Subject Area 8.1: Environmental sustainability and economic viability of agricultural and pollution abatement programs

Research Article

Impact of a Smelter Closedown on Metal Contents of Wheat Cultivated in the Neighbourhood*

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Abstract

Background. The contamination of soils by heavy metals engenders important environmental and sanitary problems in Northern France where a smelter has been located for more than one hundred of years. It has been one of the most important Pb production sites in Europe until its closedown in March 2003. Ore smelting process generated considerable atmospheric emissions of dust. Despite an active environmental strategy, these emissions were still significant in 2002 with up to 17 tonnes of Pb, 32 tonnes of Zn and 1 tonne of Cd. Over the years, the generated deposits have led to an important contamination of the surrounding soils. Previous studies have shown pollutant transfers to plants, which can induce a risk for human and animal health. The objective of this study was to evaluate the consequences of the smelter closedown on the Cd and Pb contents of wheat (grain and straw) cultivated in the area.

Methods. Paired topsoil and vegetable samples were taken at harvest time at various distances to the smelter. The sample sites were chosen in order to represent a large range of soil metal contamination. Sampling was realised on several wheat harvests between 1997 and 2003. 25 samples were collected before the smelter closedown and 15 after. All ears of about 1 m long of two rows were manually picked and threshed in the lab. Similarly, straw was harvested at the same time. Total metal contents in soil and wheat samples were quantified.

Results. A negative correlation between metal concentrations in soil and the distance to the smelter was shown. The wheat grain and straw showed significant Cd and Pb contents. The straw had higher metal contents than the grain. During the smelter activity, the grain contents were up to 0.8 mg kg^{-1} DM of Cd and 8 mg kg^{-1} DM of Pb. For the straw, maximum contents were 5 mg kg^{-1} DM of Cd and 114 mg kg^{-1} DM of Pb. After the smelter closedown, we observed a very large decrease of Pb in the grain (82%) and in the straw (91%). A smaller decrease was observed for Cd in grain. Despite this improvement, 80% of the studied samples remained non-acceptable for human consumption, according to the European legislation values, due to a high Cd content.

Discussion. Results highlighted a difference in metal accumulation in the plant organs as well as a difference in metal uptake. The approach pointed out the importance of atmospheric fallout in the wheat contamination pathways for Pb. The smelter closedown has lead to a decrease of the Pb content in wheat. It is interesting to relate this finding with the lead blood levels in children living close to the smelter.

Conclusions. Those results have confirmed the importance of dust fallout in the plant contamination pathways. Before the closedown, Pb measured in the plant was principally originating from the smelter dust emissions. It raised the question of the sanitary risks for humans and animals living in the surrounding area of the smelter.

Recommendations and Perspectives. In the literature, very few articles take the dust deposit as contamination pathways for crops into consideration. However, in highly contaminated sites, this pathway can be very important. Thus, it would be worthy studying the uptake of metal contaminants by plants through the foliar system.

Keywords: Atmospheric deposition; cadmium; contaminated soil; lead; metals; smelter; wheat

Introduction

The contamination of soils by heavy metals can mean important environmental and sanitary problems in old industrial areas. This was the case in the North of France (Noyelles-Godault) where a lead smelter called Metaleurop Nord has been under activity for more than one hundred years. This smelter was set up in 1894 and was producing around 170,000 t of lead and 105,000 t of zinc per year. Ore smelting process generated considerable atmospheric emissions of dust. Despite an active environmental strategy, these emissions were still important with up to 1 tonne of Cd, 17 tonnes of Pb and 32 tonnes of Zn for 2002 (DRIRE 2003). In addition to the smokestack emissions, the slag generated by the pyrometallurgic process and piled in an outside heap nearby the smelter was subject to being carried in the wind, thus contributing to dust emissions. During the last decade, the slag heap, which reached 50 m high, was regularly covered with a soil layer in order to lower wind erosion.

The emissions generated by this smelter have led to an important contamination of the surrounding soils. Pollutants were mainly Pb, Cd and Zn, but also to a less degree Ag, As, Bi, Cu, Hg, In, Ni, Sb, Se, Sn and Tl. The normal metal contents of agricultural topsoils were multiplied by a factor of 1 to 50, depending on the element (Sterckeman et al. 2002). Furthermore, those authors established that most of the Cd and Pb were found in the ploughed horizon of agricultural soils, i.e. in the first 20 or 30 cm. The sanitary risks result from the high degree of soil contamination and also

*ESS-Submission Editor: Prof. Zhihong Xu (zhihong.xu@griffith.edu.au) probably from the soil uses. In fact, a large part of the area corresponds to agricultural fields (60%) and urban soils (30%) (Godin et al. 1985). The transfer of heavy metals to natural and cultivated plants growing close to a smelter has been shown by previous works (Dudka et al. 1996, Dudka et al. 1995, Gzyl 1990, Moolenaar and Lexmond 1999). This transfer leads to a high metal accumulation in the crops which increases the exposure to the surrounding populations (Bacon et al. 2003, McLaughlin 2000).

After the smelter closedown in March 2003, the remaining contamination source was principally the top of a slag heap that was not completely covered with protective soil. Although the smelter activity had ceased, the problems induced by the high contamination of the area remained of concern.

To our knowledge there is very little literature dealing with the effects of a smelter closedown on the surrounding agricultural soils and crop metal contents. The aim of this study was to look at the short-term effects of the smelter closedown, i.e. the dust emission cessation on wheat grain and straw Cd and Pb contents. For this, soil and wheat samples were collected from 1997 to 2003 in the surrounding area of the smelter. In addition, the wheat Cd and Pb contents were examined with regard to the European legislation maximum levels for foodstuff and feedstuff.

1 Materials and Methods

1.1 Sampling sites

Paired soil and wheat samples were taken at harvest time in agricultural fields at various distances from the smelter. The sampling sites were chosen in order to represent a large scale of soil metal contamination. The choice of the sampled sites was randomly performed due to agricultural land management. The distance of the samples varied from 0.8 to 5.6 km to the smelter (**Fig. 1**). Sampling before the smelter closedown was realised between 1997 and 2001. 8 samples were taken in 1997, 7 in 1998, 8 in 2000 and 2 in 2001. A total of 25 sampling sites were studied before the smelter closedown. Sampling after the smelter closedown was realised in 2003 with a total of 15 sites. The harvest of the wheat was realised in July 2003 and it was thus considered as unaffected by smelter dust emission. Indeed, the shoots were barely developed before March, date of the smelter closedown. In addition, the smelter had seriously decreased its activity since January 2003.

In 1997, 3 sites considered as references were taken thirty kilometres far from the smelter and distant from any industrial development, urban area or major road. These samples were considered as not affected by a massive anthropogenic contamination and their physico-chemical parameters were closed to the studied, contaminated soils. For each site, the soil and wheat samples were taken far from the field limits.

1.2 Soil sampling and analysis

Topsoil samples (0–25 cm) were taken with a spade in the ploughed layer just after sampling of wheat plants. The topsoil samples were dried at a temperature below 40°C, crushed and sieved to 2 mm. A representative subsample was crushed and passed through a 0.315 mm sieve for the measure of the total Cd and Pb contents. Ashing at 450° and a mixture of hydrofluoric (HF) and perchloric ($HClO_4$) acids, as described by the NF X 31-147 (1996) standard, were used for the total dissolution of Cd and Pb. Metal contents in soil samples were quantified by the Laboratory of Soil Analysis of INRA (Arras, France). They were determined by Inductively Coupled Plasma – Mass Spectrometry (ICP-MS). The detection limits were 0.02 mg kg^{-1} dry weight (DW) for Cd and 0.2 mg kg^{-1} DW for Pb. All precautions were taken with

Fig. 1: Location of the study area in North of France and sampling sites

respect to the protocol application and the calibration. Quality control was based on the use of certified samples (BCR 141 and 142; GBW 07401, 07402, 07404, 07405 and 07406), samples from inter-laboratory comparisons, internal control samples and duplicates of the analysis.

For samples taken from 1997 to 2001, physico-chemical parameters were measured. The particle size distributions were carried out according to the NF X 317-107 (1983) standard, through the dispersion of mineral particles after the destruction of organic matter by hydrogen peroxide and the separation of the different classes of particles through sedimentation (particles <50 µm) and sieving (particles >50 µm). The organic carbon was determined by sulfochromic oxidation according to the NF X 31-109 (1993) standard. Soil pH was measured in a 1:5 (v/v) ratio of soil and water suspension following the norm NF ISO 10390 (1994) and the total carbonate content (measurement of the CO_2 volume released through reaction with HCl) were measured according to the NF ISO 10693 (1995) standards.

1.3 Wheat sampling and analysis

Wheat cultivar 'Tremie' is the most important cultivated variety in the North of France and thus selected for sampling in this study. The choice of this crop was explained by its importance in regional farms but also in human or animal diet. At harvest time all ears of two rows of 1 m long were manually picked. In order to take into account the individual variability, more than 50 ears were taken per sample. Straw was cut with a knife at 10 cm over the ground. In the lab, the ears were manually threshed. Glumes and dust were removed with compressed air to separate the grains. Similarly to agricultural and food-industry practices, no washing of the grain and straw was performed. Wheat grain and straw samples were dried at a temperature below 50°C, crushed and passed through a 0.315 mm sieve. Then a subsample was digested with concentrated nitric acid and hydrogen peroxide using a closed microwave. Metal contents in wheat samples were quantified by the Laboratory of Soil Analysis of INRA. They were determined by ICP-MS. The detection limits were 0.02 mg kg^{-1} dry weight (DW) for Cd and 0.2 mg kg^{-1} for Pb.

1.4 Comparison with legislation values

The concentrations of Cd and Pb in wheat grain and straw were compared with the maximum permissible contaminant levels specified by the European Commission Regulation. These values depend on the use of the product as a foodstuff (European Commission 2002a) or a feedstuff (European Commission 2002b). For foodstuff, European limit values are given on a fresh weight basis. For foodstuff, a humidity content of 15% was considered in regard to the usual market practice for wheat grain. The calculated limit value was 0.24 mg kg^{-1} of dry weight for both Cd and Pb in grain. For feedstuff, these limit values are expressed on a 12% humidity basis as defined in the European legislation. The feedstuff limit values on a dry weight basis were calculated to be 1.14 mg kg^{-1} for Cd and 11.4 for Pb. This was done to allow the comparison with our wheat grain and straw values.

1.5 Statistical analysis

Before analysis, the data were checked for normality and homogeneity of variances. A t-test was done to determine for the influence of soil types on the Cd and Pb contents in soil and wheat. In order to test for the effect of smelter closedown on the Cd and Pb contents in soil, grain and straw, a t-test was performed as well. Similarly, differences with reference sites were tested. A correlation analysis was realised to determine if the distance to the smelter was influencing soil, wheat Cd and Pb contents before and after the smelter closedown. In addition, a correlation analysis was used to determine the relation between wheat grain or straw Cd and Pb contents and soil Cd and Pb contents. All analyses were performed with Statistica 6.0 for Windows.

For samples having Cd and Pb contents below analytical detection limits, values equal to the detection limits were used in the analysis. This was done in order not to minimize the risks.

2 Results

2.1 Soils

Table 1 showed the main physico-chemical parameters of sampled topsoils. For most of the studied soils, the fraction of silt was predominant. The soils were lightly alkaline and the mean content of total $CaCO_3$ was relatively low (26 g kg^{-1}). A few samples were nevertheless calcareous and reached 219 g of $CaCO_3$ per kg of soil. The average content of organic carbon was around 34 g kg^{-1} but some sample reached high concentrations (75 g kg^{-1}).

In the studied area, three main soil types were identified: loess loam, loess sandy loam and alluvial loam. This last group was the smallest and presented the highest $CaCO_3$ concentrations. Some soil parameters such as clay, organic contents and pH, are known to influence the mobility and bioavailability of metals. However, the limited number of samples did not allow one to differentiate the soil types for the analysis. In addition, no significant differences were observed amongst soil types for Cd and Pb contents in soils ($p>0.05$). The total metal contents in studied topsoils reached 14.5 mg kg^{-1} for Cd and 821 mg kg^{-1} for Pb (see Table 2).

Table 1: Physico-chemical characteristics of agricultural topsoils sampled before the smelter closedown. Mean, minimum, maximum and standard deviation (SD) are provided

	Clay	Silt	Sand	Organic carbon	C/N ratio	pH	$CaCO_3$	P_2O_5	K_2O	MgO
	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}			g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
Mean	204	640	156	34	12.2	7.9	26	0.36	0.26	0.14
Min	149	379	76	23	8.7	6.7	1	0.14	0.16	0.06
Max	348	765	410	75	17	8.4	219	1.31	0.78	0.51
SD	47	97	91	14	1.7	0.4	54	0.23	0.13	0.09

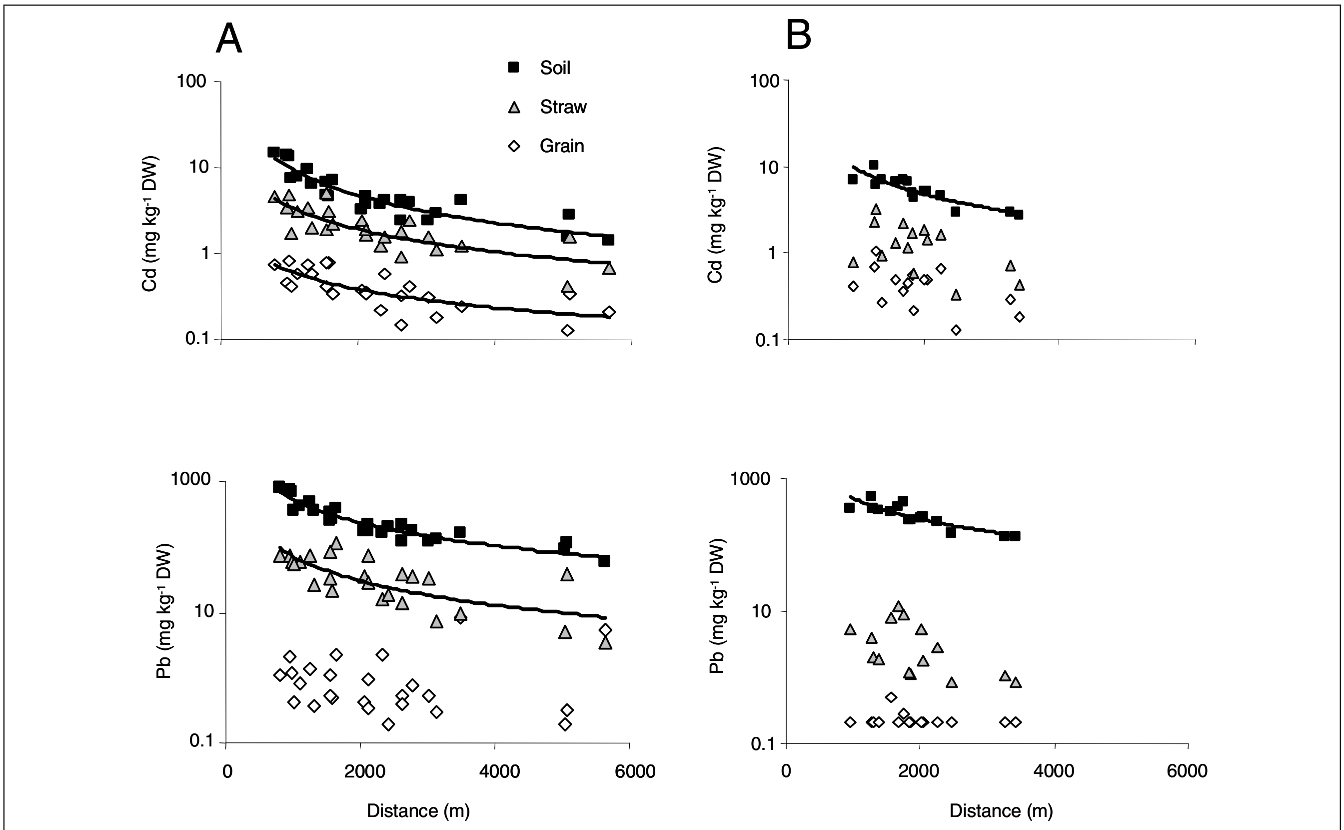

Fig. 2: Relationships between soil, grain, straw Cd and Pb contents and the distance to the smelter before (A) and after closedown (B). Models presented here are significant ones ($p<0.05$). DW means dry weight

Table 2: Mean, minimum, maximum values and standard deviation (SD) for total Cd and Pb contents in topsoils sampled around the smelter before and after closedown, and in reference area. Results are expressed in mg kg^{-1} of dry weight

	Smelter area				Reference area	
	Before closedown		After closedown			
	Cd	Pb	Cd	Pb	Cd	Pb
Mean	5.8	292	5.6	290	0.7	42.2
Min	1.4	59	2.8	134	0.7	41.8
Max	14.5	821	10.4	540	0.75	42.6
SD	3.8	209	2	116	0.06	0.6

The smelter closedown did not have a significant effect on the soil Cd and Pb contents ($p>0.05$). The samples taken before and after the smelter closedown were presenting a close range of contamination.

There was a significantly negative correlation between the soil Cd or Pb contents and the distance from the smelter ($p<0.001$) for both before and after smelter closedown (**Fig. 2**). The comparison of metal contents in soils from the smelter surrounding area with the reference soil values confirmed the great degree of metal soil contamination (**Table 2**). Most samples of soil originating from the smelter surrounding area had significantly higher Cd and Pb contents than the reference soils ($p<0.02$). Some of them were as much as 20 fold higher than the average concentrations of the reference soils. However, the metal contents measured in 2 soil samples collected from the furthest points to the smelter (5 and 5.6 km, respectively) tended to come close to that in reference soils.

2.2 Metal concentrations in cereals

Wheat grain and straw metal contents are presented in **Table 3**. Cd contents both before and after smelter closedown were significantly higher than in the reference sites ($p<0.05$). The straw Cd contents decreased significantly after the smelter closedown ($p=0.02$). The grain Cd contents did not show any decrease with the smelter closedown ($p=0.8$). The wheat grain had a significantly lower Cd content than the straw ($p<0.001$).

Table 3: Mean, standard deviation (SD), minimum and maximum values for Cd and Pb in wheat grain and straw sampled before and after smelter closedown, and in reference area. Results are expressed in mg kg^{-1} of dry weight

		Smelter area								Reference area			
		Before closedown				After closedown							
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Cd	Grain	0.43	0.21	0.13	0.82	0.45	0.24	0.13	1.05	0.11	0.03	0.09	0.14
	Straw	2.22	1.23	0.42	4.96	1.36	0.80	0.33	3.22	0.29	0.07	0.22	0.39
Pb	Grain	1.31	1.83	<0.2	8.30	0.23	0.08	<0.2	0.51	0.2	0.00	<0.2	0.2
	Straw	41.15	28.54	3.47	113.7	3.79	3.40	0.83	11.84	1.92	0.33	1.56	2.21

Before smelter closedown, the ratio of the mean straw Cd content over the mean grain Cd content was equal to 5 and diminished to 3 after closedown. There were some significant negative correlations between Cd contents in wheat grain and straw and the distance from the smelter before closedown ($p<0.001$, see Fig. 2). After smelter closedown, no more significant correlations were observed ($p>0.05$).

For Pb, the comparison of the straw coming from the smelter surrounding area before smelter closedown with the ones obtained from the reference sites showed that they had significantly higher Pb contents ($p<0.03$). Although the grain content was higher in wheat from the smelter surrounding area before closedown, no statistical difference was observed with the reference area ($p=0.3$). After the smelter closedown, no more differences with reference area values were measured for both straw and grain Pb contents ($p>0.05$). The wheat grain samples obtained from the smelter surrounding area were even under the detection limit (13 out of 15 samples). After the smelter closedown, the wheat grain and straw showed significantly lower contents ($p<0.02$). Similar to Cd, the wheat grain had significantly lower Pb contents than the straw ($p<0.001$). The ratio of the mean straw Pb content over the mean grain Pb content dropped from 31 to 16 with the smelter closedown. A significantly negative correlation was found between straw Pb content and the distance from the smelter before its closedown ($p<0.001$). In contrast, the grain Pb content did not show any significant correlation ($p=0.2$). Similar to Cd, no more correlations between Pb grain and straw contents and the distance from the smelter were found after smelter closedown ($p>0.05$).

2.3 Cd and Pb contents with regard to the European legislation

The relationships between topsoil and wheat contents were plotted in Figure 3 and compared with legislation limits.

Before smelter closedown, 76% and 84% of the wheat samples were over the foodstuff European legislation limit values for grain Cd and Pb contents, respectively. After smelter closedown, 80% and 13% of the samples were over the foodstuff limit values. As we have to consider the two metals altogether, 96% of the samples were over the legislation limits before closedown and 80% after closedown.

For feedstuff, no grain samples exceeded the Cd and Pb legislation limits before and after smelter closedown. However, for the straw, 84% of the samples were over the legislation limits for either Cd or Pb contents before closedown. After smelter closedown, 53% and 7% of the straw samples were over Cd and Pb legislation limits, respectively. If we consider the two metals altogether, 88% and 53% of the straw samples were over the feedstuff limits before and after smelter closedown, respectively.

Thresholds of agricultural soil contents above which the European legislation limits are not respected were obtained from the power models given in **Fig. 3**. For foodstuff, in the range of studied soil contents before the smelter closedown, the threshold value was 2.2 mg kg^{-1} for Cd. No power model was available for Cd after smelter closedown and, for Pb, both before and after smelter closedown. This was due to a lack of significant correlation amongst soil and grain contents. For feedstuff, European legislation limits were likely to be exceeded for the straw at 2.45 mg kg^{-1} for Cd and at

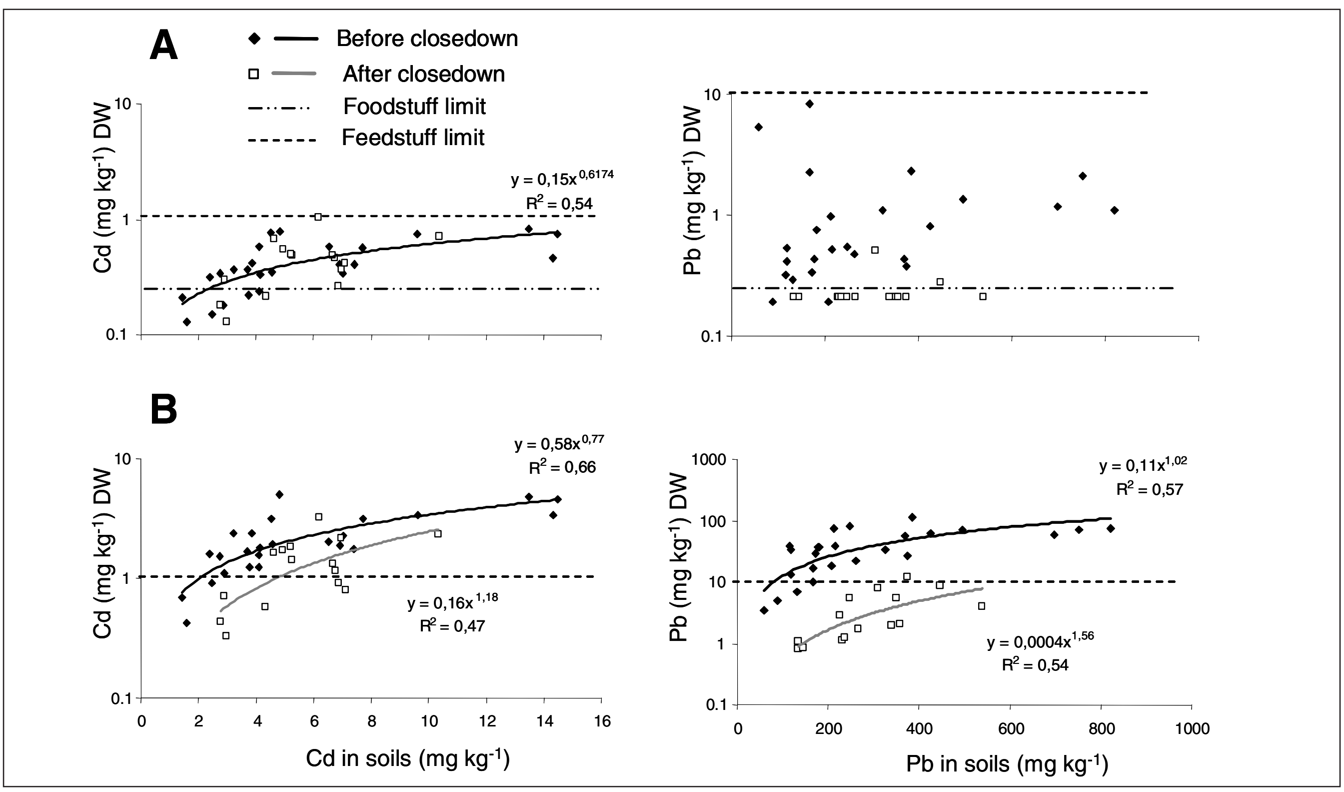

Fig. 3: Relations between soil and wheat Cd and Pb contents for grain (A) and straw (B). A power model is applied when there is a significant correlation amongst soil and grain or straw metal contents. Equations and determination coefficients are given. European legislation limits for foodsuff and feedstuff based on dry weight are shown in dotted lines. DW means dry weight

90.5 mg kg^{-1} for Pb before the smelter closedown. After the smelter closedown, the threshold increased and was 5.25 mg kg^{-1} for Cd.

3 Discussion

3.1 Soils

The reference area values were in accordance with the average background concentrations of Cd and Pb in the ploughed layer of uncontaminated agricultural soils of northern France (Sterckeman et al. 2006). Those last ones were obtained with the same analytical process as this study and were 0.41 mg kg^{-1} for Cd and 30.3 mg kg^{-1} for Pb. It allowed us to compare the reference area values with the smelter surrounding area values.

No decreases in topsoil metal contents were found after the smelter closedown. In fact, the samples were taken less than one year after the smelter had ceased its activity. Thus, it was too short a period to notice any difference in soil metal contents. Moreover, the mobility of those metals in soils is very low, especially for Pb which have a very low solubility and, thus, a long residence time in soils. It has been confirmed on the agricultural soils of the Metaleurop Nord smelter area by François et al. (2004), which evaluated the mobility of Pb in soils from chemical extractants (water, acetic acid). The half-life of Pb in soil has been estimated to range from 740 to 5900 years (Kabata-Pendias and Pendias 1992). However, Cd has been shown to have a higher solubility than Pb. But, as for Pb, this solubility in the studied soils is a function of the physico-chemical parameters of the soils such as pH, organic matter, carbonates, and particle size distribution (François et al. 2004).

In addition, we showed that metal contents in soils were correlated with the distance from the source. Similar results have been exposed by other authors that worked in the Noyelles-Godault area (Douay et al. 2001, Frangi and Richard 1997, Luttringer and de Cormis 1979). They showed that the concentrations of Cd and Pb in the soils around the smelter were inversely proportional to the distance from the source. Those authors demonstrated that the pollution in this area was closely related to the direction of the prevailing winds (SW and NE). It means that dust emission was one of the main factors of soil pollution in this area. Nowadays, although the smelter activity has ceased (and with it smokestack dust emissions), the contamination level of the soil will remain of concern due to the heavy metal persistence.

3.2 Metal concentrations in cereals

A first observation showed that metal contents of wheat grains obtained from the reference area were comparable to the results published in France (Mench et al. 1997), Sweden (Öborn and Eriksson 2002), and UK (Adams et al. 2001).

The smelter closedown did not result in a noticeable decrease in the wheat grain Cd content. The soil Cd mobility was probably allowing a large wheat uptake principally from the rhyzospheric system. It is known that much of the Cd taken up by plants is retained in the root, but a portion that is translocated to the aerial portions of the plant and into the seed (Grant et al. 1998). Mengel and Kirkby (1982) showed that the Cd transfer from soils to the edible parts of agricultural food crops is significantly greater than for other heavy metals (except for Zn). Our results showed the importance of the soil contamination in the case of wheat grain Cd uptake. In the meanwhile, the smelter closedown had a slight effect on the decrease of the straw Cd content. As the soil metal contents did not vary with the smelter closedown, the only possible variation of plant contamination resulted from the decrease of dust fallout. Thus, the lower straw Cd content had to be related with lower dust fallout. In fact, Dalenberg and Van Driel (1990) showed that the contribution of direct atmospheric deposition to the Cd concentrations of wheat straw was significant.

With regard to Pb, the smelter closedown led to an obvious decrease of the wheat grain and straw contents. The grain contents even reached the reference grain levels. This indicated that smelter dust emissions played an important role in the Pb contamination of the surrounding crops. It has previously been shown in the Upper Silesia region that soil was not the only source of contamination (Gzyl 1990). Deposition of contaminants from the atmosphere onto plant surface contributed greatly to overall contamination (Dudka et al. 1995, Gzyl 1990). These authors explained as well that the relative contribution of contaminant deposition from the atmosphere onto plants surface depends upon the degree of atmospheric contamination and the element type. Normally, more Pb comes from the atmosphere than Cd (Dudka et al. 1995). Dalenberg and Van Driel (1990) found that direct atmospheric deposition contributed considerably (up to 95%) to Pb concentrations in the wheat grain and straw. Similarly, Kachenko and Singh (2004), in their study on heavy metals contamination of vegetables, concluded that the elevated concentrations of Pb was probably a result of foliar uptake of aerial Pb deposit originating primarily from the nearby smelter. Indeed, dry and wet deposition of heavy metals on the aerial part of plants, and especially on the leaves, can contribute to their contamination (Gramatica et al. 2006). It can be considerable and may even exceed that of the uptake from soil (Moolenaar and Lexmond 1999). Zimdhal and Koeppe (2004) established that the Pb content in plant leaves is present mainly as surface coatings that are embedded in, or fixed to, the waxy cuticle of leaves. It seems that the Pb deposition and accumulation on plant leaves is the primary route of uptake of this non essential element (Pilegaard and Johnsen 1984). In a similar way as in our study, Westerheim et al. (2003) showed that levels of heavy metals (including Cd and Pb) in natural vegetation were decreasing after a copper smelter closedown. They stated that the high heavy metal levels recorded during smelter activity were mainly due to direct deposition on the plant tissue.

The ratio of the straw over the grain content was quite important for Pb and more moderate for Cd before smelter closedown. The storage organs seemed to be less metal accumulating than the foliar system. It has been previously shown by Weber and Hrynczuk (2000), who found that Cd and Pb contents of the wheat grains were almost ten times lower than those found in the straw. They stated that the low uptake and the low translocation of lead in the vegetative organs of wheat may result from lack of specific carriers (ion exchangers). Similarly, Barman et al. (2000) found that wheat cultivated in agricultural land irrigated with polluted effluents had lower Pb contents in grain than in stem and leaves. After smelter closedown, the ratio between straw and grain contents decreased by nearly half for both Cd and Pb. This diminution was due to a lower Cd and Pb content in straw and it emphasizes the importance of dust foliar contamination during the smelter activity.

3.3 Cd and Pb contents with regard to sanitary risks

The calculated soil threshold level above which wheat was likely to exceed the legislation was quite low (2.2 mg kg^{-1} for Cd for foodstuff and 90.5 mg kg^{-1} for Pb for feedstuff). Nonetheless, those values are corresponding to the French legislation (government decree 97-1133 of the 8^{th} of January 1998) which forbid the spreading of sludge in agricultural fields that present topsoil Cd and Pb contents over 2 and 100 mg kg^{-1}, respectively.

The results obtained for the first year after the smelter closedown showed a slight improvement for the grain and the straw metal contents in regard to the European legislation. They nevertheless should be validated by further studies to consider the possible variability linked to climatic conditions, cropping practices and wheat cultivars.

The question of the sanitary risks for humans and animals living in the surrounding area of the smelter was raised in regard to such results. Heavy metal pollution not only affects the production and quality of crops, but also influences the quality of the atmosphere and water bodies, and threatens the health and life of animals and human beings by way of the food chain (Cheng 2003). It is interesting to put side by side those results with epidemiologic data obtained from population living close to the smelter. In this industrial area, one of the main sanitary problems was due to high lead blood level. Indeed, it is known that lead can cause nervous system damage to young children (ATSDR 2005). From 1994 to 2002, 10 to 15% of children (2 to 4-years-old) living near the smelter had a level of Pb which exceeded 100 µg L^{-1} of blood (Declercq and Beaubois 2000, Leroyer et al. 2000). In the town situated close to the smelter and under the prevailing winds, it even reached 30%. In this period, despite a reduction of annual atmospheric emission (from 24 to 17 tonnes of Pb), the proportion of children showing a lead blood level over 100 µg L^{-1} remained stable. Recent measurements of children lead blood levels showed that only 2.4% were over 100 µg L^{-1} after the smelter closedown (Declercq et al. 2005). To conclude, if we join those data together with our results, it allows us to think that dust emission may have a role in the Pb population exposure as well as in the crop contamination.

4 Conclusions and Recommendations

This study showed a clear effect of the smelter closedown on the wheat Cd and Pb contents. More specifically, it highlighted a difference in metal accumulation in the plant organs as well as a difference in metal uptake. These results necessitate a validation with further sampling and, more specifically, to exclude variability due to climatic conditions.

In addition, the approach pointed out the importance of atmospheric fallout in the wheat contamination pathways for Pb. In the literature, very few articles are considering the dust deposit as contamination pathways for crop. The smelter closedown has led to the suppression of the major dust emission source. Nevertheless, considering their high contamination level, the surrounding soils represent a risk for the environment and the population health. The uncovered soils can be a source of contamination by run-off, erosion and dust emission. The French environment and energy management agency (ADEME) in charge of the polluted area around the former smelter excludes from agricultural production the most contaminated fields and stabilizes the soil by herbaceous and planted tree coverage.

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Conference Announcements

Genotoxicity in Aquatic Systems: Causes, effects and regulatory needs

2. International Symposium
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- Water Chemical Society
- Division of the German Chemical Society
- Working Group: Genotoxicity
- Federal Environment Agency (UBA)
- Federal Institute of Hydrology (BfG), Koblenz
- SETAC Europe German Language Branch

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29th New Zealand Land Treatment Collective (NZLTC) Conference

Decentralised Waste Management
Queenstown, New Zealand, 16th-18th April (www.ensisjv.com/nzltc)

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