Numéro d'enregistrement scientifique: 1322
Symposium n°: 25
Présentation: poster

Cadmium Flow in Soil-Plant-Animal System within a Polluted Area
Flux de Cadmium dans le système "sol-plante-animal" au sein d'une aire polluée

LACATUSU Radu (1), RAUTA Corneliu (1), AVRAM Nicolae (2), CARSTEA Stelian (1), LUNGU Mihaela (1), KOVACSOVICS Beatrice (1)

(1) Research Institute for Soil Science and Agrochemistry, Bd. Marasti 61, 71331 Bucharest 32, Romania
(2) National Institute of Veterinary Medicine *Pasteur*, Calea Giulesti 333, Bucharest, Romania

INTRODUCTION

The continuous emission into atmosphere, for more than 50 years, of sulphur oxides and particles loaded with heavy metals from a non-ferrous metallurgical factory in Copsa Mica caused a severe environmental pollution. The main polluting heavy metals are: cadmium, copper lead and zinc. Among these, cadmium has the highest toxicity. Near this metallurgical factory, a black carbon factory operated until few years ago, whose emissions caused a desolated environmental aspect.

The pollution evaluation level of soils and forest vegetation within the Copsa Mica area is presented by Rauta et al. (1988), while Lacatusu et al. (1995) reveal the general soil-plant-animal relations within this area.

This paper presents some detailed aspects concerning the cadmium effects on soils, plants, and animals within the considered area.

MATERIALS AND METHODS

Six pastures, lying at different distances (between 0.5 and 14.0 km) from the emission source and oriented eastwards and westwards along the main air currents were investigated.

The investigated pastures are on the both slopes of the Tarnava Mare valley and on the south-eastern border of the Blaj plateau. Two predominant soil kinds have been investigated: Typic Regosols, in the case of pastures located on the higher part of the slope and on the plateau, and Argilluvial Brown soils located on the lower half of the slope. The Regosols are characterised by alkaline reaction, low-moderate calcium carbonate content, loamy texture, moderate content of organic matter and total nitrogen, and moderately supplied with mobile phosphorus and potassium. On the other hand, the Argilluvial Brown soils are moderately-slightly acid, with loamy-sandy texture, low

content of organic matter and total nitrogen, slightly supplied with mobile phosphorus and slightly-moderately supplied with mobile potassium (Table 1).

Table 1: Main physical and chemical properties of soils (topsoil) in pastures within the Copsa Mica area

Soil	Covering degree (% of investigated pastures)	pH-H_2O	$CaCO_3$ %	N %	C×1.72 %	P_{AL}* ppm	K_{AL}* ppm	Clay %	Texture
Regosol	38	7.72-8.05	0.8-4.6	0.13-0.28	2.3-3.4	5-22	132-218	24.0-27.4	Loam
Argilluvial Brown soil	62	5.30-6.21	0.00	0.09-0.15	2.1-2.9	6-18	98-175	18.0-19.7	Loamy sand

*) *P, K - soluble in ammonium lactate-acetate*

The floristic associations of the investigated pastures are predominantly characterised by species of *Festuca rubra*, *Poa pratensis*, *Agrostis tenuis*, *Koeleria macrantha*, having a moderate grazing value. The vegetation of pasture near the emission source is predominantly represented by *Agropyron repens*, in fact the pasture being totally degraded.

Soil and plant samples were collected from pastures. The soil samples were collected on genetic horizons in the first 80-100 cm of soil profile, and the plant samples were collected around the soil profile up to a distance of 20 m.

The soil samples have been chemically and physically analysed to establish the soil nature and properties, as well as the total and mobile cadmium content. The total cadmium content has been determined in hydrochloric solution obtained by dissolution of the precipitate resulted after the digestion of soil in a mixture of concentrated nitric acid and perchloric acid, and the mobile cadmium content has been determined in EDTA-CH_3COONH_4 solution buffered at pH 7.0. The fractionation of the total cadmium content in soil was made using the procedure proposed by Lacatusu and Kovacsovics (1994), and separating: cadmium soluble in soil solution, cadmium adsorbed by soil colloids, cadmium bound by organic matter and sesquioxides, and cadmium in crystalline structure of soil minerals.

Likewise, cadmium content was determined in samples of vegetation and animal organs.

All the cadmium measurements were made using atomic absorption spectrometry, in its flame atomisation variant.

RESULTS AND DISCUSSIONS

The impact of acid rains and heavy metals contributed to a severe environmental deterioration within the investigated area.

The SOIL in pastures has, in topsoil, a mean cadmium content 2.3 times higher than the maximum allowable limit (MAL - 3.0 ppm, after Kloke, 1980), and the maximum recorded value is almost 4 times higher than the MAL.

The maximum depth of soil profile with cadmium content higher than the MAL depends on the pollution severity and the soil horizon nature. In many cases this depth is of 40-50 cm, in the upper part of Bt horizon of the Argilluvic Brown soils or of the C horizon of the Regosols.

The natural acidity of the Argilluvic Brown soils and the general acidification of soils, to which acid rains contribute, determine the mobilisation of cadmium in soil at high values, on an average, 3.4 times higher than the MAL in the case of the soil mobile cadmium, measured in EDTA-CH_3COONH_4 solution at a pH of 7.0 (Table 2).

Table 2 Variation intervals and statistical parameters of total and mobile cadmium content of soils (topsoil) and of cadmium content of pasture vegetation within the Copsa Mica area, as compared with the values of the maximum allowable limits (MAL) and the normal contents (NC)

Parameter	Cd in soil		Cd in vegetation
	Total	Mobile	
	mg/kg		mg/kg
x_{min}	4.4	1.7	2.1
x_{max}	11.9	5.5	6.3
$\bar{x}$	6.9	3.4	4.4
σ	2.8	1.4	1.4
c.v. (%)	40.0	41.0	32.0
Mo	6.2	3.6	4.7
Me	6.4	3.5	4.6
MAL [*]	3	1	-
NC [**]	0.3 - 1.0	0.1 - 0.5	0.2 - 0.3

[*)] *After Kloke (1980) for total content, and after Lacatusu et al. (1987, 1993) for mobile form.*

[**)] *After Bergmann and Neubert (1976), and Bergmann (1992).*

The intensive mobilisation of cadmium in soil is also reflected by the high values of the fractions dependent on the soil solution (45.2% of the total cadmium) and the exchangeable complex (8%) as compared to the fractions bound by the organic matter, iron and manganese oxides or the crystalline net of the soil silicates (47.9%).

The VEGETATION in pastures represents a screen against the acid rains and heavy metals in their way towards the soil. For this reason, a part of the particles loaded with heavy metals remain on the foliar system of plants, from where animals ingest them together with the vegetation, during grazing.

The statistical values of cadmium content in the vegetation of pastures (Table 2) reveal that, on an average, this vegetation has a cadmium content 14 times higher than the limit (0.3 ppm) on the right of the normal interval of concentration. If the comparison is made with the maximum determined value, the increase is 21 times higher.

Between the soil mobile cadmium content, soluble in EDTA-CH_3COONH_4 solution, and the plant cadmium content, a relation of statistically ensured direct proportionality was obtained, having the correlation ratio value equal to 0.632. The relatively low value of this ratio is due to cadmium deposited by the airborne particles on the leaves and to which the cadmium physiologically translocated from soil into plant was added, on the occasion of chemical analysis.

The high content of cadmium, as well as of the other heavy metals and the deficient level of some macronutrients (Lacatusu et al., 1995) determine the decrease of the mean pasture grazing value, appreciated only according to the nature of the floristic associations.

Therefore, the pastures within the Copsa Mica area provide the animals with a low nutritional forage which also has partially toxic chemical elements.

The ingestion by the ANIMALS of a low quality forage having some toxicity has caused a progressive deterioration of the livestock health condition, especially with cattle and horses. Numerous cases of saturnism, marasmus consecutive to toxico-deficient syndrome, toxic abortion, gastro-enteritis and abortion with dystrophic and haemorrhagic lesions of the foetus have been recorded.

The implication of cadmium in cattle reproduction processes is well emphasised by the analytical data presented in Tables 3 and 4, which reveal the presence of cadmium in some parts of the genital tract and its translocation from the maternal organs and tissues to those of the foetus.

The cadmium content in the target organs (liver, kidney) of the cattle within the Copsa Mica area is, on an average, higher than in the case of cattle within a non-polluted area, namely 9 and 20 times, respectively. Also, the cadmium content of long bones is 12 times higher with the cattle in the Copsa Mica area. Unfortunately, cadmium passed through the mammary barrier, being traced in the cow milk (Figure 1).

Therefore, the accumulation of cadmium and other heavy metals (lead, copper, zinc) in the body of cattle in this area is the effect of chemical elements flow in the soil-plant-animal system. This flow of heavy metals occurs at high intensities in this area. An illustration of this flow in the Copsa Mica area, as compared with another non-polluted area, is presented in Figure 1.

To calculate the cadmium translocation from an environmental component to another, data from special literature on the daily mean quantity of forage (Hateganu et al., 1978) and soil (Thoronton, 1986) ingested by cows were used. Regarding the soil, the research in New Zealand showed that a dairy cow, during grazing, might ingest up to 454 kg/year. The calculation made in this paper took into account only half of this quantity.

Table 3 **Mean values of cadmium content (mg/kg) in some genital parts of cows within the Copsa Mica area**

Organ parts	$\bar{x}$	σ
Uterine horns	0.13	0.09
Ovaries	0.27	0.29
Vagina	0.12	0.02
Valve	0.05	0.02

Table 4 **Cadmium values (mg/kg) in samples of organs and tissues collected from two pregnant cows and their foetuses in the Copsa Mica area and from a cow and a foetus in a non-polluted area**

Organ or tissue	Copsa Mica area				Non-polluted area	
	Mother		Foetus		Mother	Foetus
	(1)	(2)	(1)	(2)		
Liver	1.73	0-90	0.13	0.08	0.06	0.02
Kidney	21.80	1.41	0.07	0.01	0.14	0.005
Brain	-	0.25	0.07	0.02	0.01	0.03
Long bone	3.29	1.13	0.51	0.24	0.19	0.15

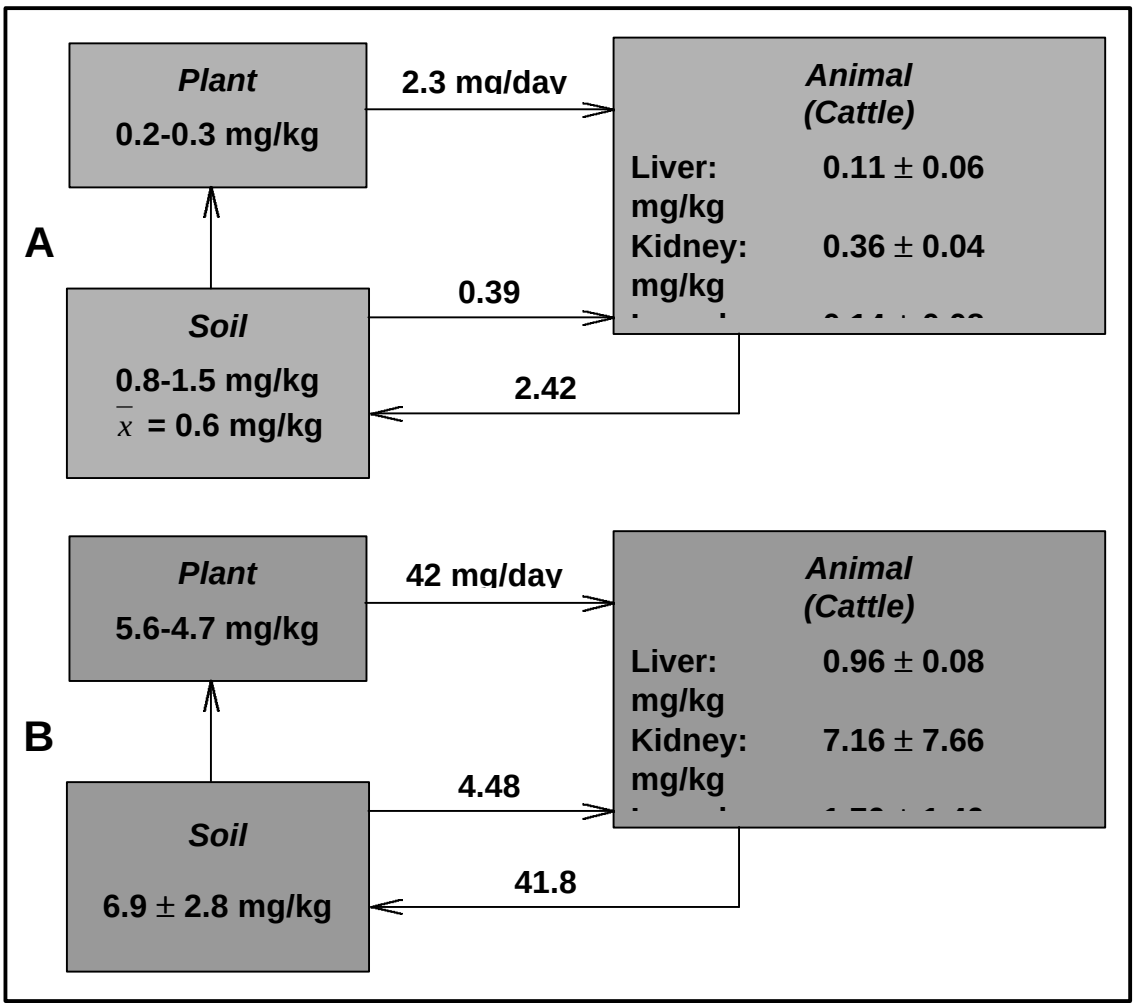

Figure 1. Cd flow in soil-plant-animal system within the Copsa Mica area (B) and within a non-polluted area (A) during the grazing period

To evaluate the elimination level from the animal body, 90 per cent of the total quantity of cadmium ingested was considered as being eliminated and only 10 per cent as physiologically absorbed.

The examination of data in Figure 1 shows that the translocation speed of cadmium from plants into animal body is 18 times higher in the Copsa Mica area than in a non-polluted area; the translocation from soil into animal body is 11 times higher; and the elimination of cadmium from the animal body on soil is 17 times higher.

On the other hand, within a non-polluted area, only 0.26 mg Cd may enter the metabolic flow of animals, while 4.65 mg Cd are running in the metabolic flow of animals within the Copsa Mica area.

Cadmium and the other heavy metals presented in this paper, their interaction, as well as other chemical elements at a toxicity or deficiency level, significantly contribute to a high rate of morbidity and mortality of animals within the Copsa Mica area.

CONCLUSIONS

1. The emissions from the Copsa Mica metallurgical factory have polluted the pasture soils within the affected area with cadmium at levels up to 2.3 times higher than MAL (3 ppm).
2. The cadmium content in pasture vegetation is 14 times higher than the normal content.
3. The translocation speed of cadmium from plant to animals within the Copsa Mica area is 18 and 11 times, respectively, higher than within a non-polluted area.
4. Cadmium, as well as the other heavy metals (lead, copper, zinc) contribute to the pollution of the area and to the alteration of the animal health condition by incidence of saturnism, hepato-renal dystrophy, toxic abortion, etc.

REFERENCES

1. **Bergmann W., Neubert P.,** 1976, Pflanzendiagnose und Pflanzenanalyse, *VEB Gustav Fischer Verlag, Jena*.
2. **Bergmann W.**, 1992, Nutritional Disorders of Plants, *Gustav Fischer Verlag, Jena , Stuttgart, New York.*
3. **Haþeganu V., Nichita C., Zabava I., Stavila S.,** 1978, Bazele nutritiei animale si controlul sanitar-veterinar al furajelor, *Ed. Did si Ped., Bucuresti* (published in Romanian).
4. **Kloke A**., 1980, Richtwerte '80 Orientierungsdaten für tolerierbare Gesamtgehalte einiger Elemente in Kulturböden, *MIH. VDLUFA, H.2, 9-11.*
5. **Lacatusu R., Kovacsovics Beatrice,** 1994, Metoda pentru fractionarea metalelor grele din sol, *Pub. S.N.R.S.S., vol. 28A, 187-194* (published in Romanian).

6. **Lacatusu R., Rauta C., Mihailescu A., Medrea N., Kovacsovics Beatrice, Lungu Mihaela,** 1997, Cercetari referitoare la sistemul sol-planta-animal din zona de influenta a Uzinei pentru Valorificarea Cenusii Piritice de la Turnu Magurele, *Analele I.C.P.A., vol. XLVIII, 281-292* (published in Romanian).

7. **Lacatusu R., Rauta C., Avram N., Medrea N., Kovacsovics Beatrice, Carstea S., Ghelase Ileana,** 1995, Soil-Plant-Animal Relationships in the Copsa Mica Area Polluted with Heavy Metals, *Soil Science, XXIX, 1, 81-89, 1995* (published in Romanian).

8. **Rauta C., Mihailescu A., Carstea S., Toti M., Neata Gabriela, Gament Eugenia, Mihalache Gabriela, Dumitrescu Florentina, Zelinschi Cecilia, Dancau Haralambie,** 1988, Poluarea industriala a solurilor si vegetatiei forestiere din zona Copsa Mica, *Analele I.C.P.A., XLVIII, 269-280* (published in Romanian).

9. **Thoronton I.**, 1986, The Role of Soil Ingestion in the Transfer of Trace Metal Contaminants and Essential Trace Elements to Grazing Livestock, *Spurenelements Symposium, Jena, 266-279.*