, it can be showed that decadmiation is the most profitable option for phosphate rock with a cadmium content exceeding $\frac{C}{(1-\beta)T}$ (in grammes cadmium per tonne of P_2O_5), in which C is the cost of decadmiation (in EUR per tonne of P_2O_5), β is the proportion of cadmium remaining in the phosphoric acid after decadmiation, and T is the charge rate (in EUR per gramme of Cd)[14]. Stated differently, there are

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[11] It takes longer to establish a new phosphate rock mine than it does to build an new fertiliser plant (IFA/UNEP, 1998).

[12] From our interviews it became clear that in the Netherlands TSP producers are already increasingly using low cadmium phosphate rock, because the amount of heavy metals in waste water is lower and less treatment is necessary (in order to comply with waste water standards).

[13] To what extent this assumption is justified is unclear. An analysis of the prices paid for phosphate rock imported in the Netherlands (based on CBS, 1995) suggests that some "low-cadmium premium" might already exist as a result of the regulations and voluntary commitments regarding cadmium emissions by the Dutch phosphate fertiliser industry: phosphate rock from Jordan and South Africa costs about EUR 3.50 more than the average price. However, the price of phosphate rock from Russia (also low-Cd) is about EUR 2.50 lower than the average. Differences in quality of the raw material are probably a much more important factor than differences in Cd content (see also Subsection 5.3.3).

[14] This is a specific case of a more general model, which is presented in Appendix I.

no economic reasons to apply decadmiation as long as phosphate rock is available with a cadmium content below the mentioned concentration. If we assume that T equals EUR 1 per gramme cadmium, as in the ‘stringent’ version of the charge, and that β is negligible, then the costs of decadmiation (in EUR per tonne P_2O_5) equal the concentration of cadmium (in grammes per tonne P_2O_5) below which decadmiation is unprofitable. Assuming, for example, that decadmiation costs are 10 EUR per tonne of P_2O_5, using phosphate rock with a cadmium content below 10 grammes per tonne is cheaper than applying decadmiation. If the charge rate were EUR 0.25 per gramme, as in the ‘moderate’ version, the ‘break even point’ would be 40 grammes of cadmium per tonne P_2O_5.

Table 5.1 shows the estimated global reserves[15] of phosphate rock and the range of their cadmium contents. For some countries, a feasible option might be to apply ‘selective mining’ and use the phosphate rock with the lowest Cd content for export to the EU. However, it is likely that low-Cd rock will be mainly provided by countries with large reserves of magmatic P rock, i.e. South Africa and Russia. Given the fact that the current annual consumption of phosphate fertiliser in the EU is less than 4 million tonnes P_2O_5 per year, it can be concluded from Table 5.1 that the stocks of low-Cd phosphate rock in South Africa and Russia are sufficient to provide the EU with P fertiliser for about 300 years[16]. Many of these reserves have a cadmium content of less than 1 gramme per tonne P_2O_5. Thus, under the assumptions mentioned before, the costs of decadmiation would have to decrease to 1 EUR per tonne P_2O_5 or less to make decadmiation profitable at a charge rate of 1 EUR per gramme cadmium. Alternatively, with constant decadmiation costs of 10 EUR per tonne P_2O_5, the charge rate would have to increase to 10 EUR per gramme cadmium or even higher.

The question then is, of course, whether the producers of low-Cd phosphate rock are able to supply the raw material at a price which would keep the profitability of decadmiation below that of using low-Cd rock. In any case, the introduction of a cadmium charge allows them to increase their prices to some extent. The maximum price increase is approximately the same as the cost of decadmiation[17]. Thus, low-Cd phosphate rock can become almost 10 EUR per tonne P_2O_5 more expensive than high-Cd rock and still remain competitive.

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[15] A “reserve” (or “economic reserve”) is ususally defined as a mineral deposit of established extension that is – or could be – profitably mined under prevailing costs, market prices and technology. A “resource” (or “reserve base”) is considered to be a deposit of less well defined size which is not now economically exploitable but which could potentially become so, if there was a sufficiently favourable change in costs, prices or technology (IFA/UNEP, 1998). In 1998, world phosphate rock reserves were estimated by the US Geological Survey to amount to about 11 billion tonnes, with a reserve base of about 33 billion tonnes. Botschek and Van Balken (1999) reported somewhat higher figures: 14.1 and 36.6 billion tonnes, respectively.

[16] For the whole world, the present level of P_2O_5 consumption (about 40 million tonnes) could be covered for some 30 years by these low-cadmium reserves.

[17] This is shown mathematically in Appendix I.

Table 5.1. Current production and reserves of phosphate rock with different cadmium contents.

Origin	Cd content range (mg per kg P_2O_5)	Annual production 1994 (mln tonnes P_2O_5)	Economic reserves (mln tonnes P_2O_5)
South Africa	0.1 – 10	1	800
Russia	0.3 – 5	2.8	400
USA	7 – 375	14	400
Jordan	12 – 28	1.5	200
Morocco	13 – 165	6.5	2000
Israel	16 – 126	1.2	60
Tunisia	94	2.1	90
Senegal	161 – 336	0.7	50
Togo	164 – 179	0.7	10
Other (*)	0.2 – 63	2.5	240

(*) Algeria, Syria, Finland and Sweden.

Note: A global mean P_2O_5 content of 33% in phosphate rock is assumed. Economic reserves are recoverable at a cost below USD 35 per tonne P rock. China, Kazakhstan and Brazil omitted because of unknown cadmium content.

Source: Calculated on the basis of Botschek and Van Balken (1999).

It is unknown what the exact impact of production expansion will be on the costs (and thus on the price) of low-Cd phosphate rock. Sedimentary rock is said to be less expensive, since it can be mined in an open pit and therefore is much cheaper than the mining of (low-Cd) magmatic rock. However, it is estimated that the South African and Russian reserves (amounting to 3800 million tonnes of phosphate rock) can be produced at a cost below USD (or EUR) 35 per tonne (Botschek and Van Balken, 1999). Current market prices of South African phosphate rock in the Netherlands are about 35 EUR per tonne (cif) (calculated on the basis of CBS, 1995). Allowing for transport costs (which can amount to 10 or 20% of total end-user costs - Coster, 1999; Demandt, 1999; IFA/UNEP, 1998), one can conclude that the South African reserves can be mined at a cost which is less than 7 EUR per tonne higher than at present.

The above analysis was based on the assumption that the coefficient β was zero, i.e. the decadmiation process is 100% effective and no cadmium is left in the purified phosphoric acid. In reality, decadmiation will have a maximum effectiveness of about 90% (see Table 3.3), so β is around 0.1. This implies that, regardless of the charge level, decadmiation could only become attractive if there were 'high-Cd' phosphate rock with a cadmium content which is less than ten times as high as the Cd content of the available low-Cd rock. However, the reserves of 'high-Cd' rock usually have Cd contents exceeding 10 mg per kg P_2O_5, while those of the 'low-Cd' rock reserves are often below 1 mg/kg. This is an additional reason why the Cd charge will favour the use of igneous, low-Cd phosphate rock.

The expansion of phosphate mining (and possibly also investments in processing capacity, such as phosphoric acid and fertiliser production) in South Africa and Russia will of course only take place if potential investors have sufficient confidence in its profitability. One precondition to achieve this is a consistent and determined cadmium policy in the EU. The 'stringent' version of the Cd charge will be most supportive, because it creates the largest incentive as well as the largest market for low-Cd fertiliser. Another precondition is probably some degree of economic and political stability in the country where the investment is planned. At present, the situation in South Africa seems to be somewhat better than in Russia in this respect. On the other hand, Russia is likely to have a substantial amount of excess production capacity[18], which might be refurbished and modernised at relatively low cost.

Obviously, the preceding presupposes that magmatic (igneous) phosphate rock is an equivalent substitute for sedimentary rock. To what extent this assumption is justified, is unclear. According to Botschek and Van Balken (1999), igneous rock may be more difficult to process. Furthermore, phosphoric acid production plants are usually 'tailored' for a specific source and grade of rock. Changing this source and grade is costly in terms of the time taken to re-adjust the process. A different source of rock may often necessitate additional equipment (IFA/UNEP, 1998). Nevertheless, the example given in Table 5.2 suggests that industry can deal with substantial changes in the origin of phosphate rock within a few years' time.

Table 5.2. Phosphate rock imports in the Netherlands by country of origin (in % of total phosphate rock imports).

country of origin	1992	1995
Russia	8	23
Morocco	18	13
South Africa	6	1
USA	21	15
Syria	1	8
Israel	20	13
Jordan	21	27

Source: CBS (1992, 1995).

In some cases, igneous rock can not be used at all as a raw material for technical reasons (in particular for the production of triple superphosphate, TSP – Coster, 1999). However, TSP accounts for only 10% of phosphate fertiliser use in the EU (EFMA, 1997a), and only one third of the phosphate in TSP comes directly from phosphate rock (the other two third comes from phosphoric acid). Moreover, there are also sedimentary deposits with low cadmium contents which could be used in these cases[19].

5.2.4 'Decadmiation breakthrough'

In the preceding section, it was argued that even in the case of a 'minimum rate and stringent' charge on cadmium the large scale application of decadmiation technologies in phosphate fertiliser production is not to be expected in the near future. This conclusion was based on the assumption that large amounts of low-Cd phosphate rock are available at competitive prices. If this assumption is violated (e.g. because of technical barriers for using low-Cd rock, or lack of short term expansion opportunities for low-Cd rock pro-

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[18] In 1988, phosphate rock production in the then USSR peaked at 39 million tonnes. In 1996, the total production of the former USSR states was only 10.2 million tonnes (8.7 in Russia and 1.5 in Kazakhstan) (FAO, 1997).

[19] In addition to the countries mentioned in the upper part of Table 3.2, China is also reported to have reserves of low-Cd sedimentary phosphate rock (Demandt, 1999).

ducing countries, leading to price increases for this type of rock), conditions may become more favourable for a 'decadmiation' scenario[20]. Decadmiation might also become more attractive if the cost of these technologies can be drastically reduced[21], and/or if the cadmium charge rate is increased well above 1 EUR per gramme, but only if the decadmiation technology leads to very low residual levels of cadmium in the fertiliser (substantially lower than the cadmium concentrations in low-Cd phosphate rock).

Various decadmiation technologies have been or are currently being developed and tested. Basically, there are two ways to remove cadmium: either from the phosphate rock (by means of calcination) or from the phosphoric acid. The latter option is considered to be the most feasible one, with the 'CC' process (co-crystallisation of cadmium with anhydrite) being the most promising route. A more detailed description of the various technologies and their estimated costs was presented in Chapter 3.

5.2.5 Conclusions

At current prices and costs, using low-Cd phosphate rock is likely to be the preferred strategy to be followed by fertiliser producers in response to the introduction of a cadmium charge in the medium and probably even in the long run. The reserves of low-Cd phosphate rock are large, and it seems unlikely that they will be rapidly depleted, as concern over cadmium in fertiliser is confined to the EU and some other rich countries. It is therefore unlikely that scarcity of low-Cd rock will soon lead to considerable price increases. The 'low-Cd rock' option is thus expected to be a relatively low-cost response to the introduction of a Cd levy. The fact that with a charge producers can decide themselves whether and when to switch to low-cadmium raw materials adds to the cost-efficiency of this scenario.

5.3 Impacts on producers of phosphate rock and fertilisers

5.3.1 Introduction

In chapter 2 it was already stated that Finland is the only producer of phosphate rock in the EU: most of it is imported, mainly from Morocco (37.1%). Processed phosphate is to a large extent also imported, mainly from Morocco (33.8%), the former Soviet Union (22.7%) and Algeria (14.1%); some is traded within the EU (14.3%). More phosphate rock is imported in the EU than processed phosphate (cf. Figure 2.1). The profit margins are low since the FSU is exporting large quantities in order to receive hard currencies. In the long run it is expected that this situation will change once the economic situation in

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[20] Our contacts in the fertiliser industry (Langeveld, 1999; Bertilsson, 1999; Van Balken, 1999) suggested that such barriers do indeed exist and that decadmiation will become necessary once the demand for low-Cd fertiliser increases. However, they could not give estimates for the maximum amount of low-Cd reserves which can be readily used as substitutes for currently used high-Cd rock.

[21] This cost reduction may be achieved by the scale and learning effects which usually occur when a new technology becomes more common. Another source of cost reduction could be subsidies: from the governments of phosphate rock producing countries (interested in maintaining their export revenues) and/or from the EU.

the Russian Federation has improved and specifically the economic situation in agriculture area has enhanced.

In this analysis a distinction is made regarding producers within the EU and producers outside the EU. This section provides an overview of the factors determining the competitiveness of the phosphate fertiliser industry.

5.3.2 The cost of phosphate fertiliser production

Besides the capital cost of investment in the plant itself, the cost of raw materials, energy and transport and distribution has to be taken into account. For phosphate fertiliser, the cost of energy is relatively low compared to ammonia or nitrogen fertilisers. Depending on the quality of the rock, 1.3 to 1.6 tonnes of phosphate rock is needed to produce a tonne of TSP (containing 45% P_2O_5). In addition, 0.35 tonne of phosphoric acid is needed that requires about the same amount of sulphur. In other words: the price of TSP largely depends on the price of phosphate rock and sulphur. Transportation and distribution can count for 10 up to even 20% of consumer price (cf. Subsection 5.2.3).

5.3.3 The sales price of phosphate fertiliser

Over the last years the prices of phosphate fertilisers were stable, because of supply control programs of major exporters. In the third quarter of this year the prices have decreased: prices for diammonium phosphate (DAP) fell by 8% and for triple superphosphate (TSP) by 7%. The drop in prices is explained by overcapacity and weak demand due to low grain prices (Global Commodity Markets, EFMA press release October '99). For the current market prices cadmium content is not an issue, prices are set basically on the basis of a negotiating process involving the duration of the contract (even up to 5 years) and the quality of the rock.

As can be seen from Table 5.3, the cost price of phosphate fertiliser has increased somewhat due to higher price of phosphate rock, while at the same time the market price has decreased, putting more pressure on the profitability margins (assuming the price of sulphur remained stable).

Looking at different Quarterly Reports from the fertiliser industry, it turns out that many have conducted downsizing operations in their fertiliser operations to cut labour costs.

Table 5.3 Commodity prices (USD/metric ton).

	Annual averages			**Quarterly averages**					**Monthly averages**		
	Jan – Dec 1997	Jan-Dec 1998	Jan-Oct 1999	Jul-Sep 1998	Oct-Dec 1998	Jan-Mar 1999	Apr-Jun 1999	Jul-Sep 1999	Aug 1999	Sep 1999	Oct 1999
P.R.	41.0	43.0	44.0	43.0	43.0	44.0	44.0	44.0	44.0	44.0	44.0
DAP	199.9	203.4	184.2	209.5	204.4	199.3	189.7	173.9	175.0	164.5	152.9
TSP	171.9	173.1	157.8	175.0	168.9	164.1	162.6	150.9	151.3	147.5	145.1

Note: P.R. stands for phosphate rock

Source: World Bank (1999)

5.3.4 Short term impact of the levy on fertiliser sales

European consumption of phosphate fertiliser has decreased by 1.4% by during 1998/1999, after a decline of some 45% since the peaks of fertiliser consumption in the 1970s and 1980s. The main reductions achieved during the past decade were due to:

- the price reductions in the common market regimes of the CAP, reducing intervention prices of cereals, oilseeds and protein crops, which were accompanied by agri-environmental policies in the context of Regulation 2078/92;
- environmental legislation in several Member States, resulting into an improved use of organic nutrients. Such legislation also reduced the overuse in some countries, and contributed to a more rationalised used of nutrients in agriculture.

The national statistics developed by EFMA (1999) indicate that demand by 2009 will be decreased by another 10% within EU15. The reduction is projected to slow down relative to the past trends. The estimate is based on their market perspectives considering a 10% set-aside requirement until 2006 and a 15% reduction cut of intervention prices of cereals.

Assuming a general cadmium content of 25 mg/kg phosphate rock and a charge of 1 Euro/g Cd in phosphate fertiliser, the price of phosphate fertiliser will increase by 75 Euros per tonne P_2O_5, (assuming a 33% P_2O_5 content in phosphate rock), being about 34 Euros per tonne TSP and resulting in about a 23% price increase for that type of fertiliser. Given the economic situation of the industry (low profit margins) it is highly probable that the levy will be entirely passed on to the final consumers. In a Swedish study (Drake and Hellstrand, 1998) the demand elasticity for phosphate fertiliser is estimated to be –0.1 to –0.25, so decline in consumption of, in this case, TSP would be between 2 to maximum 6% due to the levy. For other phosphate fertilisers, with lower P_2O_5 content, the impact would be smaller. In reality, the price increase (and thus the decrease in fertiliser sales) will be even less, because it will be more attractive for the producers to use low-Cd rock (in the ‘low-Cd’ scenario) or to remove cadmium from the phosphoric acid (in the ‘decadmiation’ scenario) than to pay the full charge on an unchanged cadmium content.

In the ‘divergent’ version of the charge, farmers in border regions may decide to buy their fertiliser in a neighbour country which does not apply a cadmium charge. The same may happen in the ‘minimum rate’ version, where Member States are allowed to apply a higher charge rate than the EU minimum. However, the extent of this border traffic will remain limited due to transport costs.

It can be concluded that the impact of the levy on fertiliser sales will be small. The levy might to an almost negligible extent accelerate the downward trend in consumption and might initiate some substitution from fertiliser to manure (or sludge) (see also Section 5.4).

5.3.5 Impact of the levy on EU producers

To a large extent, the fate of the EU phosphate fertiliser industry in the years ahead will be determined by the decrease in demand on the home market, and the increasing competition from non-EU producers. Companies will close because their production lines for phosphate fertiliser are no longer economically viable. The levy can accelerate this trend somewhat, and can at the most be one additional factor for closing down. However, the levy will not contribute significantly to the relocation of fertiliser industries outside the EU. The levy does not favour production in non-EU countries, as it applies equally to domestic and foreign phosphate fertilisers. The main determinant and justification for industry relocation are usually the better market perspectives outside the EU.

'Rush for low-Cd rock' scenario

A levy on cadmium in fertiliser will be faced by all producers within the EU using phosphate rock for fertiliser production. Raw material costs for industry will slightly increase, but this will not affect their competitive position substantially, as their competitors face the same cost increase. There will be some once-only costs (for investment, adaptation and transition) as well, because production processes may have to be redesigned so as to be able to process igneous phosphate rock (which is structurally different from sedimentary rock). Producers already using low cadmium phosphate rock will have a comparative advantage over those who don't, since they will not need to make any technological adjustments for using different rocks[22].

Most companies will shift to low cadmium rock once their contracts are finished to the technical extent possible. The adjustments made and the finetuning of the technology to a new kind of rock can take several months to sometimes 2 years before the plant is running efficiently again. The economics of such decisions will vary depending on the technological status of a company and the economic lifetime of its technology.

These temporary problems can be overcome if the levy is announced long before it is actually put into place, to allow some transition time for companies. Moreover, the advantage of using a charge as the policy instrument is that companies can determine on an individual basis the optimum timing of the necessary investments, rather than having to comply simultaneously and instantaneously with some mandatory maximum cadmium concentration. This helps to avoid capital destruction.

'Decadmiation breakthrough' scenario

Decadmiation raises the production cost of phosphate fertiliser. Given the early stages of development in which most technologies find themselves, it is not surprising that cost estimates are rough and contain wide margins of uncertainty. The available estimates for various decadmiation technologies were presented in Table 3.3. Generally, it can be assumed that the production costs of phosphate fertiliser will increase by some 10%[23]. As all phosphate fertiliser suppliers are confronted with this cost increase, they will be able to pass the additional costs on to their customers and the economic impact will be lim-

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[22] Obviously, this advantage will be smaller if there is time for adaptation between the announcement and the actual introduction of the tax.

[23] Lin and Schorr (1997) mention a figure of 20%. On the other hand, the figures mentioned in ERM (1997) (about USD 30 per tonne P_2O_5, but possibly down to USD 9) are much lower (assuming a production cost of some 500 USD per tonne P_2O_5). Langeveld (1999) estimates the price increase at 8 to 10%.

ited. However, it is conceivable that for some ‘marginal’ fertiliser producers the additional costs will be the last straw breaking the camel’s back[24].

5.3.6 Producers outside EU

‘Rush for low-Cd rock’ scenario

The producers of low cadmium phosphate rock (South Africa, Russian Federation) will benefit from the levy on cadmium. Currently South African production is about 3 million ton/year, estimated resources 2.5 billion tonnes. Within the FSU production is 8.5 million tonnes and an estimated reserve of 1.3 billion (1994 numbers). In combination with the envisaged decline in phosphate fertiliser use, rock scarcity is unlikely to increase the price level in the long term, but limited production capacity might do so in the short term. It is not expected that the FSU will export less in the near future, meaning that the export to the European Union will not be harmed, especially if the downward trend in consumption will continue.

Thus, the ‘low-Cd phosphate rock’ scenario/stage will lead to market segmentation and have dramatic consequences for the supply pattern of phosphate to the EU. South Africa and probably also Russia will replace Morocco as the EU’s main phosphate supplier. Countries producing P rock with the highest levels of cadmium concentration (such as Senegal, Togo and Tunisia) will have to look for other markets, as demand from the EU fades. Whether they will find such markets depends on the extent to which cadmium policies are pursued in the rest of the world as well. The best opportunities will probably be found in the developing countries, where cadmium in fertilisers is not much of an issue and where the demand for fertilisers is expected to increase at an annual rate of 3.8% in the period until 2010 (FAO, quoted in EC, 1997)[25].

Obviously, the largest impact on phosphate trade will occur in the case of the ‘uniform’ and the ‘minimum rate’ approach, combined with the ‘stringent’ version of the charge, where a cadmium charge rate of (at least) 1 Euro per gramme applies in all EU countries. The ‘divergent’ approach implies a lack of action in about half of the EU, which means that these countries have no need to look for other phosphate suppliers. Moreover, in the ‘moderate’ version a threshold is applied, below which no levy is due. This creates an opportunity for countries producing sedimentary phosphate rock with a Cd content below that threshold (eventually 20 mg/kg P_2O_5) to supply uncharged phosphate rock to the EU by selective mining. These countries include Jordan, Syria, Israel, Morocco, the USA and possibly China.

‘Decadmiation breakthrough’ scenario

To maintain their market share, producers of phosphates can decide to decadmiate on site: this means that the cadmium problem is tranferred to outside the boundaries of the European Union. The Commission could provide assistance for an action plan to make

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[24] Large fertiliser producers may decide to keep their prices initially at the existing lower level, in order to get rid of smaller competitors who do not have the financial strength to do so.

[25] This shift in export markets is already visible in the case of Morocco, whose largest single customer for phosphoric acid is India (Demandt, 1999).

sure that this is done in a environmentally responsible manner. The option that Moroccan (or other) producers will decrease prices to compensate for the tax is not likely given the current market circumstances (see Section 5.2.2).

As in the case of the ‘low Cd rock’ scenario, the main economic impact of a decadmiation breakthrough is likely to be a shift in the trade flows of raw material. The impact on trade flows of phosphate rock depends on the type of decadmiation technology which will turn out to be the most cost-effective. If calcination (cadmium removal from phosphate rock) would be the preferred decadmiation technology, demand for phosphate rock would shift to those countries which can supply types of rock which are suitable for this treatment. However, calcination has a number of limitations and disadvantages: it is not suitable for all kinds of phosphate rock (only for those with a high organic matter content), it requires high temperatures, it changes the structure of the phosphate, and there is a risk of cadmium emissions to air (Ghoshesh *et al.*, 1996; ERM, 1998; Lin and Schorr, 1997; Coster, 1999). In the more likely case that a process for the decadmiation of phosphoric acid will be the winning technology, the impact on phosphate rock trade will depend on the version of the levy.

According to Van Balken (1999), the amount of cadmium removed by the process is a certain percentage of the initial concentration. This means that in the ‘stringent’ version of the levy there will still be a tendency for the demand to shift towards low-Cd rock. For example, if the effectiveness of the process is 90%, phosphate rock with an initial Cd concentration of 50 mg per kg P_2O_5 will lead to a post-treatment concentration of 5, whereas the residual concentration is twice as high if the phosphate rock contained 100 mg/kg. Thus, even with decadmiation, using low-Cd rock remains the most attractive option. In the ‘moderate’ version, however, where there is a threshold for the concentration below which no charge is due, there will be less of an impact on phosphate rock trade flows, because a 90% removal efficiency would ensure a final Cd concentration of less than 20 mg per kg P_2O_5 for almost any kind of phosphate rock used.

Countries that are currently expanding their export-oriented phosphoric acid production capacity (such as Tunisia and Jordan) could profit from an early ‘decadmiation breakthrough’ scenario, because they may incorporate the decadmiation process in the design of their new production facilities.

5.3.7 Conclusions

The main economic impact of a cadmium levy will be a major shift of phosphate (rock, but probably also acid and fertiliser) trade flows. In the ‘stringent’ version of the levy, South Africa and possibly Russia will probably become the main suppliers of the EU at the expense of Morocco and other African countries.

The advantage of using a charge as the policy instrument is that companies can determine on an individual basis the optimum timing of the necessary investments, rather than having to comply simultaneously and instantaneously with some mandatory maximum cadmium concentration. This helps to avoid capital destruction.

If the introduction of a cadmium charge would lead to a transition towards decadmiation of phosphoric acid, this could mitigate the adverse impact on the exports of countries producing phosphate rock with a high cadmium content. However, such a transition is only likely to take place if several conditions are fulfilled:

- the costs of decadmiation should substantially decrease and/or the charge rate should be substantially higher than the assumed 1 Euro per gramme Cd;
- there should be a threshold concentration below which the charge does not apply (as in the 'moderate' version);
- the cadmium concentration in the phosphate after decadmiation should be substantially lower than the concentrations found in igneous (low-Cd) phosphate rock.

It seems questionable whether these conditions will easily be met in the foreseeable future, even if the development of decadmiation technology is speeded up by massive financial support from the EU and others.

5.4 Impacts on agriculture

An assessment on the economic and environmental impacts of a charge on cadmium in fertilisers requires information on the response by farmers to an increase in the price of phosphate fertilisers. A tax on cadmium in fertilisers may lead to a change in the composition of phosphate fertilisers. Also, it may lead to a reduction in fertiliser input. Several studies however indicate the inelastic nature on the demand for chemical fertilisers following price changes. Short-run own-price elasticity on the demand for chemical fertilisers ranges from –0.2 to –0.3 (Bäckmann, 1999). However, a stronger response of a price change is expected in the long-run and the own-price elasticity may reach –0.5 to –0.6 due to improvements in farmers' efficiency of using agrochemicals. Also, a tax on chemical fertilisers would increase the opportunity costs of organic fertilisers and may result in a more efficient use of livestock manure for crop production.

Limited information is available on the price elasticity of phosphorus fertilisers. The price elasticity for phosphorus fertilisers is assessed to be low in Sweden. For conditions in Sweden it is considered to be in the range between –0.1 and –0.25 (Drake and Hellstrand, 1998). No information is available on the long-run price elasticity, but it might possibly be some 50% higher than the estimated short-run price elasticity.

The relative importance of the charge is examined for various types of farming in Sweden and the Netherlands.

Sweden

Drake and Hellstrand (1998) quantify the costs of a tax on cadmium in phosphorus fertilisers for Swedish farmers at regional level. Currently, a tax is applied of 30 SEK per gram cadmium for levels above 5 gram cadmium per tonne phosphorus. The average level of cadmium in phosphorus fertiliser currently is 25 gram per tonne phosphorus, and the price of phosphorus fertilisers is increased by 0.60 SEK per kg. This is based on the consideration that the tax is completely covered in fertiliser prices.

The calculated costs for tax on cadmium on average are less than 5 SEK per hectare, which is to have an insignificant impact on the application of phosphate fertiliser use (Table 5.4). The total costs of the tax are small and amount to less than 0.05% of total revenues in the agricultural sector.

Table 5.4 Annual costs of a tax on Cadmium in phosphorus fertilisers for agriculture by region

Production region	Costs (SEK per ha)	Total (million SEK)
Plain districts, South Götaland	5.52	1.73
South east Götaland	3.66	1.09
Plain districts, North Götaland	6.84	2.60
Plain districts, Svealand	5.46	2.74
Forest districts, Götaland	3.30	1.56
Forest districts, central Sweden	4.38	0.74
Lower parts of Norrland	2.88	0.43
Upper parts of Norrland	4.50	0.48
Total	4.74	11.30

Source: Drake and Hellstrand (1998).

The Netherlands

Total use of phosphate fertilisers in the Netherlands is 71 kton P_2O_5. It includes NPK-, NP- and PK-nutrients (41 kton), triple-superphosphate (13 kton) and di-ammonium-phosphate (17 kton).

The assessment in this section is based on an agricultural sector model for the Netherlands (DRAM). The model can be characterised as a price-endogenous, spatial equilibrium market model. The model has endogenous economic and environmental variables. Agricultural policies, technical development and environmental policies are exogenous variables. The model is built around a set of linear regional demand and supply functions describing the most important regional input and output markets of the Dutch agricultural sector. The model distinguishes fourteen regions. Seven regions have clayey soil, five regions have sandy soil and two regions have peat soil. Each region is treated like a large, more or less mixed farm.

First, some figures are presented for some major crops on fertiliser consumption in the Netherlands (kg P_2O_5 per hectare). The figures are based on recommended dosages for the Netherlands:

• Edible potatoes	79.7
• Starch potatoes	71.2
• Grass	18.8
• Sugarbeet	47.1
• Wheat	8.4

Table 5.5 shows the regional distribution of these five crops in the Netherlands. More than half of the agricultural land is used to grow grass. Dairy production (using grass for fodder) is the dominant land use category in the peat areas of the country. Cereals, potatoes and sugarbeet are the three major arable crops grown. The production of edible potatoes is mainly concentrated in the clay areas of the country (the polder provinces along the Ijsselmeer and the south-west of the country, Zuidelijk Zeekleigebied). The production of starch potatoes is concentrated in the Veenkoloniën. In these regions, the use of phosphate per hectare is relatively high.

Table 5.5 Area by crop and region (in hectares).

	Edible potatoes	Starch potatoes	Grass	Sugarbeet	Wheat
Centraal Zandgebied	459	615	59227	956	2582
Hollandse Droogmakerijen and Ysselmeerpolders	18635	48	20598	20806	26517
Noordelijk Weidegebied	781	1132	160644	814	2185
Noordelijk Zand	2778	23811	149122	10228	12805
Noordelijk Zeekleigebied	3162	4200	62959	12687	37884
Overig Noord-Holland	397	3	15966	118	631
Oostelijk Zandgebied	1772	3776	135829	2242	5469
Overig Zuid-Holland	135	0	3261	85	246
Rivierkleigebied	2530	216	85974	3257	6606
Veenkoloniën	603	27763	12949	12774	14698
Westelijk Weidegebied	2326	94	162336	2879	5626
Zuid-Limburg	1954	67	13253	4473	6373
Zuidelijk Zandgebied	14295	1047	119437	16991	19096
Zuidelijk Zeekleigebied	33484	49	33244	27891	58859
Total	83310	62820	1034801	116201	199579

The analysis is based on the consideration of a fixed charge per gram cadmium. The total load of cadmium is estimated for the Netherlands at a level of 1800 kg. A charge of 1 Euro per gram cadmium implies total revenues of Euro 1,800,000. The analysis is based on the consideration of an equal content of cadmium per kg of phosphate.

Table 5.6 shows the charge (Euro per hectare), based on calculations made with the DRAM model. The charge ranges between around 2.2 Euro per hectare (growing edible potatoes) and around 0.2 Euro per hectare (wheat). Charges are a very small part of total costs. No shifts in agricultural production are observed with such small levels of the charge. A doubling of the charge rate (as in the ‘stringent’ version) would still have very limited consequences on the costs per hectare.

Table 5.7 shows the total amount paid by farming type. It is based on the charges per hectare and the acreage covered for each farming type. The total charge of 1,800,000 Euro is covered mainly by grazing livestock farms (more than 800,000 Euro) and arable farms (almost 600,000 Euro). The amounts charged to arable farms (around 40-60 Euro per holding) on average are substantially above those of grazing livestock farms (less than 20 Euro per holding).

Table 5.6 Charge (Euro per hectare) by region and crop.

	Edible potatoes	Starch potatoes	Grass	Sugarbeet	Wheat
Centraal Zandgebied	2.12	1.98	0.52	1.26	0.30
Hollandse Droogmakerijen and Ysselmeerpolders	2.28	1.98	0.54	1.36	0.08
Noordelijk Weidegebied	2.12	1.98	0.52	1.26	0.08
Noordelijk Zand	2.00	1.98	0.52	1.26	0.42
Noordelijk Zeekleigebied	2.28	1.98	0.54	1.36	0.14
Overig Noord-Holland	2.28	1.98	0.52	1.26	0.16
Oostelijk Zandgebied	2.06	1.98	0.52	1.26	0.72
Overig Zuid-Holland	2.30	0.00	0.52	1.26	0.22
Rivierkleigebied	2.26	1.98	0.52	1.36	0.18
Veenkoloniën	2.06	1.98	0.52	1.26	0.30
Westelijk Weidegebied	2.26	1.98	0.52	1.26	0.06
Zuid-Limburg	2.28	1.98	0.52	1.26	0.18
Zuidelijk Zandgebied	2.02	1.98	0.52	1.26	0.82
Zuidelijk Zeekleigebied	2.28	1.98	0.54	1.36	0.10
Total	2.22	1.98	0.52	1.32	0.24

Table 5.7 Total amount charged by farming type and region (in Euro)

	Arable farms	Horticulture farms	Grazing livestock holdings	All holdings
Centraal Zandgebied	4680	316	42318	61008
Hollandse Droogmakerijen and Ysselmeerpolders	118768	13320	15946	169758
Noordelijk Weidegebied	6164	784	101378	112902
Noordelijk Zand	62888	1764	120050	209924
Noordelijk Zeekleigebied	66520	1290	35434	114428
Overig Noord-Holland	1524	16148	8656	29322
Oostelijk Zandgebied	20688	924	131658	194670
Overig Zuid-Holland	730	5968	1544	8852
Rivierkleigebied	11702	1366	65146	94550
Veenkoloniën	69924	452	12322	94632
Westelijk Weidegebied	12114	11190	93532	128114
Zuid-Limburg	9336	136	13086	29682
Zuidelijk Zandgebied	47586	15638	153140	327588
Zuidelijk Zeekleigebied	162746	5564	23726	224566
Total	595366	74862	817936	1800000

Conclusions

Generally speaking, the introduction of a charge on cadmium in fertilisers is unlikely to have major economic impacts on agriculture. The share of fertilisers and soil improvers in the total costs of various farm types in the EU is usually (well) below 20%. As phosphate accounts only for part of these costs, the cadmium charge (which will presumably increase the price of phosphate fertiliser by some 10%) will in most cases lead to a cost increase for farmers of less than 1%.

Other mechanisms might also take place. Phosphate fertilisers might be replaced by other sources of phosphate (such as manure, sewage sludge and compost). There is no empirical evidence on the extent to which this substitution might take place.

5.5 Impacts on the environment

The environmental impact of the ‘Business as usual’ scenario is clearly negligible. This section will therefore only discuss the impact of the two other scenarios. The analysis takes the present levels of phosphate fertiliser use as the baseline. Changes in cadmium load to the environment due to changes in phosphate fertiliser use are therefore not taken into account. Given the expected reduction in phosphate fertiliser use in most EU countries, this implies an underestimation of actual cadmium flow reductions.

Figure 5.2 shows the initial flows of cadmium contained in the phosphate rock which is used to make the P fertilisers which are applied in EU agriculture. The total amount of cadmium in phosphate rock is estimated at 175 tonnes (3,500 Kt P_2O_5 with an average Cd content of 50 mg per kg), and the figure shows the division among the different fertilisers (the boxes at the right hand side of the figure) and the phosphogypsum. On the basis of available data and some assumptions regarding the share of products and production processes[26] and the division of cadmium between phosphoric acid and phosphogypsum[27], it can be shown that about 80% of the cadmium ends up in the fertiliser and 20% in the gypsum. In the following subsections, the changes in amounts and percentages under the two scenarios will be assessed.

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[26] The shares of the various P fertilisers are taken from EFMA (1997, Table II). It is assumed that 50% of the NP(K) fertilisers used in the EU is made by means of the nitrophosphate process. The category “other straight P fertilisers” is assumed to contain all the cadmium that was present in the phosphate rock used to make it.

[27] It is assumed that the “wet process” acidulation leads to a division of 30% of the cadmium in the waste gypsum and 70% in the phosphoric acid. According to Lin and Schorr (1997), these proportions vary between 20/80 in the case of Morocco and Togo rock, and 33/67 in the case of various Florida rocks. UNEP (1998) states that 20 to 40% of the cadmium in the phosphate rock passes into the phosphogypsum, depending on the process. CBS (1993) states that Hydro Agri in the Netherlands used to have a process in which the proportions were 50/50.

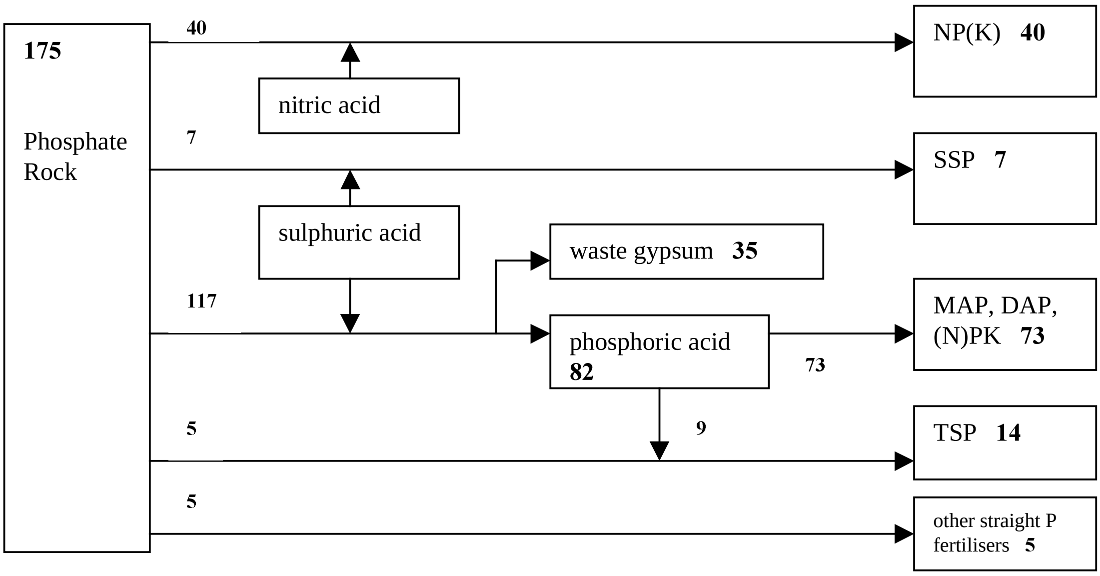

Figure 5.2 Flow of cadmium (tonnes) in phosphate by type of fertiliser and production process, initial situation (see Appendix V for explanation of abbreviations).

5.5.1 'Rush for low-cadmium phosphate rock'

Substituting low-Cd for high-Cd phosphate rock to produce phosphate fertiliser implies that a certain amount of cadmium remains in the earth's crust instead of being brought into circulation. The percentage reduction in cadmium load to the environment will be the same as the percentage reduction in average cadmium content of the phosphate rock mined. The relative division of cadmium flows among the various routes depicted in Figure 5.1 does not change (provided that the use of the different fertiliser types remains the same). Assuming a reduction of average Cd content in phosphate rock from 50 to 5 mg per kg P_2O_5, the cadmium flows will become like in Figure 5.3. Both the cadmium load to agricultural land and in the phosphogypsum will be reduced by 90%. Part of the latter reduction would take place in phosphoric acid producing countries outside the EU.

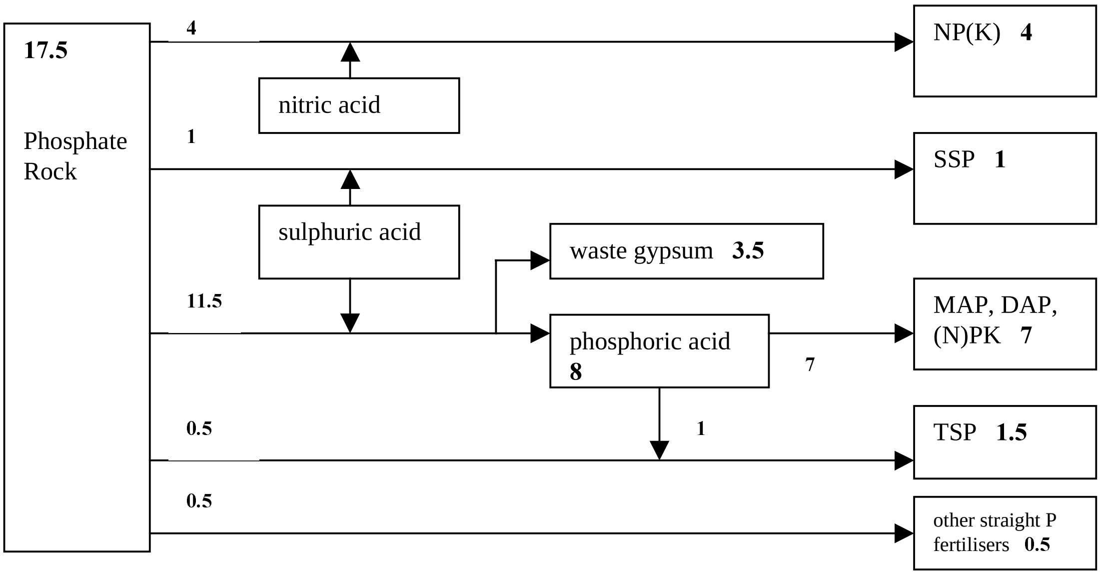

Figure 5.3 Flow of cadmium (tonnes) in phosphate in the 'low cadmium' scenario.

Part of the latter reduction would take place in phosphoric acid producing countries outside the EU. Obviously, the reductions will be smaller in the ‘moderate’ version and the ‘divergent’ approach of the charge. Furthermore, there will be geographical differences in the environmental impact of the reductions in cadmium load, depending on soil conditions, fertilisation practices and crops grown .

The relocation of phosphate mining and phosphoric acid / fertiliser production activities will have impacts on the (local) environment in the producing regions. The seriousness of these impacts will depend largely on the extent to which Best Available Technology (BAT) is used in the production processes. Furthermore, it means that closure of existing mines and plants will be speeded up, with implications for site remediation and clean-up.

A possible indirect environmental impact of the ‘low-Cd rock’ scenario is an increase in the use of high-Cd phosphate fertiliser (and thus higher cadmium discharges) in other parts of the world, especially in (developing) countries which have no policies for cadmium reduction in place. Such an increase could be caused by a relative price decrease of high-Cd phosphate rock resulting from the EU’s demand shift towards low-Cd rock. However, given the minor (albeit not negligible) role of the EU as a player on the world phosphate market, this impact will probably not be very substantial.

Another indirect impact could be an increase in the use of other kinds of fertilising products, such as manure or sewage sludge, induced by the relative price increase of (chemical) phosphate fertiliser. These products may contain a range of environmental contaminants, including cadmium[28]. The extent to which this effect will occur will probably be limited, because the substitution elasticity between artificial and organic fertilisers is quite low, because of agronomic limitations (e.g. the much more limited availability of nutrients in manure, its variability in nutrient composition, and the fact that the proportions of nutrients often do not match the requirements of the crops).

Finally, the shift in resource use could imply that the decrease in cadmium is accompanied by an increase in other contaminants. According to Coster (1999), magmatic (low-Cd) rock can contain other undesirable heavy metals. However, according to Kongshaug *et al.* (1992, cited in Mortvedt and Beaton, 1995) the contents of heavy metals in Russian and South African phosphate rock are generally equal to, or lower than the average values in reserves elsewhere. Only the copper content in South African phosphate rock is significantly higher.

5.5.2 ‘Decadmiation breakthrough’

In this scenario, the direct impacts in terms of a reduction of cadmium load to agricultural soils in the EU are similar to those in the ‘low-Cd rock’ scenario if we assume that:

- the percentage cadmium reduction in the decadmiation process is the same as the average decrease in cadmium content in the ‘low-Cd rock’ scenario (90% in our example);

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[28] However, a reduction in Cd content of fertilisers will also reduce the Cd content of manure to some extent, if the livestock is fed with domestic feedstuffs.

- the cadmium content of phosphate rock used in the WPA process (with decadmiation) remains the same (presumably 50 mg Cd per kg P_2O_5)[29];
- for phosphate fertilisers which are not produced by means of the WPA process, phosphate rock is used with a reduced cadmium content, similar to that in the 'low-Cd rock' scenario (presumably 5 mg Cd per kg P_2O_5).

The amount of cadmium in the phosphogypsum will be higher than in the former scenario, because part of the cadmium is transferred to the gypsum before the decadmiation of the phosphoric acid takes place.

In addition, decadmiation produces a by-product containing cadmium, which will usually have to be disposed of as hazardous waste[30]. The nature and amount of this by-product depend on the specific decadmiation process. To the 'CC' decadmiation process (co-crystallisation of cadmium with anhydrite) a concentration step can be added which leads to the most concentrated and least toxic residue: cadmium metal itself (Davister, 1996).

Figure 5.4 shows the cadmium flows under the 'decadmiation' scenario.

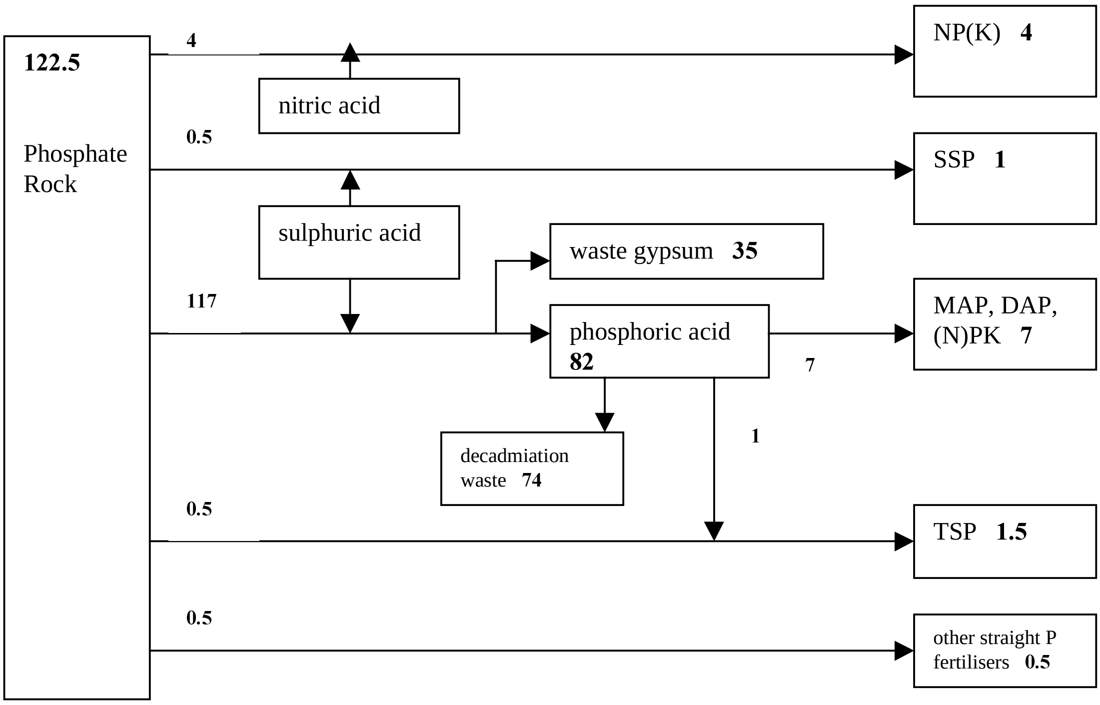

Figure 5.4 Flow of cadmium (tonnes) in phosphate in the 'decadmiation' scenario.

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[29] Nevertheless, as noted in Section 5.3.6, the "stringent" version of the charge may provide an incentive to use phosphate rock with a low cadmium content, even if decadmiation takes place.

[30] We assume that the decadmiation is applied to phosphoric acid, not to phosphate rock (calcination). In the latter case, the byproduct would be cadmium emissions to air.

The assumed fact that decadmiation of phosphoric acid is the most efficient option to produce low-Cd phosphate fertiliser may induce fertiliser producers to use the phosphoric acid route as much as possible. This means that the main alternative technology for producing phosphate fertilisers, the ‘nitrophosphate’ route, will be much less applied. The nitrophosphate production process (see Box 5.1) does not allow decadmiation: all cadmium from the phosphate rock will end up in the fertiliser. The consequence of a shift towards the wet process is that the amount of waste gypsum will also increase (the nitrophosphate route does not produce waste gypsum).

Box 5.1: The nitrophosphate production process

In the nitrophosphate (or ‘Odda’) process, phosphate rock is acidulated using nitric acid. It has some advantages over the WPA process: it does not involve the use of sulphuric acid (and hence does not lead to the production of waste gypsum), it uses its raw materials almost completely, it can use lower quality phosphate rock and it is more flexible with regard to water-soluble P_2O_5 in the product. However, in other respects it is less flexible than the phosphoric acid route: it can only be used for NP and NPK types of fertiliser (which have a relatively low P_2O_5 content), it leads to the production of high amounts of nitrofertilisers (AN and CAN), and the relatively complex process technology requires a large-scale operation to be economic (EFMA, 1995b; Demandt, 1999). An environmental disadvantage is the emission of NO_x and the greenhouse gas N_2O in the production of the nitric acid. On the other hand, the (acidifying) emissions associated with the production of sulphuric acid are avoided.

In Europe, some producers have switched to the nitrophosphate technology in response to environmental pressures (e.g. Norsk Hydro in Porsgrun, Norway; BASF in Antwerp, Belgium; and Chemie Linz in Austria) (Heerings, 1993).

Waste gypsum is already a significant environmental problem, because of the large quantities involved[31], its content of cadmium and other impurities, and its radioactivity. Using the gypsum as a building material is not a solution, essentially for the same reasons (there is simply too much of it, and it is contaminated). Other possible applications of the gypsum are agricultural use (e.g. for rehabilitating saline soils and soils that have been inundated with sea water), road building, and the enhancement of municipal waste disposal in landfill (Demandt, 1999). Discharging phosphogypsum to water is still common practice, but it is considered not to be ‘Best Available Technology’ anymore (Coster, 1999). Land-based disposal methods are most common (Demandt, 1999).

The growth in waste gypsum production may accelerate the already ongoing trend towards relocation of phosphoric acid production from the EU to the phosphate rock producing countries, such as Morocco[32]. These countries usually have ample potential stor-

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[31] Five tonnes of gypsum are generated for every tonne (P_2O_5) of product acid produced (EFMA, 1995).

[32] The number of wet-process phosphoric acid production sites in western Europe declined from 45 in 1980 to 10 in 1994, and is still decreasing (Demandt, 1999).

age capacity for the gypsum, or they do not consider discharging the gypsum into the sea to be a problem. Producers in these countries might also try to maximize the part of the cadmium from the phosphate rock ending up in the gypsum, so as to minimize the Cd concentrations in the phosphoric acid to be exported to the EU.

On the positive side of the environmental balance, a 'spin off' of decadmiation technology to other parts of the world could be a long term effect, once the technology has reached maturity (overcome growing pains, benefited from economies of scale etc.) and the cadmium content of fertilisers is recognised as an environmental problem elsewhere as well.

5.5.3 Conclusions

The primary environmental impact of the Cd levy in the 'low-Cd rock' scenario is a substantial reduction of cadmium loads to agricultural land in the EU (indicatively estimated at 90%), as well as a reduction of cadmium discharges in phosphogypsum, both in the EU and in other countries producing phosphoric acid[33]. These impacts are to be expected if the 'stringent' version and the 'uniform' or the 'minimum rate' approach of the charge is chosen. The 'moderate' version and the 'divergent'approach will lead to similar, but less pronounced results. The reductions come on top of the decrease in cadmium load that can be expected as a result of lower rates of phosphate fertiliser use.

The 'decadmiation' scenario may have less favourable environmental outcomes than the 'low-Cd rock' scenario: no reduction and maybe even an increase in the amount of cadmium in waste gypsum, as well as the production of (more or less concentrated) cadmium waste, which will occur primariliy in the producing (developing) countries.

5.6 Costs of administration and enforcement; revenues

In the 'uniform' approach, only importers to the EU and producers within the EU have to be charged. If a cadmium charge is levied in some Member States only ('divergent' approach), or at rates which differ by Member State ('minimum rate' approach), it will also have to be levied from fertilisers which are traded between Member States. In those cases, the number of chargepayers will be higher[34]. Moreover, in these cases additional administrative costs are involved with reimbursements in cases where fertilisers on which the charge has been paid are exported to another Member State.

In any of the approaches, national tax authorities will be responsible for collecting and enforcing the charge. Administrative costs can be kept low by applying a system in

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[33] This reduction of cadmium flows to agricultural soils can not be directly translated into a figure for the reduction of human cadmium uptake in food. There are large uncertainties concerning the behaviour of cadmium in soils and plants. Moreover, the outcome will be dependent on soil type, climate, crops and other factors.

[34] In Sweden, there are 45 firms registered under the fertiliser tax, of which 5 import for their own professional use, 37 import for resale and 3 manufacture in the country (Swedish EPA, 1997). If we extrapolate this figure to the EU level by dividing it by Sweden's share in the EU phosphate fertiliser use (1.24%), the number of taxpayers in the EU would amount to some 3600. However, the actual number will be lower, because among the Swedish taxpayers there are probably firms which only deal with nitrogen fertilisers.

which registered firms are required to declare the amounts of chargeable fertiliser and the cadmium content[35] periodically. Checks can be incorporated in the general examination schedules of the tax authorities. Normally, administrative inspections (audits) should be sufficient. Sample testing of actual cadmium contents can be limited to cases where a suspicion of fraud exists.

A rough estimate of the administrative costs can be made on the basis of the following assumptions:

- number of taxpayers: 1000 in the ‘uniform’ approach; 2000 in the ‘minimum rate’ approach and 1000 in the ‘divergent’ approach (where the number of participating countries is lower);
- 1 person-year (valued at 50,000 EUR) is needed in the tax authorities to deal with 100 firms;
- administrative costs for firms are equal to those for the tax authorities.

The total administrative costs would then amount to some 1 million EUR in the ‘uniform’ and the ‘divergent’ approach and 2 million EUR in the ‘minimum rate’ approach.

The (gross) *revenues* of the cadmium charge will depend on the approach and the version of the charge as well as on the scenario. In the ‘uniform’ and the ‘minimum rate’ approaches and the ‘stringent’ version, the revenues (in EUR) are (at least) equal to the amount of cadmium (in grammes) in phosphate fertiliser sold on the EU market. In Section 5.5 these were estimated at 175 million in the ‘Business as usual’ scenario, and 14 million in the two other scenarios. In the ‘divergent’ approach and the ‘moderate’ version, the revenues will be substantially lower. The exact level of revenues in the ‘divergent’ approach will depend on the choices made by the participating Member States (charge level and thresholds). In the ‘moderate’ version of the charge, revenues will depend on the distribution of cadmium between below-threshold and above-threshold concentrations.

It can be concluded that in the ‘uniform’ or ‘minimum rate’ approach, combined with the ‘stringent’ version of the charge, revenues are likely to exceed administrative costs by a wide margin, even if the charge effectively reduces the cadmium content of fertilisers. Under the other charge options, positive net revenues are somewhat less certain.

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[35] It is assumed that suppliers of phosphate fertilisers know the cadmium content of their product. In some EU countries, such as Sweden and the Netherlands, monitoring the cadmium content of fertiliser is already common practice. This practice should be extended to all Member States applying the charge. Indeed, any policy aiming at a reduction of the cadmium content would require such a monitoring system.

6. Conclusions and recommendations

6.1 Conclusions

Cadmium from phosphate fertilisers poses a potentially serious threat to soil quality and, through the food chain, to human health. The European Commission is considering the possibility of using an EU-wide charge on cadmium in fertilisers so as to improve the competitive position of the ‘low-Cd’ product *vis-à-vis* the ‘high-Cd’ one. The present study aims at evaluating the economic and environmental implications of an EU wide charge on the content of cadmium in mineral fertilisers, as well as the possibility and effects of an EU wide framework for charges, within which each Member State could set its own rate.

The aim of the levy is to decrease the cadmium content of phosphate fertilisers, in order to decrease the flow of cadmium to the soil. Three types of approaches are proposed:

- a ‘uniform’ approach, in which all Member States apply the charge at equal rates;
- a ‘minimum rate’ approach, in which all Member States apply the charge at a rate equal to or higher than a specified minimum;
- a ‘divergent’ approach, in which the charge is applied in some Member States only, at different rates.

Each of these approaches can be applied in a ‘moderate’ version (with a relatively low (average) charge rate of EUR 0.25 per gramme Cd, thresholds and phasing), or a ‘stringent’ version (charge rate at or around EUR 1.00 per gramme Cd; no thresholds or phasing).

In the analysis, three scenarios are distinguished:

- ***‘business as usual’:*** this scenario (which may prevail in the short term) implies a lack of impact from the charge on supply and demand;
- ***‘rush for low-Cd phosphate rock’:*** in this scenario (which is the most likely one in the medium and probably also in the long term), a massive shift in the use of raw material takes place. Countries with vast reserves of low-cadmium phosphate rock, such as South Africa and Russia, will become the EU’s main phosphate suppliers;
- ***‘decadmiation breakthrough’:*** in this scenario (which may occur in the long term if certain market and technological conditions are fulfilled), decadmiation technology is assumed to be used on a large scale.

At current prices and costs, using low-Cd phosphate rock is likely to be the preferred strategy to be followed by fertiliser producers in response to the introduction of a cadmium charge in the medium and probably even in the long run. The reserves of low-Cd phosphate rock are large, and it seems unlikely that they will be rapidly depleted, as concern over cadmium in fertiliser is confined to the EU and some other rich countries. However, some uncertainty remains on the question whether these reserves can be regarded as equivalent substitutes for the high-Cd rock that is being used presently.

The main ***economic*** impact of a cadmium levy will be a major shift of phosphate (rock, but probably also acid and fertiliser) trade flows. In the ‘stringent’ version of the levy, South Africa and possibly Russia will probably become the main suppliers of the EU at the expense of Morocco and other African countries.

If the introduction of a cadmium charge would lead to a transition towards decadmiation of phosphoric acid, this could mitigate the adverse impact on the exports of countries producing phosphate rock with a high cadmium content. However, such a transition is only likely to take place if several conditions are fulfilled:

- the costs of decadmiation should substantially decrease and/or the charge rate should be substantially higher than the assumed 1 Euro per gramme Cd;
- there should be a threshold concentration below which the charge does not apply (as in the ‘moderate’ version);
- the cadmium concentration in the phosphate after decadmiation should be substantially lower than the concentrations found in igneous (low-Cd) phosphate rock.

It seems questionable whether these conditions will easily be met in the foreseeable future, even if the development of decadmiation technology is speeded up by massive financial support from the EU and others.

Generally speaking, the introduction of a charge on cadmium in fertilisers will not have major economic impacts on ***agriculture***. The share of fertilisers and soil improvers in the total costs of various farm types in the EU is usually (well) below 20%. As phosphate accounts only for part of these costs, the cadmium charge (which will presumably increase the price of phosphate fertiliser by some 10%) will in most cases lead to a cost increase for farmers of less than 1%.

The primary ***environmental*** impact of the Cd levy in the ‘low-Cd rock’ scenario is a substantial reduction of cadmium loads to agricultural land in the EU (indicatively estimated at 90%), as well as a reduction of cadmium discharges in phosphogypsum, both in the EU and in other countries producing phosphoric acid. These impacts are to be expected if the ‘stringent’ version and the ‘uniform’ or the ‘minimum rate’ approach of the charge is chosen. The other version and approach will lead to similar, but less pronounced results.

The ‘decadmiation’ scenario may have less favourable environmental outcomes than the ‘low-Cd rock’ scenario: no reduction and maybe even an increase in the amount of cadmium in waste gypsum, and the production of (more or less concentrated) cadmium waste.

The environmental and economic impacts of the Cd charge are in addition to the changes which will occur as a result of other developments, e.g. the Common Agricultural Policy (CAP). Some of these developments will lead to a drop in fertiliser use, thus contributing to the decrease in cadmium load to agricultural land. This ‘autonomous’ decrease in cadmium load is, however, much smaller than the decrease that can be achieved through the charge. It should be emphasised that, although the main conclusions are probably quite robust, quantification of the impact of a cadmium charge is only possible within relatively wide margins, given the uncertainties regarding a number of variables.

6.2 Recommendations

On the basis of our analysis, the following suggestions for the possible introduction of an EU wide Cd charge can be made.

First of all, the ‘ideal’ cadmium charge would have a regionally differentiated rate, because of the variety in soil quality, sensitivity and background Cd concentrations in the EU. However, such a charge would be administratively unfeasible. It is therefore suggested to introduce minimum charge rates at the EU level. Member States can choose to increase the rate depending on the severity of the cadmium problem. This ‘minimum rate’ approach is better able to reflect the differences of the problem between Member States than a uniform EU-wide charge.

The levy revenues for each Member State will be relatively low. The aggregate maximum for the EU as a whole can be roughly estimated at 175 million Euro in the (on the long term unlikely) ‘Business as usual’ scenario under the ‘stringent, uniform’ charge option. It will be much less in other options and in the two other, more likely, scenarios, where cadmium contents are effectively reduced.In principle, the net revenues of the levy could be recycled to the sector paying them: industry and the farmers. Industry could be supported by R&D funding for promising low-Cd fertiliser technologies. If these technologies include decadmiation, special attention will be needed for the problem of safe disposal of waste products containing cadmium. Farmers can receive support through awareness raising and training programmes to optimise the use of (phosphate) fertilisers. However, since the net revenues are expected to be low, due to the use of low cadmium fertilisers, it is questionable if such earmarking makes much sense from an economic point of view. Nevertheless, revenue recycling might enhance the acceptance of the charge.

Administrative costs should be minimised. In the ‘uniform’ approach, the charge can be levied from the relatively small number of producers and importers to the EU market. This also makes the charge controllable and less sensitive to fraud. In the two other approaches, the number of taxpayers is higher, as the charge has to be levied (and in some cases reimbursed) on fertilisers traded between Member States as well. Thus, a compromise will have to be found between low administrative costs and differentiation between Member States.

Preferably, the introduction of a charge on cadmium should be announced well in advance. This would enable companies using high cadmium phosphate rock to switch to an alternative and in this way a situation of comparative disadvantage for these producers could be avoided. A (probably small) disadvantage of early announcement is the risk of traders or farmers building up stocks of untaxed high-Cd fertiliser during the intermediate period.

The advantage of using a charge as the policy instrument is that companies can determine on an individual basis the optimum timing of the necessary investments, rather than having to comply simultaneously and instantaneously with some mandatory maximum cadmium concentration. This helps to avoid capital destruction.

The impact of the charge on North- and Central-African countries mainly exporting high cadmium phosphate rock to the EU may need to be taken into account. It will be hard for at least some of these countries to remain competitive under a cadmium charge, even if profitable decadmiation technologies become available. Applying a threshold for the cadmium content (of say 20 mg Cd / kg P_2O_5) below which no charge is due could be helpful in this case (although a threshold reduces revenues and is environmentally less advisable, because it removes the incentive for continued Cd reduction). However, under a ‘low-Cd rock’ scenario these countries will need assistance to find other export opportunities. Possible instruments are the EU association treaties (for countries like Tunisia, Jordan, and Morocco) and the Lomé Convention (for countries like Senegal, Togo and Nauru).

Finally, a cadmium charge implies the need to introduce a labelling system for P fertilisers, specifying their cadmium content. Such a system might be introduced anyway, regardless of the possible introduction of a charge. This would make farmers more aware of the amount of cadmium they put on their land, which in itself could already create a demand for low-Cd fertiliser.

The overall conclusion of the report is thus that an EU wide charge would in most options analysed have the effect of an increase in the demand for low-cadmium raw material for the production of phosphate fertilisers for the EU market. The effects on the producers of fertilisers would be limited if they were given sufficient time to prepare for the charge. The effects on EU farmers would be small. The economic effects on some raw material and fertiliser producer countries outside the EU could be significant.

The amount of cadmium put on EU soil would be considerably reduced. The cost-efficiency would be high as large reserves of low-Cd rock are probably available at limited extra cost, and this rock can in most cases be used after a limited investment in updating production facilities. In case of a breakthrough for decadmiation technologies, a waste problem in the form of cadmium would occur in the fertiliser producing countries with high Cd content in their raw material.

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Appendix I. Costs of low-Cd phosphate rock versus costs of decadmiation

Decadmiation becomes profitable if the costs of this technology, together with the charge to be paid on the remaining cadmium, are lower than the amount of cadmium charge to be paid if no decadmiation takes place. We assume that the cost of decadmiation is partly a fixed amount per tonne of phosphate, and partly related to the cadmium concentration in the raw material:

$$C_d = C_0 + \alpha \cdot Q \tag{1}$$

in which:

C_d = the costs of decadmiation per tonne phosphate;

C_0 = the fixed costs of decadmiation per tonne phosphate;

α = the variable costs of decadmiation per gramme cadmium and per tonne phosphate;

Q = the cadmium concentration before decadmiation (in g Cd per tonne phosphate).

Decadmiation is then profitable if:

$$C_o + \alpha \cdot Q + T \cdot \beta \cdot Q > T \cdot Q \tag{2}$$

in which:

T = the charge rate (in EUR per gramme Cd);

β = the proportion of cadmium remaining in the phosphate after decadmiation.

Relation (2) can be rewritten as:

$$Q > \frac{C_0}{(1-\beta) \cdot T - \alpha} \tag{3}$$

A special case, which was used in Section 3.3, is where α=0 (i.e., the cost of decadmiation is fixed per tonne of P_2O_5 and does not depend on the cadmium concentration). In that case, relation (3) reduces to:

$$Q > \frac{C_0}{(1-\beta)T} \tag{4}$$

If there is a residual concentration of cadmium which is unrelated to the initial concentration (i.e., β=0, but there is a fixed residual concentration Q_r>0), then decadmiation is profitable if:

$$Q > \frac{C_0}{T-\alpha} + Q_r \tag{5}$$

Things become more complicated if we assume that the costs of decadmiation are not linearly related to the concentration of cadmium in the phosphate rock, but that they increase more than proportionally with the degree of purification. A functional specification of the decadmiation costs could then be:

$$C_d = \alpha \cdot Q + \gamma \cdot \left(\frac{1-\beta}{\beta \cdot Q} \right) \tag{6}$$

in which γ is an additional coefficient, and all other symbols represent the same as before. Decadmiation then becomes profitable if:

$$Q > \sqrt{\frac{\gamma \cdot (1-\beta)}{\beta \cdot \{ \ (1-\beta) \cdot T - \alpha \ \}}} \tag{7}$$

It is also possible to calculate the maximum price difference between high-Cd and low-Cd phosphate rock. This is given by:

$$p_{\max} = T \cdot (Q^* - Q) + p^* \tag{8}$$

in which:

$p_{\max}$ = the maximum price of low-Cd rock;

T = the charge rate;

Q^* = the cadmium concentration at which decadmiation becomes profitable;

Q = the cadmium concentration of the low-Cd rock;

p^* = the price of phosphate rock with cadmium concentration Q*.

Using relation (4) to obtain the value of Q*, one gets:

$$p_{\max} = \frac{C_0}{1-\beta} - T \cdot Q + p^* \tag{9}$$

From equation (9) one can conclude that for small values of β and Q, the maximum price increase for low-Cd rock is approximately equal to the cost of decadmiation.

Appendix II. Fertilisers and other sources of cadmium: quantities, abatement costs and charge rates

Phosphate fertiliser is not the only source of cadmium in the European environment. Huppes *et al.* (1992) estimated the total cadmium emissions in the (then) EU for 1987 at 2,467 tonnes per year. Of these emissions, 377 tonnes (15%) were directly related to the use of commercial fertilisers, whereas another 175 tonnes (7%) were indirectly related to phosphate fertiliser (mainly phosphogypsum discharges). The contribution of phosphate fertiliser to the cadmium load of agricultural soils is generally larger than these percentages. The figures presented by Folke and Landner (1996) suggest that this share may range between 15 and 75% of the total cadmium influx. Other important sources are atmospheric deposition and manure.

The costs of cadmium emission reductions vary widely between different sources. Huppes *et al.* (1992) present cost figures ranging from 116 to 24,000 ECU per kg cadmium. The estimated costs of phosphoric acid decadmiation used in our analysis (in the order of magnitude of 1,000 ECU per kg cadmium; possibly lower) are in the lower part of this range. One should keep in mind that not all cadmium emission reduction measures are equally relevant for the influx of cadmium to agricultural soils. Most industrial discharges of cadmium to water and waste disposal, for example, will not contribute to the cadmium load on farmland, and only part of the atmospheric emissions of cadmium will be deposited there. Therefore, in terms of reducing the cadmium accumulation in agricultural soil, the use of low-cadmium fertilisers is likely to be a cost-effective measure[36]. However, if the objective is a *general* reduction in cadmium emissions to the environment, other measures (such as substituting and/or recycling NiCd batteries and zinc) may be equally or more cost-effective.

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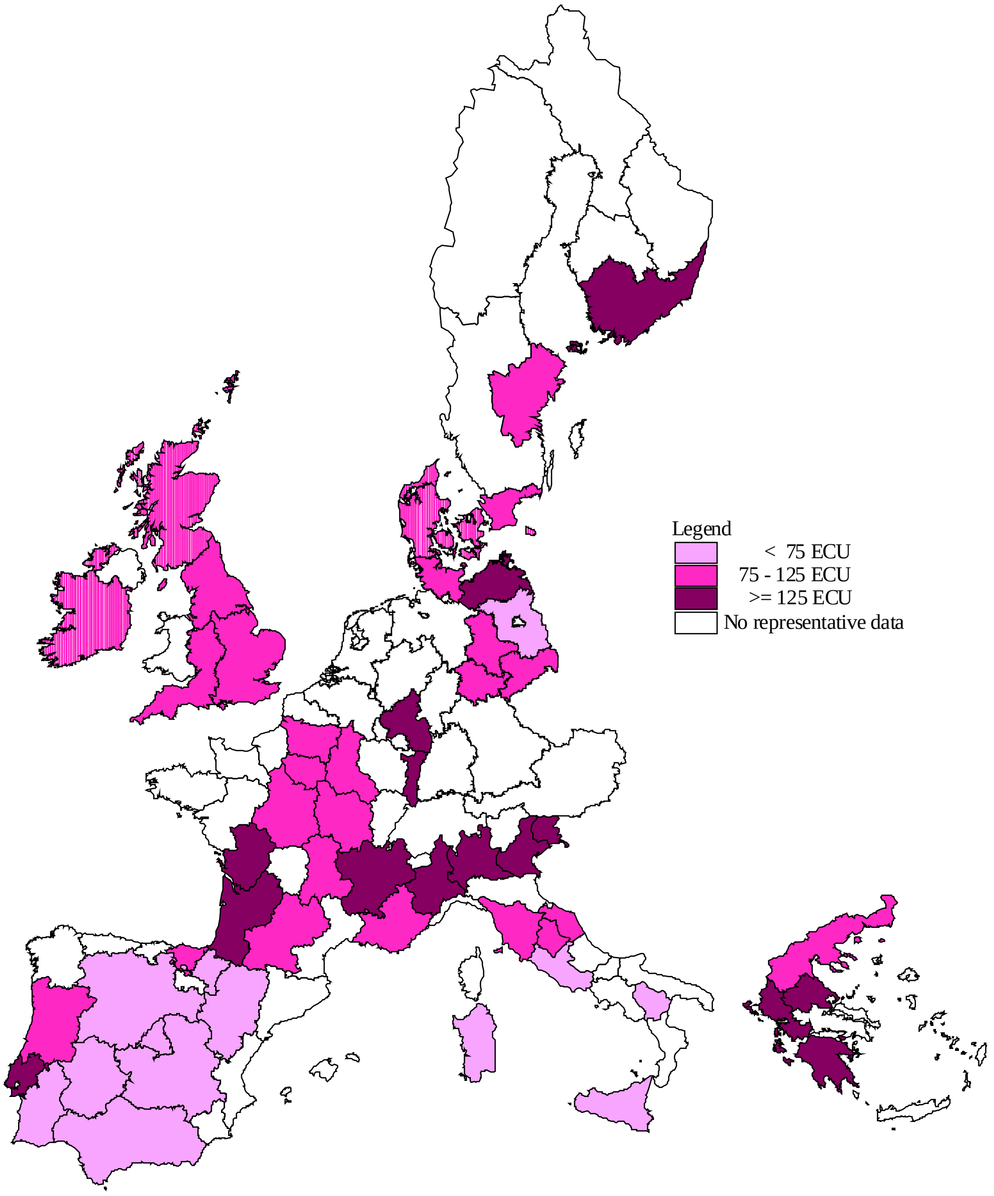
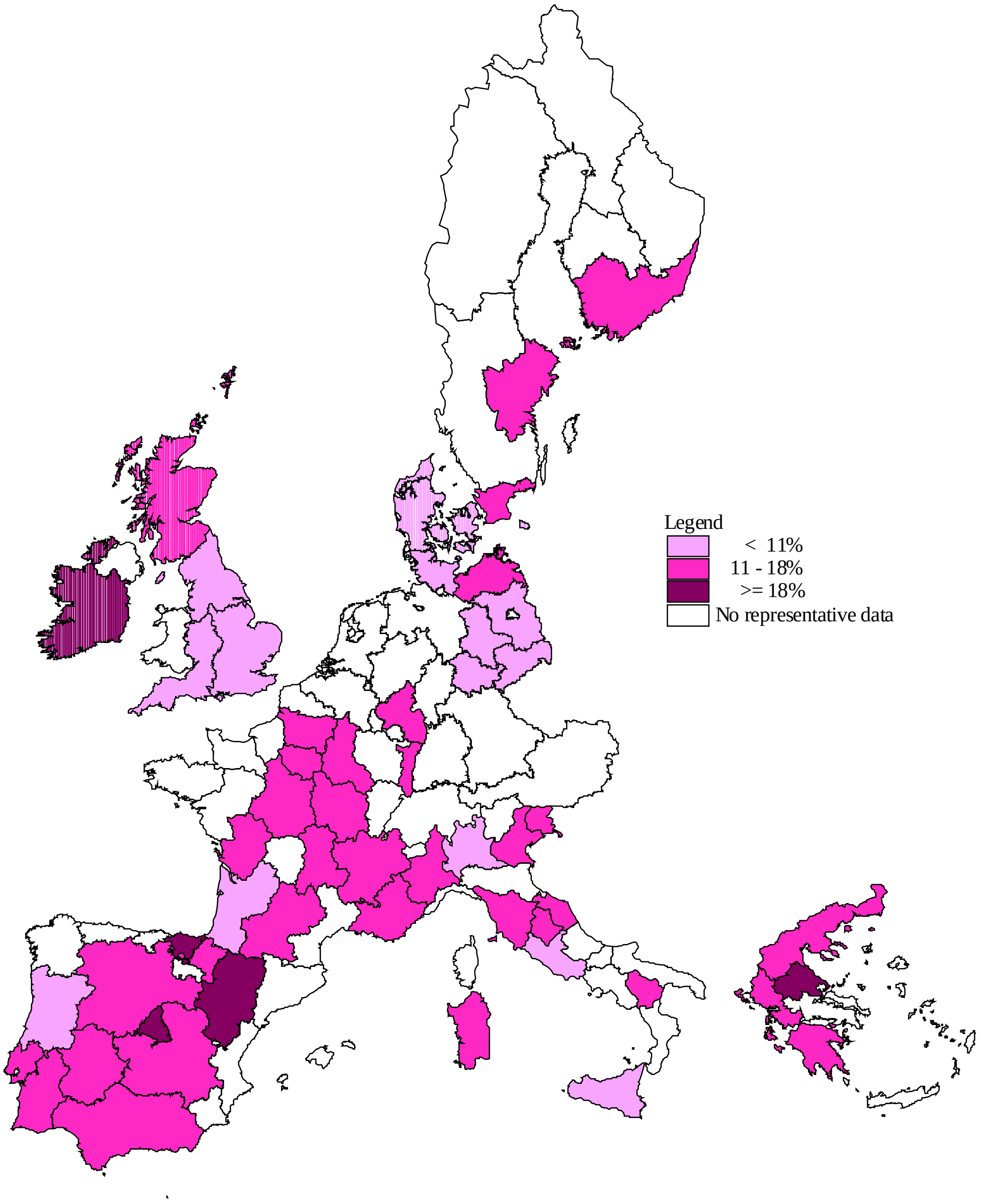
[36] Reducing excess fertiliser use and refraining from using manure, compost or sewage sludge may be even more cost effective at the farm level.

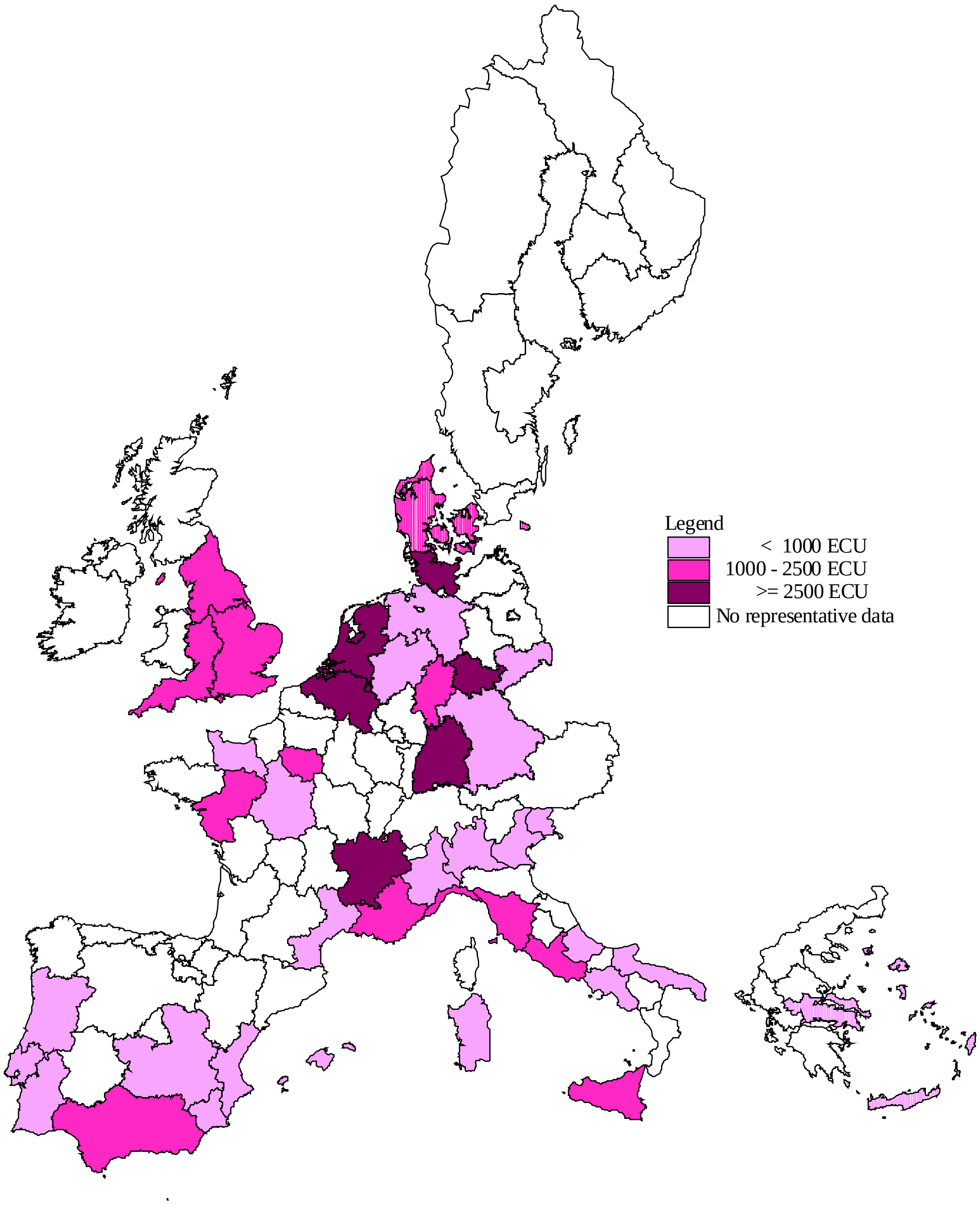
Appendix III. Fertiliser use in the EU: maps and graphics



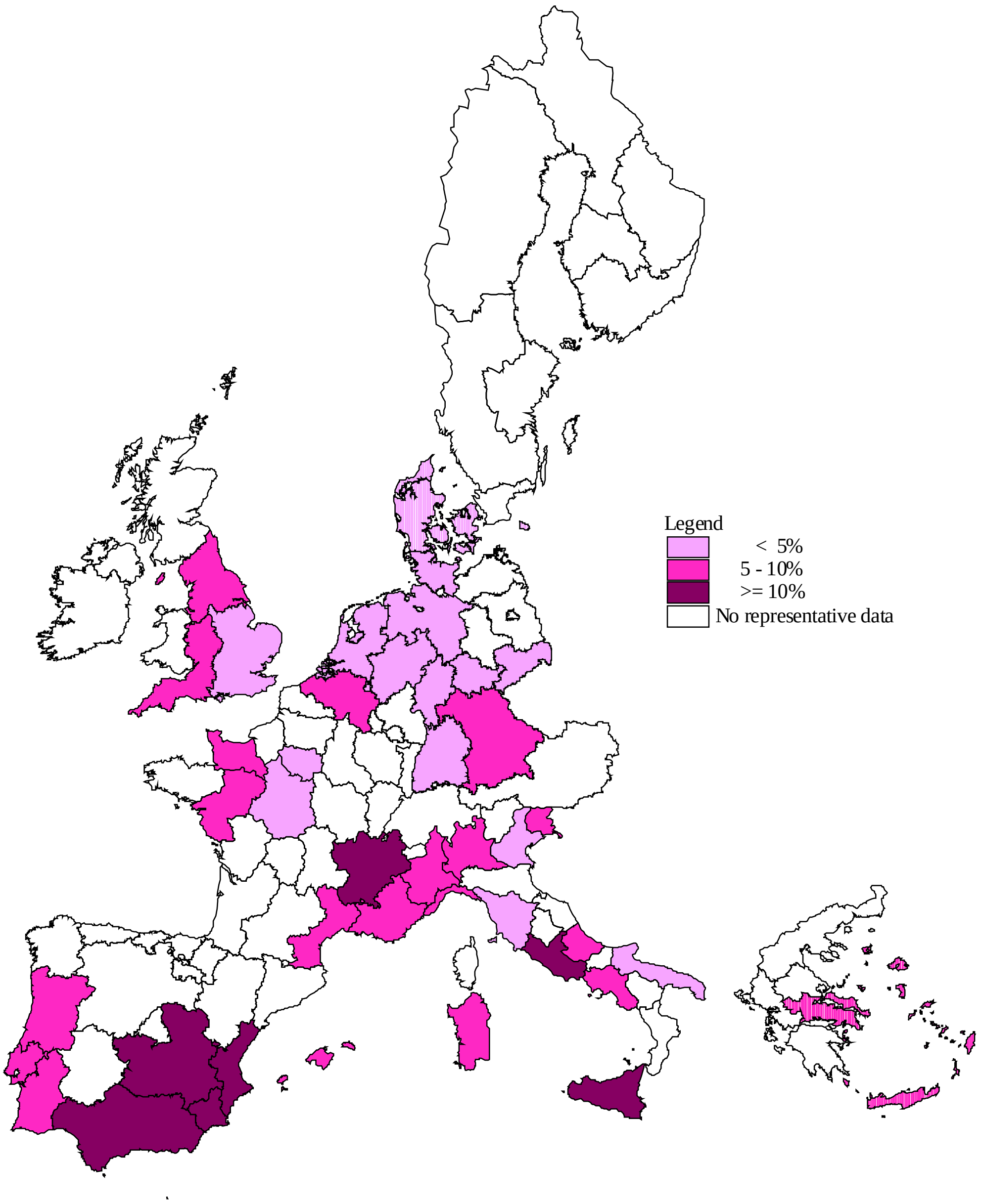
Map A.3.1. Costs of fertilizers and soil improvers per hectare utilized agricultural area (ECU) on specialist cereals in EU 15 in 1995/96.
Source: FADN-CCE-DG Agriculture/A-3; adaptation LEI.



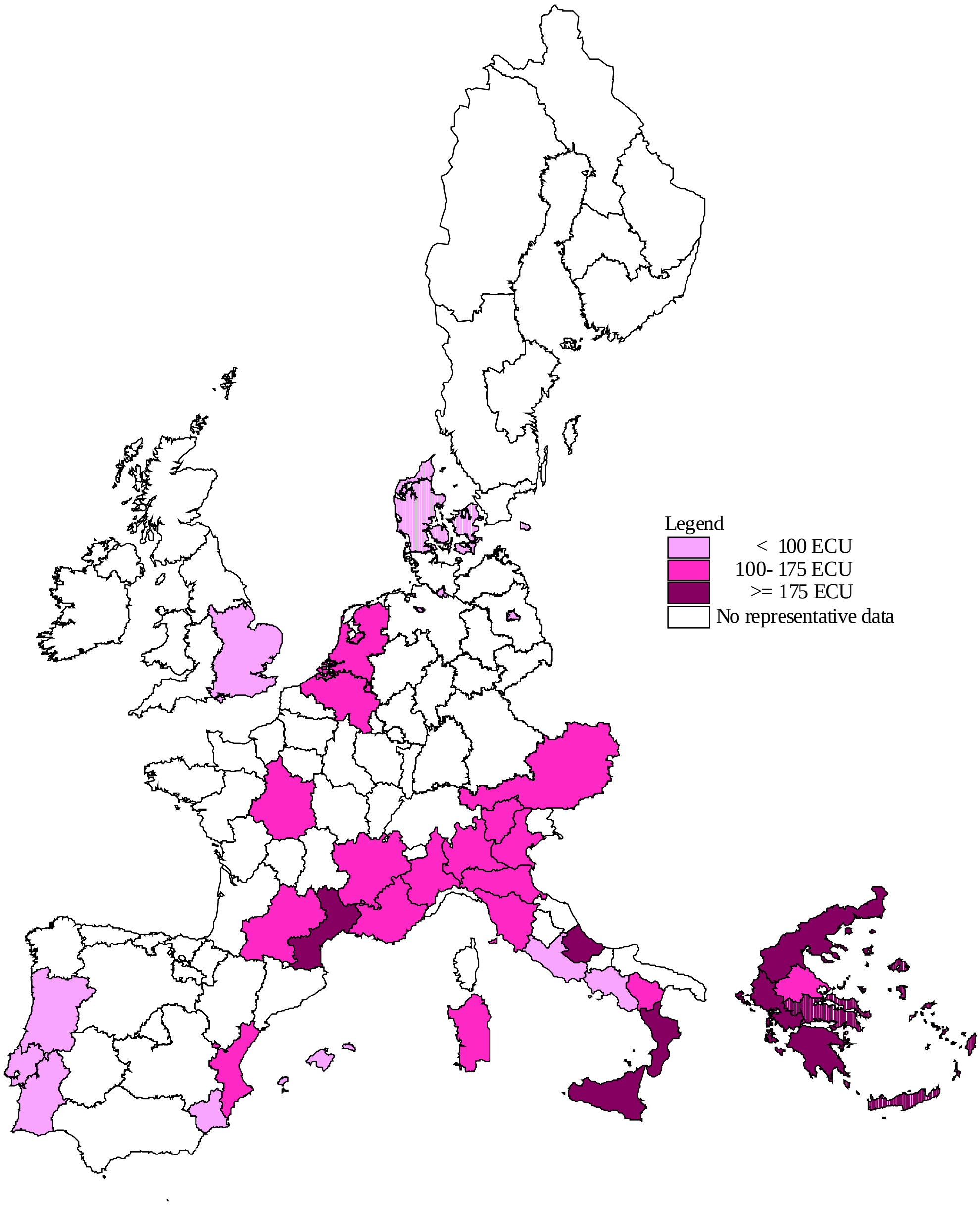
Map A.3.2 Share of fertilizers and soil improvers in total costs (%) on specialist cereals in EU 15 in 1995/96.
Source: FADN-CCE-DG Agriculture/A-3; adaptation LEI.



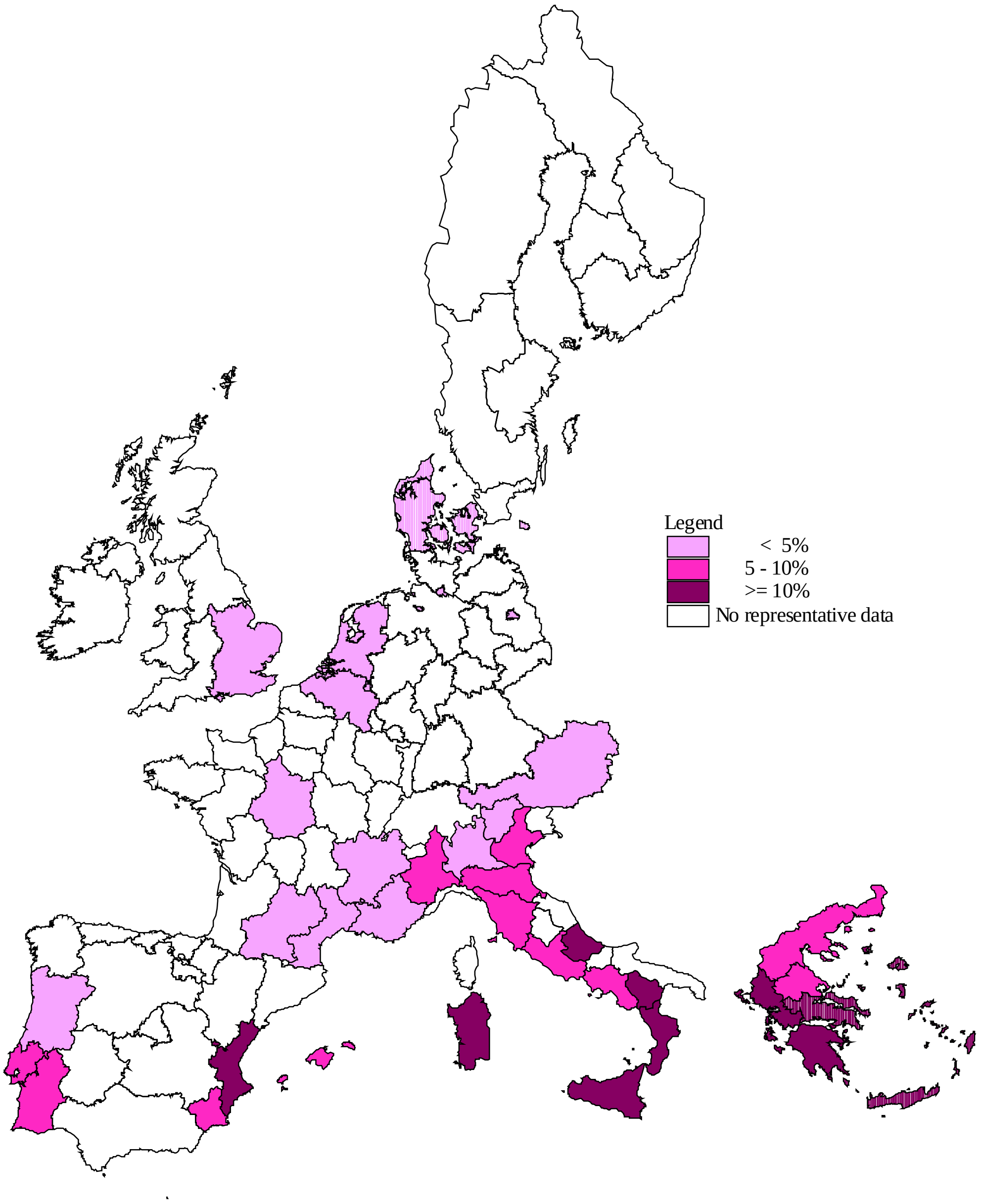
Map A.3.3 Costs of fertilizers and soil improvers per hectare utilized agricultural area (ECU) on specialist horticulture in EU 15 in 1995/96.
Source: FADN-CCE-DG Agriculture/A-3; adaptation LEI.



Map A.3.4 Share of fertilizers and soil improvers in total costs (%) on specialist horticulture in EU 15 in 1995/96.
Source: FADN-CCE-DG Agriculture/A-3; adaptation LEI.



Map A.3.5 Costs of fertilizers and soil improvers per hectare utilized agricultural area (ECU) on specialist fruit and citrus fruit in EU 15 in 1995/96.
Source: FADN-CCE-DG Agriculture/A-3; adaptation LEI.



Map A.3.6 Share of fertilizers and soil improvers in total costs (%) on specialist fruit and citrus fruit in EU 15 in 1995/96.
Source: FADN-CCE-DG Agriculture/A-3; adaptation LEI.

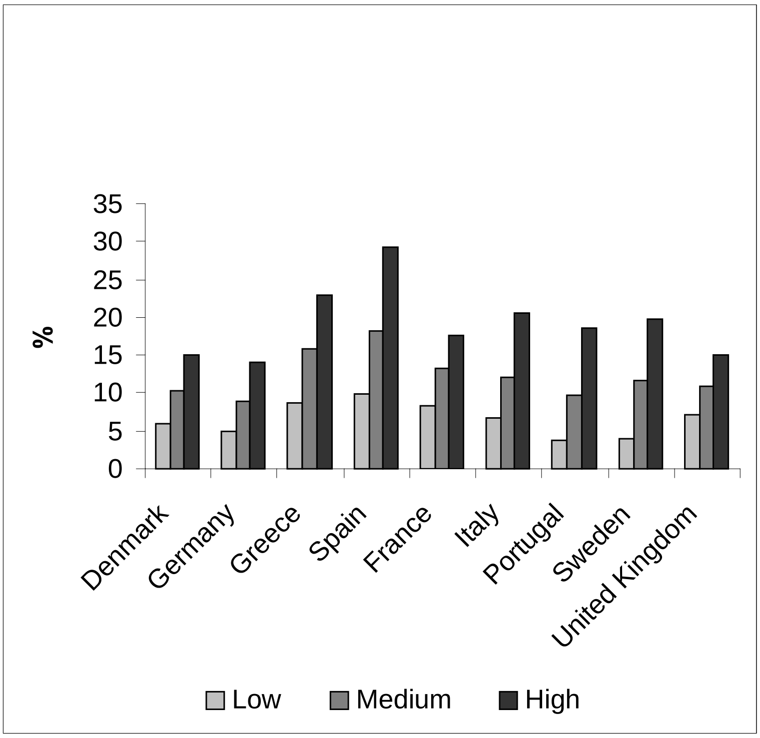


Figure A.3.1 Share of fertilizers and soil improvers in total costs on specialist cereals in EU 15 in 1995/96.
Source: FADN-CCE-DG Agriculture/A-3; adaptation LEI.

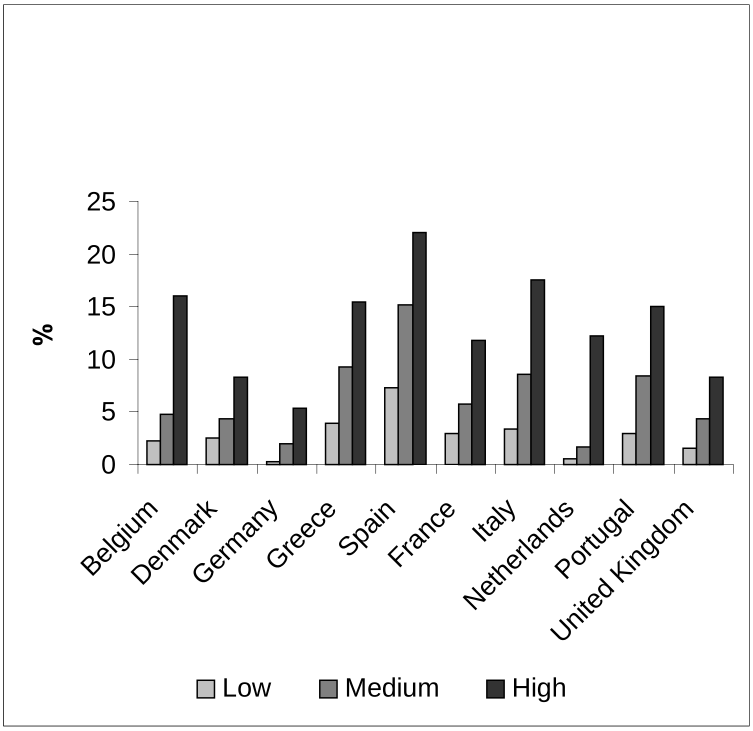


Figure A.3.2 Share of fertilizers and soil improvers in total costs on specialist horticulture in EU 15 in 1995/96.
Source: FADN-CCE-DG AgricultureVI/A-3; adaptation LEI.

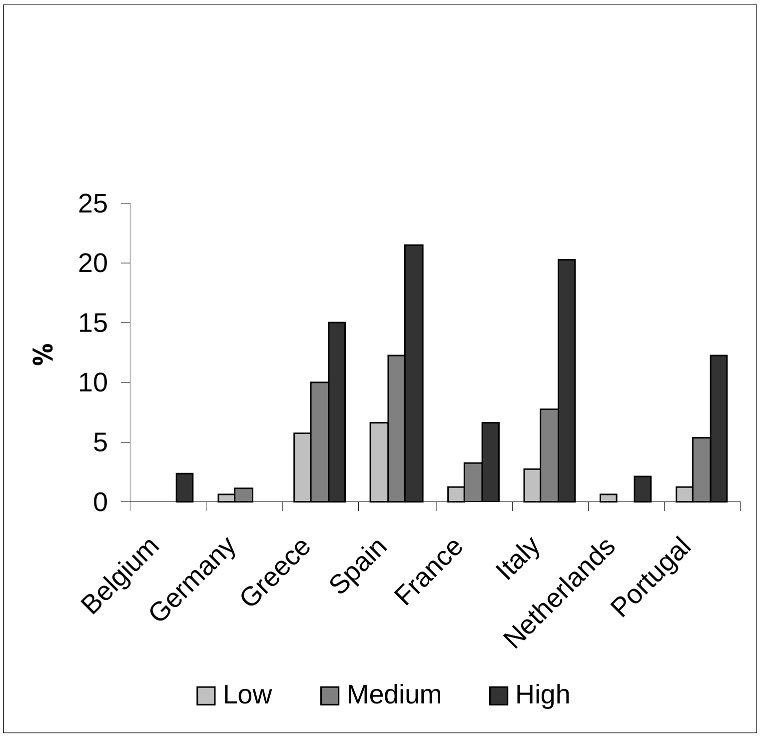


Figure A.3.3 Share of fertilizers and soil improvers in total costs on specialist fruit and citrus fruit in EU 15 in 1995/96.
Source: FADN-CCE-DG Agriculture/A-3; adaptation LEI.

Appendix IV. Interviews with fertiliser industry representatives

Interview with Mr Rein Coster, Vereniging van Kunstmest Producenten (VKP), 6 September 1999

Mr. Coster’s general remarks were:

- Cd is just one element in the rock: especially low Cd rock, found in eruptive earth crust, can contain other undesirable heavy metals;
- the rock is not selected on Cd content, but on phosphate content; a price difference is therefor not based on Cd content.
- Also, in comparison to other sources, Cd from fertiliser is definitely not the only source.
- Only a few European producers exist. Since the market is a commodity market, producers do not have a dominant position and therefor they will not pass on the tax and pay it out of their own pocket. However the margins are low due to excess supply and competition from Eastern Europe.
- For TSP no substitute exists: so banning would not help. In amounts it is only a few thousands tonnes TSP.

His remarks on the economic model were:

- the levy creates a rent for low cadmium phosphate rock: this premium can be seized by the mining company/producer of phosphoric acid (outside the EU), the distributor or the producer.
- The US uses low cadmium rock for their own production of fertiliser: so stocks available for European demand are outside the US.
- Supply of low Cd rock: will mines be able to provide more rock on the market, or will they raise prices, which is likely according to Mr. Coster, since there only few suppliers.

VKP is much more in favour of voluntary agreements than a system of levies.

Interview with Mr Peter Botschek en Mr Hans van Balken, European Fertilizer Manufacturers' Association (EFMA), 9 September 1999

Peter Botschek is Agricultural Engineer and Hans van Balken worked for DSM in the technology and environmental safety department.

General remarks:

- Risk assessment study ERM for DG 3 nearly finished;
- Raw material situation: only one producer in EU: Kemira Finland that uses low Cd rock; the waste gypsum is used to a small extend for plaster (background radiation is a problem), most is waste.
- France and Spain are big importers of raw material: mostly phosphoric acid;
- relation with phosphate content and Cd content:

- high Ph - high Cd: this is usually sedimentary rock which is easy to process;
  - low Ph - low Cd: volcanic rock, much more difficult to process (DSM developed leaching technique, however it stopped producing fertiliser);

- Average Cd content: 71 mg / kg P_2O_5 for 91% of all phosphate rock fertiliser;
- Industry has proposed to EU to lower average Cd content to 60 mg/kg P_2O_5 on a voluntary bases; this standard was based on technology assessment
- OECD 1995 reports are still up to date for technology description;

Remarks on model:

- Fertiliser is a commodity market: competition is fierce: producers may pay for tax to keep market share.
- Decadmiation technology still needs 5 to 10 years research: technical solution should be possible;
- Low Cd rock is mainly available from South Africa and Russian Federation: attached is a graph from EFMA. The biggest loser is Morocco: to a lesser extend Israel, Senegal and Togo.

Interview with Mr Cees Langeveld, Amsterdam Fertilizers B.V. (Amfert)

Background:

- AMFERT negotiates a voluntary agreement with the Netherlands Ministry of Housing, Spatial Planning and the Environment on decreasing the use of cadmium;
- Monitoring by AMFERT has shown that the use of cadmium has decreased by a factor 3 to 4;
- Average cadmium content of fertilisers in the Netherlands: around 30 mg/kg P2O5;

Remarks:

- Since the operating margins are low, the cadmium tax will be passed on to the consumer. The first reaction to a cadmium tax would be a shift to more low cadmium phosphate rock. However, not all sources of low phosphate rock can be used, because of technical restrictions. Use of low phosphate rock is the only solution for superphosphates, since decadmiation of the phosphoric acid is not possible. Unfortunately, the magmatic phosphate rock (that usually has a lower cadmium content), can not be used for production of superphosphates, only the sedimentary types: that means only sedimentary low phosphate rock can solve the problem for superphosphates.
- Decadmiation technology can solve the problem for fertilisers based on phosphoric acid: Mr. Langeveld's estimate is a price increase of 8 to 10%. Decadmiation however still has a cadmium problem: the cadmium will have to be retrieved from the waste water flow and put into a special isolated landfill site, otherwise it will still return to the environment;
- Therefore calcinating is not really solving the problem either: about 40% of the cadmium will be emitted into the air, together with carbon dioxide and other organic elements.
- The export of (low) phosphate rock from the former Soviet states is entirely a question of hard currencies: Mr. Langeveld estimates that if the economic situation improves, agriculture in these countries will grow and more fertiliser will be produced locally, which reduces the export;
- About NLG 80 million (EUR 36.3 million) was invested in the pilot on using phosphoric acid gypsum waste in construction. The annual gypsum production would be around 1.5 to 2 million tons per annum, creating a large distortion in the market. Besides, the investment is very high and KEMIRA (- and Norsk Hydro, but they are quitting production-), the company that is performing the pilot, is seriously evaluating the pilot because doubts on the viability of the technique have come up, according to Mr. Langeveld.

Suggestion:

- Since cadmium flows to the soil not only by mineral fertiliser but also by organic fertiliser, these sources should also be taxed, from an environmental point of view and based on the equity principle, if cadmium in fertiliser is to be taxed;
- Training farmers in optimising fertiliser application in combination with pH-measurements should optimally estimate the intake of fertiliser by crops.

Appendix V. Glossary

AN	ammonium nitrate
CAN	calcium ammonium nitrate
CAP	Common Agricultural Policy
$CaSO_4$	calcium sulphate (gypsum)
CC	co-crystallisation of cadmium with anhydrite (decadmiation process)
Cd	cadmium
cif	cost, insurance, freight
DAP	di-ammonium phosphate
EFMA	European Fertilizer Manufacturers(’) Association
EUR	Euro
FADN	Farm Accountancy Data Network
FAO	Food and Agricultural Organisation of the United Nations
FSU	Former Soviet Union
IFA	International Fertilizer Industry Association
Kt	Kilotonne
MAD	Moroccan dirham
MAP	mono-ammonium phosphate
N_2O	nitrous oxide
NO_x	nitrogen oxides
NP(K)	nitrogen-phosphorus(-potassium) fertiliser
P	phosphorus
PK	phosphorus-potassium fertiliser
P_2O_5	phosphorus pentoxide
SEK	Swedish crown
SSP	single super phosphate
TSP	triple super phosphate
UNEP	United Nations Environment Programme
USD	US dollar
VKP	Vereniging van Kunstmest Producenten (Dutch Fertiliser Producers’ Association)
WPA	Wet Process Acid