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Temporal changes in the fluoride levels of jaws of European deer in industrial regions of Western Pomerania, Poland

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The factories processing natural phosphates and apatites in Poland release into the atmosphere considerable amounts of fluorine compounds. Fluoride is known to accumulate in the hard tissues of animals and humans. This paper describes the determination of fluoride in mandibles of deer in the years 1982 and 1990. In recent years, the establishments have restricted their output and modernized the technology of phosphate fertilizer production. The fluoride content in jaws has decreased, particularly in those animals having their habitat in the vicinity of the two factories.

Keywords: Deer, bone, fluoride, mineral composition, environment

Introduction

Two industrial establishments producing phosphate fertilisers are situated at the mouth of the river Odra (Figure 1). These plants emit into the atmosphere, amongst other substances, fluorine compounds that may exert unfavourable effects on the natural environment, since they easily accumulate in plants and the hard tissues of humans and animals (Dabkowska, 1987). Plants can absorb and retain gaseous fluoride from ambient air. This fluoride is then absorbed by animals eating the plants (Bunce, 1985) Fluoride changes the biophysicochemical properties of bones making them become harder and more fragile with abnormal crystalline structure.

Previous papers have suggested that breeding animals living in the forest have high fluoride contents in their bones and antlers (Dabkowska, 1987; Dabkowska and Machoy, 1989; Machoy *et al.*, 1991; Nowicka, 1992; Samujlo *et al.*, 1994). In the 1980s a progressive rise in production in both of these establishments was accompanied by steady improvements in the technology of phosphate fertilizer manufacture. This was intended to diminish industrial emissions in Western Pomerania.

To verify the efficiency of the technological changes introduced it was decided to compare the content of fluorine compounds accumulating in the lower jaws of deer killed in the forests in these and other regions, in two separate years, 1982 and 1990. The results presented here continue the previous investigations performed by our team (Machoy, 1987; Machoy *et al.*, 1991).

Materials and methods

Material for the investigation came from three forest districts of Western Pomerania in Poland: Trzebiez (T) where both of the phosphate fertiliser factories are situated, and two neighbouring forest districts, Goleniów (G) and Rokita (R) lying in the path of the prevailing winds, from west to east. The distribution of the individual forest areas is shown in Figure 2. The figure shows isolines of the concentrations of fluorine compounds in the air, expressed in $\mu g\ F\ m^{-3}$. They define the mean annual range of the distribution of fluorine compounds over the area studied in 1982 (No 1′, 2′, 3′) and 1990 (1, 2, 3) (Samujlo *et al.*, 1994). Figure 3 illustrates the spatial distribution of the mean annual concentration of fluorine compounds around the two industrial establishments in 1982 and 1990, accomplished by computer.

The distributions of mean annual concentrations were calculated by mathematical modelling of fluorine compounds' expansion in atmospheric air, on the basis of technical data of emitters (height of chimney, mean rate of gas flow and temperature of gases) (Chrusciel, 1985). The three forest districts (T), (G) and (R) were the sources of jaws of deer shot dead during hunting in 1982 and

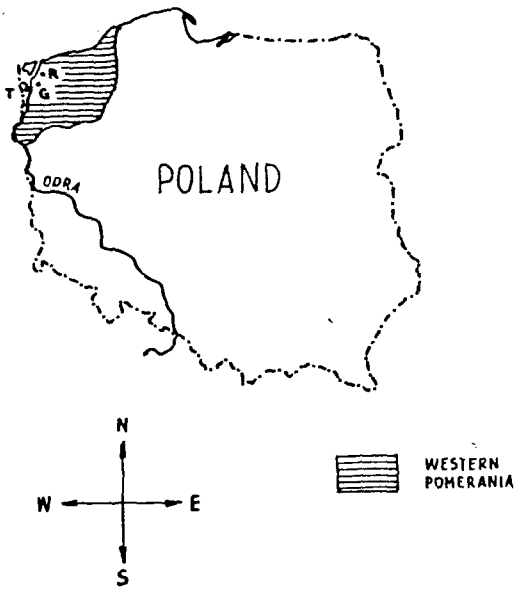

Figure 1 *Map of Western Pomerania's location inside the territory of Poland.*

1990. The cortical bone material of the dried mandibles (65°C) was pulverised for fluoride determination by a potentiometric method described by Durda *et al.* (1986).

The results were examined statistically to establish whether there were any significant differences in the fluoride content of bones between the years of 1982 and 1990, with reference to the various forest districts.

Results and discussion

The study was performed on 127 jaws of deer originating from three forest districts and divided into two age groups, of 0 to 4 years and over 4 years (Lochmann, 1987), as the fluoride content in bones increases with the animal's age (Wix and Mohamedally, 1980; Kierdorf *et al.*, 1989). The number of mandibles in the respective age groups for 1982 and 1990, the fluoride content (mg kg^{-1}), and statistical analyses of the results are shown in Table 1.

The quality of air in Poland is assessed by the permissible concentration of contamination expressed in μg m^{-3}. The normal value fixed for the mean annual fluorine concentration for protected areas in Poland is: $Sr = 1.6$ μg m^{-3}. Mean annual emission appears to be more objective than the periodic or 24-hour ones, since it is totally independent of seasonal fluctuations with regard to the production rate of chemical fertilisers. The dispersion of fluorine compounds is shown in Figure 2 and Figure 3. The isolines elongate in an easterly direction, reflecting the predominant winds blow-

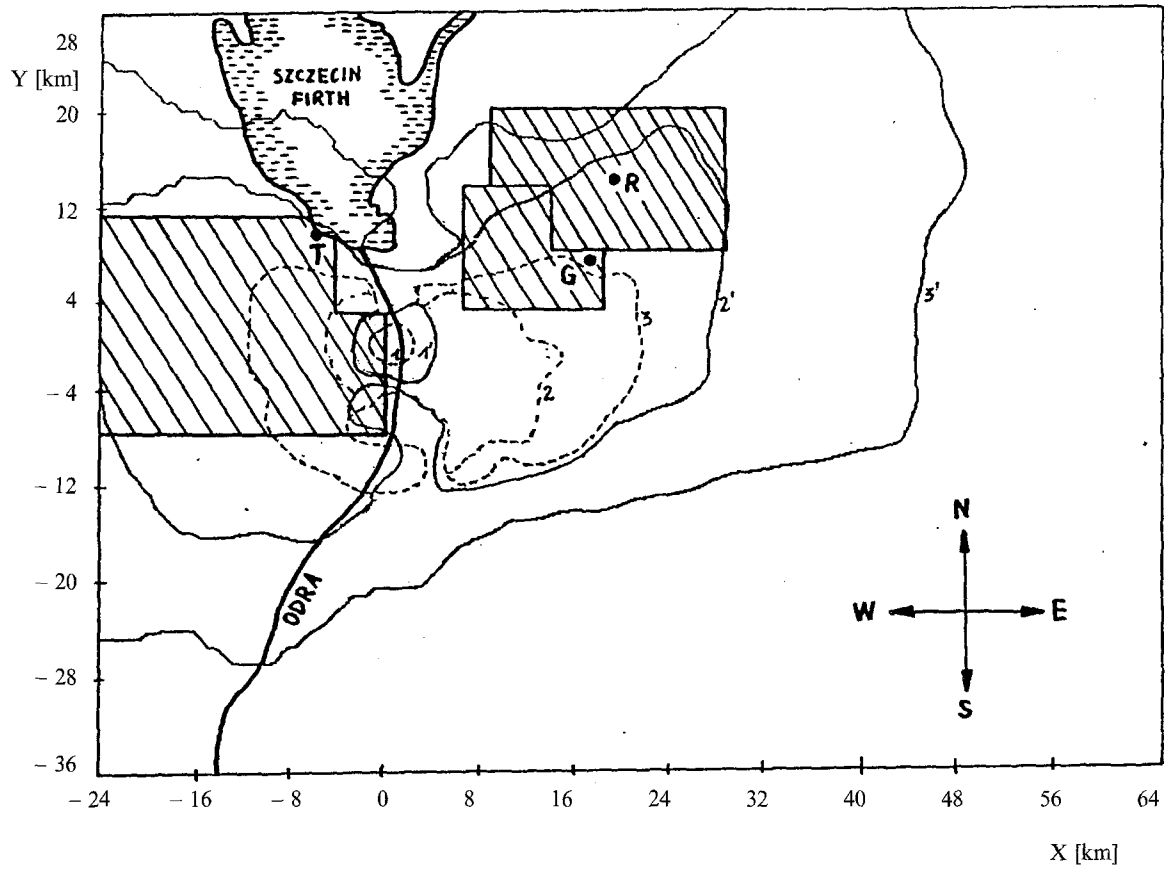

Figure 2 *Isolines of the concentration of fluorine compounds in air expressed in μg m^{-3} for the three forest districts in Western Pomerania (Poland). 1', 2' and 3' for 1982; 1, 2, 3 for 1990. 1 and 1', 1.6 μg m^{-3}; 2 and 2', 0.05 μg m^{-3}, 3 and 3', 0.02 μg m^{-3}.*

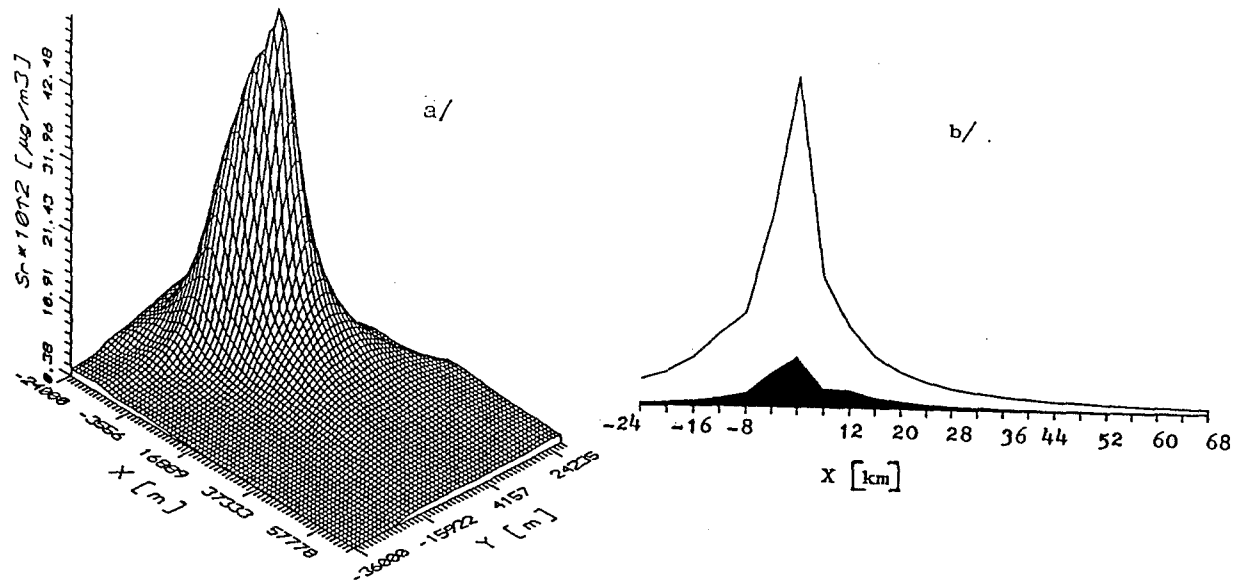

Figure 3 *Mean annual concentration (Sr 10^2) of fluorine compounds around the two plants. (a) spatial distribution in 1982, length and breadth is metres; (b) in profile projection (white field for 1982, black field for 1990), distance from emission source in kilometres.*

Table 1 *Content of fluoride of deer jaws (dry weight) from three forest districts of Western Pomerania, statistical description of variables and value of Student's* t*-test for the difference between mean values of fluoride in comparison.*

Forest district	Year	Age (years)	*n*	F mg kg^{-1}	SD	Median	Values of *t*-test	*p*
Trzebiez	1982	0–4	18	605	191.9	542.9	2.1312	<0.05
	1990		6	432.6	65.2	400.6		
Trzebiez	1982	>=4	6	1148.6	402.2	983.2	2.21037	<0.05
	1990		12	830.2	217.4	844.1		
Goleniów	1982	0–4	11	402.4	198.2	376.2	0.66951	>0.05
	1990		7	350.5	55.5	364.8		
Goleniów	1982	>=4	13	656.8	420.7	438.8	0.922463	>0.05
	1990		10	529.5	123.8	928.3		
Rokita	1982	0–4	15	313.2	101.2	344.8	1.16621	>0.05
	1990		4	1251.9	39.9	255.5		
Rokita	1982	>=4	15	531.2	126.0	547.0	1.20048	>0.05
	1990		10	474.8	95.9	425.3		

SD, Standard deviation, *p*, Level of significance.

ing from west to east. Figure 2 also shows the forest areas incorporated into the Trzebiez (T) forest districts, where the phosphate fertilisers factories are situated, and the neighbouring forest districts to the east (G) and (R).

Accumulation of fluoride was determined in the lower jaws of deer, whose habitat is in the areas of the various forest districts. Significant statistical differences between both age groups and between 1982 and 1990 were evident only in Trzebiez forest districts. This means that in the vicinity of the two factories, the diminution of emissions was reflected in the lowered fluoride content of deer lower jaws over time. In the (G) and (R) regions lying east of the sources of emission, mean values for both age groups were lower than at (T) and the differences were not statistically significant. More time is needed for normalisation in all regions since in industry-free areas the fluoride content of deer's jaws is found to be 3–4 times lower than at contaminated sites (Machoy *et al.*, 1991).

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