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CADMIUM IN THE SOIL-PLANT-HUMAN ENVIRONMENT
A SHORT REVIEW

O. Gunnarsson, Supra, Sweden

RESUME

Mining and processing of phosphate rocks to fertilizers may be considered as a transfer of the essential element phosphorus from biologically passive to biologically active reservoirs (from rocks/mines to soils, plants, animals and human beings). But "impurities" in the rocks such as cadmium may also unintentionally be transfered to biologically active reservoirs where they may cause harmfull effects on organisms.
About the toxic effects of cadmium on human beings the kidney is the critical organ first showing pathological symptoms. Severe bone diseases is a result of very high doses.
Acute toxicity of cadmium caused by heavy exposure is well known since long but is rare today since we know how to avoid it.
The problem that concerns medical scientists today is instead possible effects of comparatively low but long term exposure due to "normal" intake via food, water, inhalation and smoking.
Food is probably the most important cadmium source for the normal population at least for non smokers. Food originates directly or indirectly from plants.
Considering cadmium content of plants there is a very wide variation among species and also between different botanical parts of a plant.
Plants take their cadmium mainly from the soil but also to some extent directly from the atmosphere.

The reactions of cadmium in soils are very complex and there is no simple relation between plant uptake and amounts in the soils. The pH of the soil is an important factor. Low pH means high availability and high pH the contrary. All other plant and soil factors equal the plant uptake increases as the amount in the soil increases.

There is always a considerable but widely varying "natural" content of cadmium in soils due to geological background. But agricultural soils also receive new cadmium from different sources -atmospheric deposition, manure, sludge and phosphate fertilizers. As an average this total input exceeds the net output via agricultural products and leaching in most industrialized countries. That means - at least theoretically - a slow long term accumulation. Cadmium in fertilizers is probably not the most important input. Its effects on plant uptake has proved to be insignificant in long term field experiments with normal fertilization.
The cadmium input via fertilizers is not an acute health problem but the long term effects of a slow accumulation in the soils are worrying environmental and medical authorities and there is an increasing pressure on the industry to reduce the cadmium content of fertilizers.

ECOLOGICAL ASPECTS

Global ecological models consider chemical elements as belonging to either **biologically passive** (unavailable to organisms) or **biologically active** (available to organisms) reservoirs.

The activity of the fertilizer industry may from an ecological point of view be considered as a transfer of essential elements (nitrogen, phosphorus, potassium, sulphur and so on) from biologically passive reservoirs (atmosphere, rocks/mines) to biologically active reservoirs (soils, water, plants, animals, human beings). This transfer has generally been of very great value to mankind. The activity has made it possible to produce more and better food and fibre. Increased fertilizer use has been and is an essential prerequisite for feeding the increasing world population.

During the last decades, however, some negative consequences of this transfer has been paid increasing attention. One is that plant nutrients (specially nitrogen and phosphorus) may leak to ecosystems such as water sources where they have caused pollution and eutrophication. The role of fertilizers for pollution and unwanted eutrophication of water sources is however far from clearcut but will not be discussed further here.

Another environmental and health problem related to fertilizer use is that essential elements in the passive reservoirs may be mixed with elements which are harmful to plants, animals and human beings even in very small amounts. These biologically harmful elements may also (unintentionally) be transferred to soils and plants during the industrial and agronomic operations. Cadmium in rock phosphate is one example of such an element (Figure 1).

But cadmium is also transferred to biological active reservoirs via combustion of fossile fuels and via mining of other cadmium containing minerals and use for a number of industrial purposes such as metal alloys, colour pigments, plastic stabilizers and batteries. Production and consumption of these products have increased considerably since the beginning of this century. Only a minor part is recycled. Some of it has in one way or another contaminated the biological active reservoirs. Thus atmosphere carried cadmium is deposited on plants and soils. Compared to cadmium released from combustion and industrial uses the total content of phosphate fertilizers is small but it is more or less directed to a sensitive system - the food chain.

MEDICAL BACKGROUND

The fundamental biochemical and physiological effects of cadmium are at best incompletely understood. The toxic effects are thought to be performed by the cadmium ion (Cd^{2+}) which has similar chemical properties as zinc ions. Zinc ions play an essential role in many enzymatic systems. As zinc ions are replaced by cadmium ions these enzymatic processes are inactivated.

Human beings are exposed to cadmium from a large number of different sources. Considered one by one their effects may be negligible but the integrated effect of them all may be significant.

The main routes of exposure are inhalation and ingestion (Figure 2).
Absorption after inhalation varies between 10 and 60% depending on particle size.

The average absorption after ingestion is of the order 5%, but varies due to diet conditions. Thus low calcium intake, low vitamin D intake and low protein intake may increase the intestinal absorption up to 20-30%.

Figure 2 shows the various chronic effects developing with increasing doses. The kidney is the organ first showing pathological symptoms. Severe bone diseases is a result of very high doses.

Acute toxicity of cadmium in human beings due to comparatively heavy exposure is well known since long.

High incidence of illness among industrial workers exposed to heavy cadmium oxide exposure is well documented. Well known is also the "Itai-itai" disease in Japan where heavily cadmium polluted water from mining and melt activities was used for irrigation of rice which was an important part of the diet of the affected population. Unsatisfactory intake of protein, calcium and vitamin D was probably cofactors for the development of this disease.

Such acute cases as mentioned above are however rare and can be avoided based on today's knowledge.

The problem that concerns medical and environmental scientists today is instead possible effects of comparatively low but long-term exposure to cadmium due to "normal" intake via food, water, inhalation and smoking.

Cadmium has a long biological halflife in the human body (10-40 years). That means that it is accumulated up to an age of about fifty. The accumulation takes place especially in the liver and in kidney cortex. The content of the kidney cortex is often used as a criteria of exposure. 200 g Cd per gram wet weight of kidney cortex is considered to be a critical content above which pathological changes may appear. The average content of cadmium in kidney cortex is of the order 50 μg/gram wet weight for 50 year old individuals in industrial countries but it has been shown that this content has increased considerably during the last 100 years. There is also a wide variation among countries and among individuals and it may be postulated that some people have reached or passed the critical value 200 μg (Figure 4). It is also postulated that the number of individuals reaching the critical value will increase if nothing is done to reduce cadmium pollution in biologically active ecosystems.

CADMIUM IN PLANTS AND SOILS

Food is probably the most important cadmium source for the "normal" population (at least for non-smokers). Food originates directly or indirectly from plants.

Figure 5 shows averages and ranges of Cd-concentrations in dry matter of a number of agricultural and horticultural crops in Finland.

There are very large differences in cadmium content among different agricultural plants. The content also differs between botanical parts of the plant. The content is generally higher in roots and vegetative parts than in fruits.

It has also been shown that there are differences between varieties of the same crop, for example between wheat varieties. Striking also is the wide yearly variation for the same crop grown on the same soil. Comparatively wet climate seems to give higher content than dry conditions.

Plants take their cadmium mainly from the soil but also to some extent directly from the atmosphere.

Cadmium and zinc have a similar chemistry and are often found together in approximately the same proportions in geochemical and biochemical systems. A danish experiment indicates that a grasscrop received 30-40% of its cadmium from the atmosphere by leaf absorption.

Soil reactions of cadmium are very complex. The exchangeable cadmium (as Cd^{2+}) in the soil is considered to be the primary source of the plants. But there is no simple relation between uptake and the exchangeable amounts. The availability is dependent on many factors. Especially pH should be mentioned. Availability increases with decreasing pH.

Figure 6 shows the effect of increased amounts of Cd applied as sludge and of liming (= increasing pH) on content of Cd in fodder rape. The effect of increasing amounts applied to the soil is nearly linear but moderate. Increasing pH from 4,8 to 6,0 reduced cadmium uptake to less than half. The effect of increasing pH further from 6,0 to 7,2 was less but obvious.

Antagonism and synergism between cadmium ions and other ions in the soil influence also availability and uptake.

As is obvious from the above discussion the plant uptake of cadmium is influenced by many factors. In general, however, increased amounts in the soils means increased uptake.

Considering the content of cadmium in agricultural soils (surface soil 0-25 cm) there is a very wide variation. For "normally" cultivated and fertilized soils the main part of the content may be considered as "natural". Accounted for as gram per hectare there was found a range from 100 to 3000 for Swedish soils (Figure 7). The average content was 550 g/hectare but no significant difference was found between cultivated (= fertilized) and uncultivated (= unfertilized) soils.

On the other hand it has been shown by extensive and careful soil analyses from long term field experiments that fertilizer applied cadmium over 17 years is accumulated in the soils (Figure 8). The estimated total input was accounted for very well. Half of it remained in an easily soluble form compared with 25% easily soluble of the total "natural" background content. But the increased soil content had very small if any influence on the content of wheat grain grown in the field experiments. (See the lowest line in Fig 8).

The agricultural soils receive cadmium from different sources : phosphate fertilizers, atmospheric deposition, manure and sludge. Locally the amounts put in via sludge may be considerable : 10-15 g/hectare and year. Input via manure can partly be considered as an internal circulation but the cadmium content in imported feeding stuff means a net input to the soil. The atmospheric deposition may be considerable - in the order 1-6 g per hectare and year. But there are indications based on concentration of cadmium in moss (Figure 9) that the atmospheric deposition has decreased during the last 10-15 years in Sweden. The content 1985 was only about half of what it was 1975. This is probably a result of improved cleaning of industrial and combustion effluents.

Referring to Swedish circumstances the cadmium input via phosphatic fertilizers was of the order 3-4 g/hectare and year in the early seventies. Now it is of order 1-2 g. That is the result of lower cadmium content of the fertilizers but also of decreased phosphorus fertilization.

The yearly input via fertilizers can be compared with content of exchangeable cadmium in the surface soil (0-25 cm) - for Sweden 1-2 g as compared to 550 g. That means a yearly increase of 0,2-0,4% of the soil content. From this it is obvious that the short term effect of "normal" input cadmium via fertilizers on the cadmium content of the plants will be practically impossible to detect.

The yearly output of cadmium via products which are leaving the agricultural system is of the order 0,5-3 g per hectare depending on yield level and type of agriculture. In most cases the output is less than the total estimated input and this leads to the conclusion that there is a slow accumulation of cadmium in the agricultural soils of industrialized countries.

CONCLUSION

Due to its toxic effects on the human organism cadmium is not wanted in agricultural plants which are entering the food chain. It is, however, not possible to grow plants without uptake of cadmium. There is always a background level in the soils - natural or created by human activities. A reasonable goal, however, is to keep balance between input to and output from the agricultural system and not to increase the cadmium content of the soils. Balance sheets indicate that this is not the case today on many soils in industrialized countries. The input seems to exceed the output and a slow accumulation may be postulated.

The cadmium content of fertilizers is probably not the most important input of cadmium to soils and its influence on the cadmium intake of human beings is probably negligible at least for the nearest decades. Nevertheless it is a part of unwanted total input and there is at least in Sweden an increasing pressure from environmental groups and even medical and environmental authorities on the industry to reduce the cadmium content of fertilizers. Their reason for this is a supposed long-term accumulation of cadmium in soils and increased plant uptake in the future.

Litterature

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Figure 1

CADMIUM CONCENTRATIONS IN NATURALLY OCCURRING RAW PHOSPHATE OBTAINED FROM DIFFERENT COUNTRIES[59,93]

Country	Cadmium concentration in phosphate rock (mg/kg)	Cadmium concentration in relation to the phosphate (P_2O_5) content (mg/kg)
U.S. (Florida)	5.5—16	18—52
Morocco	8—30	24—96
Senegal	70—90	225—290
Togo	50	161
U.S.S.R. (Kola)	0.1—0.4	0.3—1.3
Tunisia/Algeria	—	60
Israel/Jordan	—	35

Source: Cadmium and Health a toxicological and Epidemiological appraisal. Volume I. Exposure, Dose, and Metabolism

Lars Friberg, Carl-Gustaf Elinder, Tord Kjellström Gunnar F. Nordberg

DOSE-EFFECT RELATIONSHIPS FOR CRONIC EFFECTS OF CADMIUM

DOSE	EXPOSURE ROUTES	
	INHALATION (AIR. GASES. SMOKE)	INGESTION (FOOD. DRINKING WATER)
LOW	SLIGHT RENAL TUBULAR DAMAGE	SLIGHT RENAL TUBULAR DAMAGE
↓	SLIGHT LUNG FUNCTION CHANGES	DECREASE IN INTESTINAL CALCIUM ADSORPTION
↓	RENAL STONES	
↓	PROGRESSING RENAL DAMAGE	PROGESSING RENAL DAMAGE
↓	CHANGES IN C AND VITAMIN D	
↓	METABOLISM	
↓	OBSTRUCTIV LUNG DESEASE	INTENSTINAL MUCOSA DAMAGE
↓	PROSTATIC CANCER ?	
↓	LUNG CANCER ?	
↓	ANAEMIA	ANAEMIA
↓	UREMIA	
HIGH	OSTEOMALACIA AND OSTEPORISIS	OSTEOMALACIA AND OSTEPOROSIS

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Figure 2.

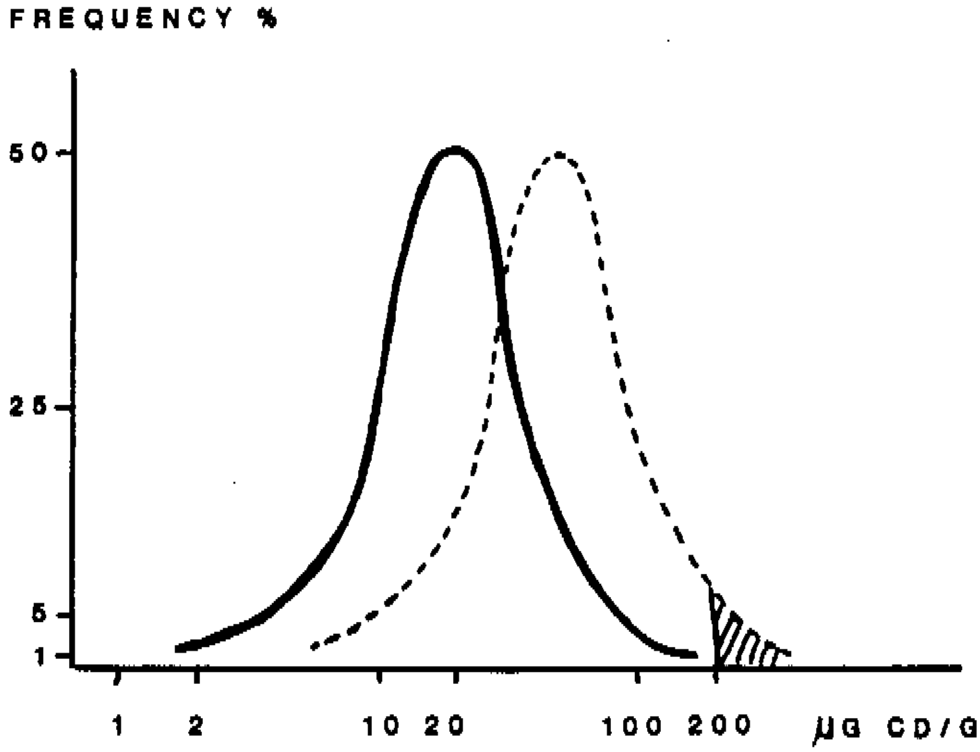
SOME MEDICAL DATA ON CADMIUM

CRITICAL LEVEL IN KIDNEY CORTEX GIVING DETECTABLE PROTEIN URIA	∼ 200 µG/G WET WEIGHT (RANGE 150-400)
WEEKLY INTAKE OVER A 50-YEAR PERIOD ESTIMATED TO GIVE THE CRITICAL LEVEL IN KIDNEY CORTEX	∼ 1400 µG/WEEK
MAX-INTAKE RECOMMENDED BY WHO	400-500 µG/WEEK

ESTIMATED AVERAGE WEEKLY INTAKE IN SOME COUNTRIES.

	µG/WEEK	REFERENCE
UNITED STATES	273	COMPILANCE PROG. EVALUATION 1974
CANADA	364	KIRKPATRICK AND COFFIN, 1977
WEST GERMANY	336	EPA - 600/6-75-003
RUMANIA	266-448	-"-
CZECHOSLOVAKIA	460	-"-
JAPAN (UNPOLLUTED AREA)	392	-"-
SWEDEN	119	KJELLSTRÖM, 1978

FREQUENCY DISTRIBUTION OF CD CONCENTRATIONS IN KIDNEY CORTEX IN SWEDEN 1974 (BLACK LINE) AND HYPOTHETICAL CURVE AT A GEOMETRIC MEAN VALUE OF 50 μG CD/G (DOTTED LINE). FROM ELINDER, ET AL, 1978.



——— FROM ELINDER ET AL, 1976

- - - - - - - HYPOTHETICAL CURVE WITH A GEOMETRIC MEAN OF 50 μG CD/G.

CADMIUM CONCENTRATION OF CEREALS AND VEGETABLES BASED ON A FINNISH SURVEY

P VARO, M NUURTAMO, E SAARI AND P KOIVISTOINEN:
MINERAL ELEMENT COMPOSITION OF FINNISH FOODS.

III. ANNUAL VARIATIONS IN THE MINERAL ELEMENT COMPOSITION OF CEREAL GRAINS. ACTA AGRIC. SCAND. SUPPL. 22, 1980, PP 27-35.

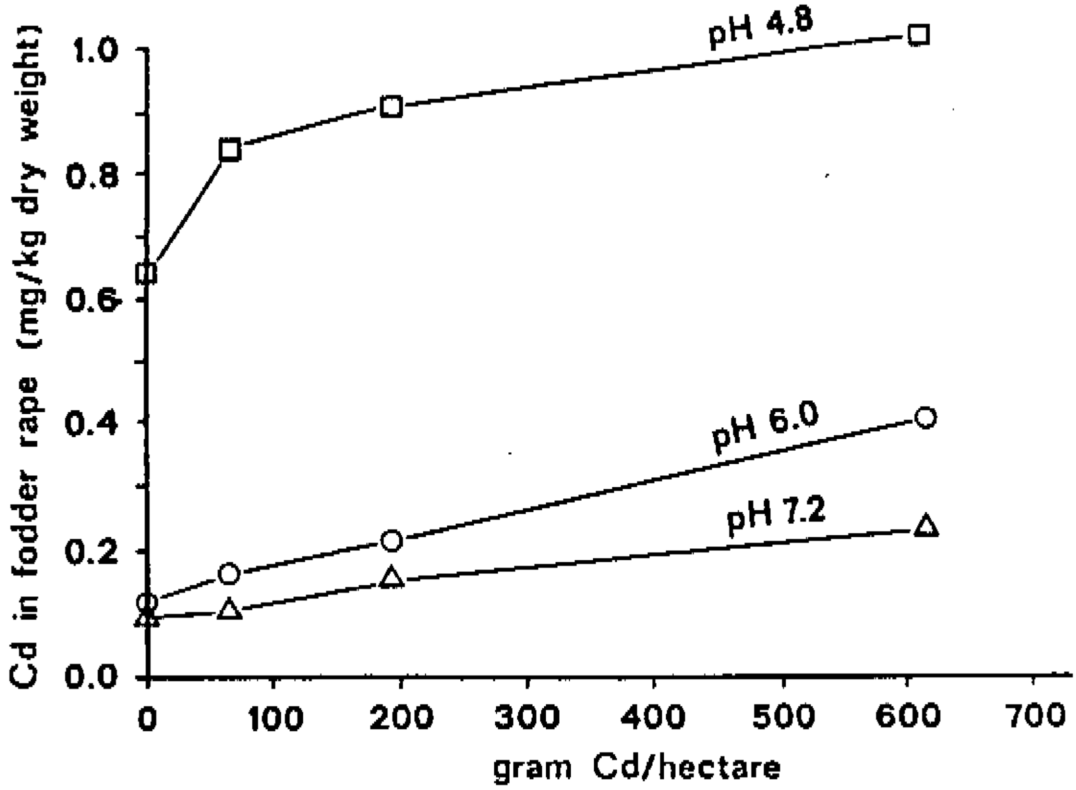
P VARO, O LÄHELMÄ, M NUURTAMO, E SAARI AND P KOIVISTOINEN:
MINERAL ELEMENT COMPOSITION OF FINNISH FOODS.

VII. POTATO, VEGETABLES, FRUITS, BERRIES AND MUSHROOMS. ACTA AGRIC. SCAND. SUPPL. 23, 1980, PP 89-113.

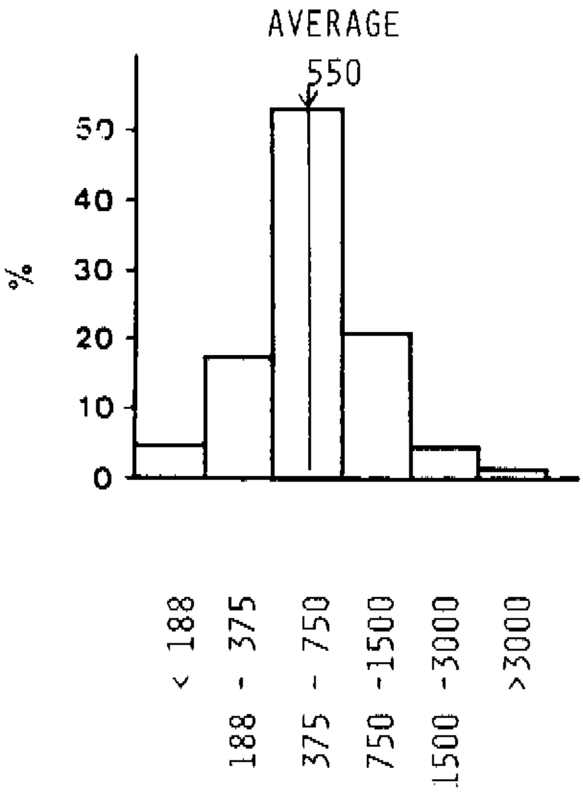
PRODUCT	NO. OF SAMPLES	NANOGRAM CADMIUM/GRAM DRY MATTER	
		AVERAGES	RANGE
GRAIN OF WINTER WHEAT[1)]	(34)	74	20 - 99
GRAIN OF SPRING WHEAT[1)]	(51)	48	29 - 79
GRAIN OF RYE [1)]	(50)	16	5 - 43
GRAIN OF BARLEY[1)]	(47)	24	5 - 43
GRAIN OF OATS[1)]	(36)	48	5 - 79
POTATO	(20)	50	20 - 100
POTATO, FRESH	(3)	150	100 - 300
CARROT	(5)	273	183 - 364
RED BEET	(5)	250	83 - 333
CABBAGE, WHITE	(5)	63	63 - 125
CAULIFLOWER	(5)	125	37 - 250
LETTUCE	(6)	1000	400 -2000
SPINACH	(4)	2143	714 -5000
ONION, YELLOW	(5)	231	39 - 385
PEASE	(3)	125	4 - 292

1) AVERAGE OF FIVE YEARS (1972-1976)

THE INFLUENCE OF PH ON THE UPTAKE OF CADMIUM IN FODDER RAPE FROM SOILS AMENDED WITH CADMIUM-CONTAINING SEWAGE SLUDGE. (DERIVED FROM ANDERSSON, A. AND NILSSON, K.O., AMBIO, 3, 198-210, 1974.)



FREQUENCY DISTRIBUTION OF CADMIUM IN SWEDISH SOILS. (FROM ANDERSSON, A.,SWED.J.AGRIC.RES., 7.7 - 20, 1977.



CD/G HECTAR (SURFACE SOIL 0-25 CM)

CADMIUM ACCUMULATION IN SOLIS DUE TO SUPERPHOSPHATE APPLICATION IN LONG TERM FIELD EXPERIMENTS.

AVERAGES BASED ON ANALYSES FROM 6 FIELD EXPERIMENTS.

	TREATMENTS			
	A	B	C	D
P-FERTILIZATION. KG/HA/YEAR	0	15	30	45
ESTIMATED CD-APPLICATION. G/HA/YEAR 1)	0	1.65	3.3	4.95
ESTIMATED CD-APPLICATION OVER 17 YEARS. G/HA	0	28	56	84
CADMIUM EXTRACTED FROM THE SURFACE SOIL THE 17TH YEAR 2)				
1. BY 2 N HCL. G/HA (TOTAL?)	913	933	967	1 000
INCREASE RELATED TO A (CONTROL). G/HA	-	+ 20	+ 54	+ 87
INCREASE RELATED TO A (CONTROL). %	-	+ 2.2	5.9	9.5
2. BY AMMONIUM LACTATE/ACELATE. G/HA ("EASILY SOLUBLE")	221	229	250	262
INCREASE RELATED TO A (CONTROL). G/HA	-	+ 8	+ 29	+ 42
INCREASE RELATED TO A (CONTROL). %		+ 3.6	+ 13.1	+ 19.0
"EASILY SOLUBLE" AS % OF "TOTAL"	24	25	26	26
CD-CONTENT OF WHEAT HARVETED THE 15TH YEAR PPB IN DRY MATTER OF GRAIN	107	106	109	111

1) ESTIMATED CD-CONTENT OF USED PHOSPHATES: 110 MG/KG P

2) CALCULATIONS BASED ON THE ASSUMPTION THAT THE SURFACE SOIL OF A HECTAR IS 2.5 X 10^6 KG.

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Figure 8.

REGIONAL DISTRIBUTION OF CADMIUM CONCENTRATION IN MOSS (HYLOCOMIUM SPLENDERS), MG/KG DRY MATTER (PPM)

REGION	1968/69	1975	1980	1985
SOUTH WEST SWEDEN	0.89	0.82	0.53	0.41
SOUTH EAST SWEDEN	0.81	0.74	0.51	0.36
MIDDLE EST SWEDEN	0.63	0.65	0.42	0.31
MIDDLE EAST SWEDEN	0.80	0.60	0.49	0.33
NORTH SWEDEN, COAST AREA	-	0.59	0.43	0.29
NORTH SWEDEN, INLAND	-	0.39	0.28	0.18

SOURCE: MONITOR. THE YEARBOOK OF THE SWEDISH ENVIRONMENTAL PROTECTION AGENCY 1987.

APPROXIMATE: 1PPM = 1.5 - 2 G/HA

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Figure 9.

TA/88/11 Cadmium in the soil-plant-human environment. A short review by O. Gunnarsson, Supra, Sweden.

DISCUSSION (Rapporteur Mr. B. Persson, Supra, Sweden).

Q - Mr. G. BRUSASCO, Agrimont, Italy

You reviewed well the problem of cadmium and its ecological impact, so we are concerned about the influence on the fertilizer business.

Can you please:

1/indicate the limits imposed by the authorities in your country

2/ comment on the influence of the phosphate market

3/ summarize the state of development of the technologies for removing Cd from phosphates.

A - 1/ There are, as far as I know, no limits imposed by the authorities.

A - Mr. B. PERSSON, Supra, Sweden

A limit of 125 mg Cd/kg P was proposed. It was never imposed due to the low Cd-content in our fertilizers.

A - Mr. O. GUNNARSSON

On the influence on the phosphate market, I would say that the optimum dosage of P2O5 cannot be given very precisely.

If the farmer is aware of the Cd problem, there will a tendency that he chooses the lower limit in the range of optimal P2O5 dosage. This means a somewhat lower use of P2O5.

Q - Mr. L.J. CARPENTIER, IFA

Are there any losses from the soil either by leaching or by volatilization of cadmium compounds ?

A - As far as I know, there are no losses by volatilization, but there are, of course, some losses by leaching. It is measured in Sweden and it is lower than 1 g Cd/ ha/year. But I suppose that it will be higher if you apply easily soluble cadmium.

Q - Mr. R.A. HUTCHINS, Texasgulf Inc., USA

Where were the samples of vegetables referred to in your overheads taken ?

A - They are based on a Finnish survey, so it is representative of Scandinavian conditions or at least Middle and North Scandinavian conditions.

Q - Mr. R. PERANDER, Kemira Oy, Finland

Can you give a brief review about the cadmium legislation situation in different countries ?

.../.../...

A - Mr. B. PERSSON, Supra Sweden.

With reservations for new or changed propositions, we believe that the current existing or proposed legislation is as follows:

Norway	no legal limit proposals:	mean 100 mg/kg P over 3 year period NH preferred 150 mg/kg P over 5 year period
Sweden:	similar position to Norway	
Denmark:	proposals	Max. 200 mg/kg P from July 1990 150 mg/kg P from July 1995 110 mg/kg P from July 1998
Finland:	legal limit	100 mg/kg P from 1989
West Germany:	voluntary	90 mg/kg P205 (200 mg/kg P)
Austria:	statutory	120 mg/kg P205 from 1987 (275 mg/kg P)
Japan:	statutory	150 mg/kg P205 (343 mg/kg P)
Switzerland:	proposed	50 mg/kg P from 31 August 1996
France:	no proposal	
U.K.:	no proposal Wait for EEC action.	

Q - Mr. G. MARROU, World Bank, USA

1/ Can you confirm that some of the commercial phosphate rocks with the highest Cd are in the US (Idaho, Montana, Wyoming) ?

Do you - or any other person in the audience - know what is the perception of that problem over there ?

What is the position of E.P.A. Any solutions ?

2/ Do you consider that Cd in phosphate rock is a real problem or a false problem ?

A - 1/ I cannot comment on that.

2/ For me, it is not an alarming problem and today it is not a real problem. But in some soils it may be a long-term real problem.

Q - Mr. A. BARBERA, Agrimont, Italy.

1/ Can you say something about which crops absorb Cd more than others ?

2/ How and where do you in your country use compost, sludges and so

.../.../...

on, that are the major sources of Cd and other toxic metals ?

A - 1/ I think that figure 5 answers your first question. It will be included in the proceedings. Grain absorb small quantities and leafy vegetables absorb quite a lot.

2/ Because of transport costs, some sewage sludge is used close to the cities, but there are restrictions on the content of Cd. It is about 10 g Cd/ton dry matter. The sewage sludge is used on less than 10% of the total agriculture area.

Q - Mr. B.K. Jain, FAI, India

DAP produced from our source of imported rock contains 44-49 ppm of Cd. Is this Cd content in DAP likely to build up to undesirable Cd accumulation in the soil ?

A - It is not so easy to answer that question. A medical expert would consider it undesirable. I do not consider it to be a problem today.

Q - Mr. P. BECKER, Duetag, France

There is a very interesting information on the cadmium content of the kidney cortex in development since 1988. Can you give the references of this information ?

A - They will be given in the proceedings (see below) N) 1 ref Friberg et al.

Q - What are your suggestions as regards the approach to the problem of reducing cadmium in fertilizers ?

A - I am not a decision-maker today, but, as I said in my conclusion, we should try to keep balance between input and ouput on a natural level.

Q - Mr. G. KONGSHAUG, Norsk Hydro, Norway

Is the crop uptake dependent on the fertilizer type ?

1/ e.g. when nitrogen is given as ammonia, the pH in the rhizosphere becomes 1-2 pH-units lower than when the nitrogen is given as nitrate.

Should this difference also reflect the cadmium uptake ?

2/ In TSP about 90% of the Cd is water soluble and in NPKs like NPK 16-16-16 only 10-20% is water soluble.

Should this difference reflect the cadmium uptake ?

A - 1/ Yes, somewhat because of acidification (ref. Fertilizer Research vol 4 N° 1, 1983, p. 63-74, Dijkshoern et al).

2/ Yes, immediately, because the immediate source is the water soluble part, but, as I see it, the cadmium problem is the long-term accumulation and looking at that, I do not think that there are big differences.

.../.../...

Q - Dr. W. RITTINGER, BASF, Germany

1/ What will be done in Sweden to reduce the atmospheric deposition ?

2/ You remark that some people may reach the critical value of 200 µg Cd/g wet weight in the kidney cortex. We know from examinations in Germany in a region with Cd emissions over a long time, that no differences were found except for a few people who were very heavy smokers.

Have you knowledge from other examinations, in which it is distinguished between smokers and non-smokers ?

A - 1/ It is going on. The emissions from industries and power plants are reduced (see figure 9).

2/ I think there are references in my literature showing that (ref N° 1).

Q - Mr. EZAHR, OCP, Maroc.

Studies seem to show that Zn affects the rate of Cd uptake from soil to plant.

What is your opinion on that question ?

A - Short-term experiments (hours) have shown that Cd uptake is depressed by increased levels of Zn (Plant and Soil, N° 44, 1976, p 179-191).