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EVALUATION OF EFFECTS OF SULPHUR COMPOUNDS ON THE SOIL ENVIRONMENT

Soil acidification by sulphur compounds and difficulties in determining soil losses due to that process are presented. The most effective method of neutralizing the acidification – limimg, i.e. the quantitative indicator of soil degradation rate – is characterized. In the final part of this paper the calcium oxide dose necessary to neutralize sulphuric acid arising in the soil as well as the method of soil losses evaluation are presented.

The present study, basing on Polish and foreign literature, is an attempt to determine the indicator of losses in the soil environment. This indicator is expressed by a correlation between sulphur dioxide concentration in the air and changes in soils (acidification).

Soil – the most permanent component of the environment – is submitted to a slow degradation due to atmospheric pollutants. The impact of these pollutants is revealed in slow, direct changes of soil properties, particularly chemical, and in more rapid, indirect changes in the plant cover.

Sulphur pollutants cause soil acidification and have an effect on its fertility, which can be observed in the following processes:

leaching of the organic matter,

mobility increase of most of the elements,

increase of the loamy minerals losses,

changes of cation exchange capacity,

increase of the nutrients stream flowing through the ecosystem adjacent to the soil and aqueous ecosystem below the soil zone,

decrease of the nitrogen availability to plants because of the high concentrations of hydrogen ions,

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increase of aluminium and manganese solubility and their toxicity as well as inhibition of plants growth,

decrease of important nutrients availability to plants.

It is very difficult to distinguish damages due to the direct effect of sulphur compounds on plants from damages due to the indirect effect of soils. It is also very troublesome to find explicit correlation between sulphur dioxide concentrations in the air and the time and range of changes in the soil [2], [8], [11], [14] .

Because of a great differentiation of soil environment and reactions in the atmosphere, model studies of soil acidification are very difficult. They concern only selected regions of Poland, Canada, the United States of America, Sweden and German Federal Republic [1], [3], [4], [13], [15], [16], and the findings are various.

The total soil degradation (acidification) rate is estimated in different ways [10]. Some scientists state that soil acidification by atmospheric sulphur, lasting from ten to twenty years, may change soil pH by one unit, the others find it impossible before one hundred years.

Total soil degradation depends on the soil type and class of the mean annual sulphur dioxide concentrations.

Free calcium carbonate content and the percentage base saturation of soil influence considerably soil resistance to acidification [5]-[7] .

McFEE [6], [7] has presented a theoretical method of determining soil pH changes in a particular time due to acid precipitation with known pH. In that case full information about the soil can be obtained.

In another conception (SIUTA [12]), the author has given a decagrade scale of soil resistance. The scale includes basic cations content that may be converted to tons of sulphuric acid that generates partial or total soil degradation. Similarly to McFee's method, Siuta's conception can be used only to theoretical determination of soil acidification and neutralization rates. Both the methods were utilized to calculate soil degradation indicator.

The most effective way to neutralize the soil acidification is the application of calcium carbonate. Up till now it is the only quantitative assessment of this phenomenon. Calcium carbonate doses depend on soil texture, organic matter content and acidification degree. In calculation of these doses for agricultural purposes (in kilograms of calcium carbonate per hectare or kilograms of calcium oxide per hectare), total hydrolytic acidity expressed in milliequivalent per one hundred grams of soil must be used.

In SOWEP research [9] , [10] , sulphur dioxide concentrations in the air were converted to a stream reaching the ground. A general settling velocity indicator was assumed for the whole country (data of Institute of Environmental Engineering of the Technical University of Warsaw). Afterwards the values obtained were converted to sulphate ions (in tons per square kilometres a year), and then to arising sulphuric acid (table 1). Basing on these theoretical, values the calcium oxide dose necessary to neutralize arising acid can be detrmined:

$$H_2SO_4 + CaCO_3 \longrightarrow CaSO_4 + H_2CO_3.$$

Table 1

Class of mean annual SO_2 concentrations ($\mu g/m^3$)	0–10	11–20	21–50		51–100		> 100
Class of SO_2 stream reaching the ground (t/km^2 year) (mean values for agrocenosis)	0–10 (6.3)	11–20 (12.6)	11–20 (20.0)	21–50 (31.5)	21–50 (50.0)	51–70 (63.0)	> 70 (> 63.0)
Annual stream of sulphate ions (t/km^2 year)	to 9.45	to 18.9	to 30.0	to 47.25	to 75.0	to 94.5	> 94.5
Amount of H_2SO_4 (t/km^2 year)	to 9.6	to 19.3	to 30.6	to 48.2	to 76.5	to 96.4	> 96.4
CaO dose required to neutralize H_2SO_4 rising in the soil during one year (t/ha year)	to 0.06	to 0.12	to 0.18	to 0.29	to 0.46	to 0.58	> 0.58
Approximate amount of 45 % calcium fertilizers	20 t/km^2 (0.2 t/ha)	25.2 t/km^2 (0.25 t/ha)	40 t/km^2 (0.4 t/ha)	63 t/km^2 (0.6 t/ha)	100 t/km^2 (1 t/ha)	126 t/km^2 (1.3 t/ha)	126–200 t/km^2 (1.3–2 t/ha)

Table according to SOWEP data.

Table 2

Classes of SO_2 concentration $\mu g/m^3$	CaO neutralization dose t/ha year	Mean cost of agricultural treatment, zł (1982)	Cost of liming per 1 ha	Cost of liming per 1 km^2
0–10	0.06	6660	399.6	39960
11–20	0.12	6660	799.2	79920
21–50	0.18	6660	1198.8	119880
	0.29	6660	1931.4	193140
	0.46	6660	3063.6	306360
51–100	0.58	6660	3862.8	386280
> 100	> 0.58	6660	> 3862.8	> 386280

As a result of this reaction a slightly soluble calcium sulphate arises. Carbonic acid is unstable and disintegrates into carbon dioxide and water. In this way sulphuric acid ion becomes immobilized and hydrogen ion become fixed with a particle of water.

Basing on the data of Ministry of Agriculture and Institute of Agriculture and Catering Economy a general calculation of liming costs was presented. The following data were used in the first calculation:

cost of the service converted to one ton of lime (40°/o calcium oxide) – about 660 zł,

cost of one ton of lime (40°/o calcium oxide) – about 450 zł,

government subvention to the production and price paid by the farmers – about 1500 zł.

In convertion to 100°/o pure component it makes about 6540 zł per one ton.

An analysis of costs for fifty standard collective farms was used in the second calculation. The costs of spreading of one ton of calcium fertilizer (40°/o calcium oxide) equals about 765 zł. In convertion to 100°/o pure component it makes about 6788 zł.

The mean cost of spreading of one ton of calcium fertilizer in pure component equals 6660 zł. The convertion to doses necessary to neutralize different streams of sulphur dioxide is shown in table 2.

Sum of the costs of neutralization in areas of different sulphur dioxide stream classes is equal to the annual total cost of sulphur dioxide neutralization. In order to calculate the total liming costs of all soils in Poland, the cost of neutralization of sulphur dioxide coming from the atmosphere and the cost of neutralization of soil acidification due to the fertilization and natural processes should be taken into account.

Losses in soil environment in 1984 due to the acidification were calculated according to this method. The mean annual sulphur dioxide concentration for Poland equals to 23 $\mu g/m^3$, and the mean cost of liming of 1 ha for particular concentrations class (21–50 $\mu g/m^3$) were taken into account. The mean value of losses equals about 2.4×10^{10} zł a year. Though it is only an approximate value, it illustrates the problem of soil acidification and economic losses due to the effect of sulphur compounds on the soil. The total cost of soil liming in Poland will increase four to five times, to one hundred miliard zł a year.

In the world literature a great variety of opinions concerning the soil acidification due to sulphur dioxide and acidification due to agricultural treatments is noted (locally the last is several times higher).

The soil losses indicator presented above is helpful in estimating the approximate values, so the soil processes that proceed simultaneously with the acidification and correlate the sulphur dioxide stream reaching the soil with the sulphuric acid rising in it should be determined. Many other factors should also be taken into account, for example the yield losses and losses due to the nutrients leaching.

REFERENCES

[1] *Acidification today and tomorrow,* a Swedish study prepared for the 1982 Stockholm Conference on the Acidification of the Environment, Ministr. of Agriculture Envir. 1982 Committee.

[2] FALLER N., HERWIG K., *Untersuchungen über die SO_2-oxydation in verschieden Böden,* Geoderma 3, 1968.

[3] GLASS N.R., ARNOLD D.E., GALLOWAY J.N., HENDREY G.R., LEE J.J., McFEE W., NORTON S.A., POWERS C.F., RAMBO D.L., SCHOFIELD C.L., *Effects of acid precipitation,* Environ. Sci. Technol., Vol. 16 (1982), No. 3.

[4] HALSTEAD R.L., RENNIE P.J., *Sulphur and its inorganic derivates in the Canadian environment.* Part III. *The effects of sulphur on soils in Canada,* Ass. Com. on Scien. Criteria for Env. Qual., 1977.

[5] LEE J.J., WEBER D.E., *Effects of sulphuric acid rain,* Report 1980, EPA-600/9-80-014.

[6] McFEE W.W., *Effects of atmospheric pollutants on soils. Sensitivity of soil regions to acid precipitation,* Environ. Sci. Res., 17, 1980.

[7] McFEE W.W., KELLY J.M., BECK R.H., *Acid precipitation effects on soil pH and base saturation of exchange sites,* Water, Air and Soil Pollution, Vol. 7 (1977), No. 3.

[8] NYBORG M., PARKER W.R., HODGINS W.L., LAUERTY H.D., TAKYI S., *Soil acidification by SO_2 emissions in Alberta, Canada,* presented at Norway Sci. Ind. Research Council at Al. ECO Impact of Acid Precipitation Conf. Norway, 1980.

[9] REJMAN-CZAJKOWSKA M., TRUSZKOWSKA R., WALSZCZAK L., TOKARSKI R., *Opracowanie koncepcji ustalania wskaźników syntetycznych. Wykorzystanie systemu informatycznego BIGLEB do uzyskania zintegrowanych wskaźników wpływu energetyki na środowisko,* 7th branch of Government Program-8: Environmental Protection, Warsaw 1982.

[10] REJMAN-CZAJKOWSKA M., *Metody oceny i wyceny zmian w środowisku przyrodniczym powstających pod wpływem energetyki,* 7th branch of Government Program-8, OBERGE, Warsaw 1983, 1984.

[11] SIUTA J., REJMAN-CZAJKOWSKA M. et al., *Siarka w biosferze, (Sulphur in biosphere),* PWRiL, Warsaw 1980.

[12] SIUTA J., *Znaczenie odporności gleb na degradację w gospodarce zasobami środowiska przyrodniczego,* IKS, Warsaw 1976.

[13] STRZYSZCZ Z., *Oddziaływanie przemysłu na środowisko glebowe i możliwości jego rekultywacji,* Kom. Ochr. Środ. Reg. Przem., PAN, Katowice 1982.

[14] *Sulphur pollution and soils. Sulphur in the environment.* Part II: *Ecological impact,* collective research, 1978.

[15] ULRICH B., MAYER R., KHANA P.K., *Frocht an chemischen Elementen in den Niederschlagen in Solling,* Zeitschrift für Pflanzen Boden, Vol. 142 (1979).

[16] ULRICH B., MAYER R., KHANA P.K., *Chemical changes due to acid precipitation in a loss-derived soil in Central Europe,* Soil science, Vol. 130(1980), No. 4.

OSZACOWANIE WPŁYWU ZWIĄZKÓW SIARKI NA ŚRODOWISKO GLEBOWE

Poruszono problem zakwaszenia gleby przez związki siarki i przedstawiono trudności w określeniu strat gleby powstałych w wyniku tego procesu. Scharakteryzowano najskuteczniejszą metodę neutralizacji zakwaszenia – wapnowanie, które jest ilościowym wskaźnikiem degradacji gleby. Określono dawkę tlenku wapnia potrzebną do zneutralizowania kwasu siarkowego powstającego w glebie oraz przedstawiono metodę szacunku strat gleby.

DIE ABSCHÄTZUNG DES EINFLUSSES VON SCHWEFELVERBINDUNGEN AUF DAS BODENMEDIUM

Die anwachsende Bodensäuerung durch Schwefelverbindungen wird besprochen und die dabei entstandenen Schwierigkeiten, die nachfolgenden Bodenverluste abzuschätzen, werden hingewiesen. Das mit Erfolg angewandte Entsäurungsverfahren ist auf der Neutralisation der im Boden entstandenen Schwefelsäure mit optimalen Kalziumdioxiddosen gestützt. Eine Methode zur Wertabschätzung der Bodenverluste wird vorgeschlagen.

ОЦЕНКА ВЛИЯНИЯ СОЕДИНЕНИЙ СЕРЫ НА ПОЧВЕННУЮ СРЕДУ

В статье затронута проблема заквашивания почвы соединениями серы и представлены затруднения в определении потерь почвы, возникших в результате этого процесса. Охарактеризован наиболее эффективный метод нейтрализации заквашивания - известкование, которое является качественным показателем деградации почвы. Определена доза окиси кальция, необходимая для нейтрализации образующейся в почве серной кислоты, а также представлен метод оценки потерь почвы.