Phyton (Austria) Special issue: "Global change"	Vol. 42	Fasc. 3	(157)-(163)	1.10.2002

Air Pollution by Sulfur Dioxide in Poland - Impact on Agriculture

By

A. PODLESNA[1)]

Key words: Agriculture, agro-ecosystems, air pollution, crop quality, nitrogen oxides, sulfur exmission, sulfur dioxide.

Summary

PODLESNA A. 2002. Air pollution by sulfur dioxide in Poland - impact on agriculture. - Phyton (Horn, Austria) 42 (3): (157)-(163).

After the Second World War there was a tremendous increase in SO_2 emission in Poland due to fast industrialization and the use of low quality coal as energy source. High levels of SO_2 pollution have resulted in negative effects on natural and agro-ecosystems. On the other hand SO_2 has been beneficial as sulfur fertilizer for agro-ecosystems. From the end of the 80's onwards there has been an ongoing decrease in SO_2 emissions by a transformation of economy and legislation to reduce emissions, which already has affected the sulfur status of agro-ecosystems. From soil tests carried out in 1996 it became evident that over 70 % of Polish soils have a low, 15 % a medium and about 5 % a high sulfur content. Since SO_2 emissions are expected to further decrease in Poland, sulfur content of soils as well as plants needs to be monitored in order to guarantee optimized sulfur fertilization.

Introduction

The first report on the possible harmful effect of industrial pollutants on forests was issued in Poland in 1922 (WROBEL 1988). SO_2 has been the most important and widely spread air pollutant. Its source is combustion and chemical treatment of coal, rock oil, ores and another stocks, which contain high levels of sulfur (1-7 %). Especially after the Second World War there was a strong increase in industrialization, accompanied with increasing levels of SO_2 emission.

[1)] Department of Plant Nutrition and Fertilization, Institute of Soil Science and Plant Cultivation, Czartoryskich 8, 24-100 Pulawy, Poland.

SO_2 Emission Levels in Poland

In the middle of the 60's SO_2 emission was about 2 million tons and during the 70's the emission exceeded 3 million tons (Fig. 1). The highest emission values occurred around 1979/1980, viz. over 4 million tons of SO_2 per year, resulting in a deposition of 130 kg sulfur per hectare (KACZOR & KOZŁOWSKA 2000). During these years the SO_2 emission rate in Poland was two times higher than that in other European countries (DECHNIK & KACZOR 1985) and predictions indicated a continuous increase in emission of up to 9 million tons in 1989. During 1987-1989 the SO_2 emission was still approximately 4 million tons per year (NOWICKI 1993). At this time Poland emitted about 10 % of total SO_2 emission in Europe (Fig. 2). However, SO_2 emission steadily decreased since the beginning of 80's. The reduction occurred for different sources of pollution (Table 1) and was the consequence of political and economical changes, which had taken place in Poland during this period. During these years there was a temporary decrease in some industrial production activity. Furthermore the 1985 Protocol of Helsinki was implemented, which aimed at a reduction of environmental acidification by a decrease in SO_2 emission by 30 % to the end of 1993, taking the emission values of 1980 as basis (FOTYMA & BORECZEK 1998). Initially Poland did not sign the Protocol because contemporary predictions provided an increase of demand on energy and subsequently an increase in SO_2 emission. Though in 1994 Poland has signed the Protocol in Oslo and has promised to reduce the SO_2 emission to a level of 1397 thousand tons per year at 2010. In 1996 there was already a 43.5 % reduction of SO_2 emission in comparison to highest emission values in 1980 (KACZOR & KOZŁOWSKA 2000). Presently there is a further ongoing reduction in SO_2 emission in Poland.

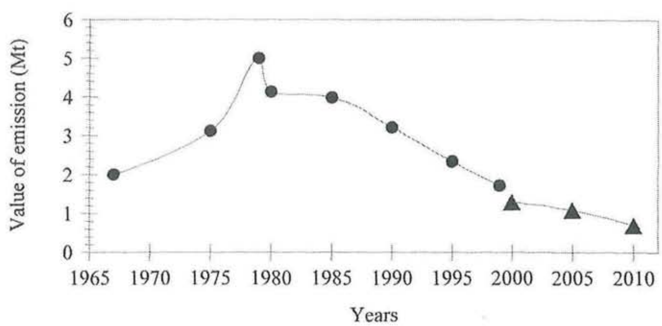

Fig. 1. Total SO_2 emission in Poland (DECHNIK & KACZOR 1985, Statistical Yearbook of the Republic of Poland. ●, Total emissions of SO_2; ▲, SO_2 emission limits according to Annex II of the Oslo Protocol.

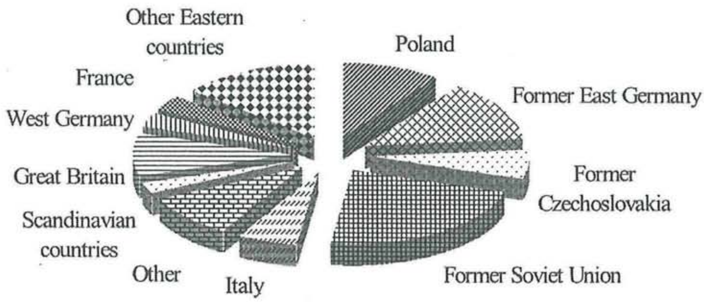

Fig. 2. SO_2 emission in Europe in 1987-1989 (NOWICKI 1993).

Distribution of SO_2 Emission in Poland

The distribution of air pollution in Poland is variable and highest pollution levels occur in the vicinity of big city agglomerations and in main industry districts. Decidedly the highest pollution occurred in the Katowice district, where in an area of 2.1 % of Poland, 20-25 % of SO_2, NO_x and dusts was emitted (NOWICKI 1993). Air pollution was also extremely high in the Kraków district. SAWICKA-KAPUSTA 1990 observed in 1980 in the agglomeration of Kraków an emission of 850 thousand tons of gaseous pollutants, amongst them were NO_x (640 thousand tons) and SO_2 (160 thousand tons). In 27 regions high air pollution levels formed a severe threat for the environment. In the 80's these regions covered about 35 thousand km^2, with about 13 million people living there. Probably only about 30 % of the population in Poland lived in areas with acceptable levels of air pollution (KASSENBERG & ROLEWICZ 1985). The government undertook action in order to change this drastic situation. New laws were accepted to preserve nature. In April 1998 the Ministry of Environmental Protection, Natural Resources and Forestry issued an instruction to regulate and implement permissible values of SO_2 concentrations (Table 2). This instruction designates: lists of pollutants and permissible values of their concentration, areas with individual permissible values and range and conditions which have to be maintained (MITOSEK & al. 1999).

Compliance with the obligatory rules on the level of emission and the concentration of SO_2 is extremely important, not only in the vicinity of its origin. Considering the mobility of SO_2 to distant regions it can harmfully affect an extensive area. In addition, other air pollutants are emitted at the production site, which might have an effect on the impact of SO_2 on natural and agro-ecosystems. It has been observed that combinations of SO_2 and NO_x, SO_2 and fluorine and SO_2 and dusts may have synergistic negative effects on plants (SAWICKA-KAPUSTA 1990).

Table 1. Total emissions of SO_2 in Poland according to the source of pollution. (Statistical Yearbook of the Republic of Poland).

Source	SO_2 (Mt)			
	1990	1993	1996	1999
Total	3.21	2.74	2.37	1.72
Energy production	1.57	1.29	1.20	0.92
Industrial technology	0.50	0.40	0.41	0.26
Other stationary sources	0.27	0.25	0.20	0.09
Mobile sources	0.87	0.80	0.56	0.45

Table 2. Permissible SO_2 concentrations in Poland for various time periods (MITOSEK & al. 1999).

Description	Permissible concentration ($\mu g\ m^{-3}$)		
	30 min.	24 h	year
Value valid till 1998	600	200	32
Value valid since 1998	500	150	40

Impacts of SO_2 Pollution on Agriculture

Sulfur is an essential element for plant growth and under normal conditions sulfate taken up by the roots is used as sulfur source. However, in polluted areas plants also may utilize foliarly absorbed SO_2 as sulfur source, which may be beneficial in the case of a sulfur deficit in the soil (SAWICKA-KAPUSTA 1990). About 15-30 % of total sulfur content in plants growing at optimal condition comes from the air, and up to 50-90 % of plants suffered from sulfur shortage (LITYNSKI & JURKOWSKA 1982). However, SO_2 also may be phytotoxic, though its harmful effects on plants depends on various factors (DECHNIK & KACZOR 1985):

1) external direct factors: degree of air pollution by sulfur dioxide, time and frequency its emission, presence of other pollutants in the atmosphere;
2) external indirect factors: humidity of environment, lightening of plants, type of soil, its physical and chemical properties and supply with other nutritive elements;
3) internal factors: species, variety, and stage of plant development.

High levels of SO_2 may result in direct injury of aboveground parts of plants, furthermore it may result in changes in chloroplast structure, cell membrane, disturbances in stomatal regulation, respiration and photosynthesis. Upon exposure for a prolonged period low levels of SO_2 also may affect plant functioning and development and its susceptibility to diseases and pests. Sensitivity of cultivated plants to SO_2 was studied in relation with very widespread environmental pollution over several years. On this basis there are three groups of plants can be distinguished which have a different tolerance to this gas (DECHNIK & KACZOR 1985):

- very sensitive: alfalfa, clover, buckwheat, white mustard
- middle sensitive: cereals - mostly oat and barley

- low sensitive: potatoes, oilseed rape and maize.

ZIMNY 1984 showed that air polluted with SO_2 could cause the following decreases in plant yields: 30-80 % for cereals, 20-80 % for sugar beet, and 20-60 % for spring oilseed rape and potatoes. Studies of WARTERESIEWICZ 1978 which were carried out over a 5 year period in regions with considerable SO_2 pollution confirmed a yield decrease of barley (10-40 %), alfalfa (10-35 %), bean (10-50 %) and potatoes (35-70 %). The highest losses were found at the highest SO_2 concentration in the air from 1.65 to 2.15 mg SO_2 cm^{-2} day^{-1}. High SO_2 pollutant levels also negatively affected crop quality, e.g. a loss of barley seed production and a decrease in starch content in potatoes.

Sulfur compounds which are emitted to the atmosphere pollute the soils directly by absorption and indirect by transmission of sulfur pollutants from the plant's surface by wind and rain (MOTOWICKA-TERELAK & DUDKA 1991). Numerous studies showed that the basic effect of these processes is acidification and connected with it chemical and biological degradation of soils (SIUTA & REJMAN-CZAJKOWSKA 1980, MOTOWICKA-TERELAK & TERELAK 2000). As the result these processes follow unfavorable changes in the plant's life environment. Excessive levels of sulfur in the atmosphere and high sulfur deposits resulting in soil acidification may affect the chemical composition of the plant. In general, it results in an increase in plant sulfur content whereas that of nitrogen and phosphorus decreases. This may lead to metabolic disturbances in plants and undesirable changes in protein and lipid structure. For instance, the quality of alfalfa proteins was very poor when plants were cultivated close to sulfur mines on soils polluted by elemental sulfur (BILCZUK & STANKIEWICZ 1983). High sulfur deposits and the subsequent soil acidification also may result in an increased rate of uptake of heavy metals as Cd, Zn, Pb and partly Ni (MOTOWICKA-TERELAK & TERELAK 1997). Crop products harvested from these areas often contain high amounts of heavy metals, which are toxic for people and animals.

Consequences of a Decrease in SO_2 Pollution on Agriculture

For the preservation of the environment a permanent monitoring of air pollution levels in essential. Valuation of the air pollution state in Poland carried on during 1998 showed that the mean values of SO_2 concentration outside the cities were 2-40 µg m^{-3} and that at the majority of stands the concentrations were lower than 10 µg m^{-3}. Also the mean values of day's SO_2 concentration measurements in cities and outside them were lower than the half-permissible value, in 98 % of the cases (MITOSEK & al. 1999). The highest sulfate concentration in rainwater ranged from 0 to 37 mg SO_4^{2-} dm^{-3} and mean yearly sulfur deposition to the soil was in the range of 58-80 kg ha^{-1} (TERELAK & MANKO 1995). These date are from the years 1981-1993. They were obtained at Experimental Stations of the Institute of Soil Science and Plant Cultivation. The results obtained by Regional Stations of Chemical and Agricultural Studies showed a considerably wider range of sulfate content in the humus horizon of Polish soils (MOTOWICKA-TERELAK & TERELAK 2000). According to these data in the middle of 90's S-SO_4^{2-} content ranged from 0.0001 to 0.775 mg g^{-1} of soil, with a mean 0.0179 mg g^{-1}. It shows that soils in the greater part of Poland (58 %) have a low content of S-SO_4. However, from the minimal value 0.0001 and the mean >0.02 mg S-SO_4^{2-} g^{-1} it is likely that sulfur deficit in soils is greater. The soil analysis by MICHNA & al. 1997 done in 1996 showed that over 70 % of soils had a low, 15 % a medium and about 5 % a high sulfur content. This can be explained by the following factors: increased intensity of agricultural production, reduction of SO_2 emission, lower mineral nutrition and a domination of light soils. From these studies it appears that the contribution of soils with a higher sulfur concentration as a result of human activity was 8 % of studied samples (MICHNA & al. 1997). This was confirmed by measurements of sulfur content of 2685 samples of carrot, potatoes, cereals and cabbage. The obtained results showed that only 2.5 % of tested plant products showed exceeding of threshold values of sulfur and they concerned mainly cabbage, particularly from the southern region.

Based on the latest results it is possible to summarize that environmental protection and agricultural as well as industrial production have to be under control. From the agricultural point of view an adequate sulfur supply of plants is important and in the next years it will probably become necessary to use mineral fertilizers.

References

BILCZUK L. & STANKIEWICZ Z. 1983. Assessment of biological value of alfalfa cultivated at region of sulfur mine in Tarnobrzeg (in Polish). - Arch. Ochr. Srod. 1-2: 95 - 107.

DECHNIK I. & KACZOR A. 1985. Yielding of plants at conditions of air pollution by sulfur dioxide. - Post. Nauk Roln. 2/3: 61 - 68.

FOTYMA E. & BORECZEK B. 1998. Sulfur – menace or deficit element in agriculture (in Polish). - Wieś jutra. 5: 21 - 22.

KACZOR A. & KOZLOWSKA J. 2000. The influence of acid rains on agroecosystems (in Polish). - Filia Univ. Agric. Stetin. 204, Agricultura, 81: 55 - 68.

KASSENBERG A. & ROLEWICZ CZ. 1985. Diagnose of natural environment state in Poland (in Polish). - Nauka Pol. 1-2: 197 - 200.

LITYNSKI T. & JURKOWSKA H. 1982. Soil fertility and nutrition of plants (in Polish). - PWN Warszawa:191 - 204.

MICHNA W., BOGUSZEWSKA M., BYKOWSKI P., DABROWSKI J.,. OBIEDZINSKI M., SOBCZAK K., SZTEKE B. & ZMUDZKI J. 1997. Report from monitoring study on quality of soils, plants, agricultural products and foodstuffs in 1996 (in Polish). - Panstwowa Inspekcja Ochrony Srodowiska, Biblioteka Monitoringu Srodowiska: 18 - 96.

MITOSEK G., SKOTAK K., IWANEK J., SIWEK U. & PRZADKA Z. 1999. Assessment of air pollution state in Poland in 1998 on the base of measurements of basal network (in Polish). - Inspekcja Ochrony Srodowiska, Biblioteka Monitoringu Srodowiska: 21 - 40.

MOTOWICKA-TERELAK T. & DUDKA S. 1991. Chemical degradation of soils polluted with sulfur and the influence of soil degradation on field crops (in Polish). - Instytut Uprawy Nawozenia i Gleboznawstwa, Pulawy, R (284).

— & TERELAK H. 1997. The effect of soil pollution with sulphur on the chemistry of field crops. - Polish J. Environ. Studies. Supl. 6:113 - 115.

— & TERELAK H. 2000. Phytotoxicity of aluminium, cadmium and zinc in sulphur polluted soil (in Polish). - Zesz. Probl. Post. Nauk Roln. 472: 517 - 525.

NOWICKI M. 1993. Air pollution (in Polish). - In: ANDRZEJEWSKI R. & BARANOWSKI M. (Eds.), State of environment in Poland, Państwowa Inspekcja Ochrony Srodowiska, Centrum Informacji o Srodowisku GRID - Warszawa: 66 -71.

SAWICKA-KAPUSTA K. 1990. Plant reaction to sulphur dioxide and heavy metals pollution in the environment – bioindication (in Polish). - Wiad. Ekolog. 26: 95 - 109.

SIUTA J. & REJMAN-CZAJKOWSKA M. 1980. Sulfur in biosphere (in Polish). - PWN i L. Warszawa: 47 - 80.

TERELAK H. & MANKO P. 1995. Composition of atmospheric precipitation in the Puławy area (in Polish). - Pam. Puł. 106: 149 - 156.

WARTERESIEWICZ M. 1978. Sulphur dioxide effect on plants (in Polish). - Zesz. Probl. Post. Nauk Roln. 206: 29 - 42.

WROBEL S. 1988. Acid rains and their effect on surface waters in Poland (in Polish). - Aura. 4: 8 - 9.

ZIMNY H. 1984. Plant cultivation at zone of industrial emission (in Polish). - Aura. 10: 24 - 26.