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# CHANGES IN THE CONTENTS OF ORGANIC CARBON IN THE LIGHT SOIL FERTILISED WITH SEWAGE SLUDGE, SUGAR-BEET WASHING EARTH, AND STRAW ASH

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A b s t r a c t. Sugar-beet washing earth (1), ash from a straw combustion furnace (2), and a mixture of both those waste products (3) were added once to pots with light soil. Subsequently, lime stabilised sewage sludge from a treatment plant in Zamość, was added in the amounts equal to 2 and 5% of the soil weight. The control "0" contained no sludge. On those substrata, maize was grown in a three-year monoculture. In the beginning and at the end of the study, the level of organic carbon content in the soil, as well as its fraction soluble in 0.1 M $Na_4P_2O_7$ + 0.1 M NaOH and 0.05 M $H_2SO_4$ was determined.

It was determined that sewage sludge had the greatest effect on the organic matter, the effect of other waste products were far less pronounced. Sludge addition increased the level of organic carbon proportionally to the amount of sludge used. The absolute content of carbon compounds soluble in pyrophosphate and sulphuric acid also increased, but the proportion of both those fractions in the total amount of organic carbon decreased. It has been established that after three years, the process of slugged organic matter transformation into the humus was already noticeable. Carbon to nitrogen ratio improved and humic acids condensation also increased, while the proportion of mobile compounds (fulvic acids and compounds extracted with $H_2SO_4$) decreased, which indicates organic matter stabilisation. A strong correlation between the amount of carbon fractions and maize yield, as well as many other characteristics of the soil and the plants were established.

K e y w o r d s: organic matter, fractions of humus, lime stabilised sewage sludge, sugar-beet washing earth, ash from a straw combustion furnace.

## INTRODUCTION

Balance of organic carbon in the ecosystems deteriorates constantly as a result of climatic changes, deforestation, and enlargement of farming areas. The above changes are not conducive to humus accumulation [2]. Therefore, a rational management of field organic matter, as well as stimulation of its increase are necessary. This is especially true for the soils in our climatic zone, as they are poor in humus. Moreover this humus is characterised by a high proportion of fulvic acids. That is why, according to Turski [12], "... observation of all the ecological rules should aim at restoring organic compounds of the biological cycle from all possible sources". Those possible sources include such waste products as washing earth or sewage sludge which is a rich source of humus-forming substances. Therefore, one of the aims of the study presented here was to determine the effect of sewage sludge and other agrogenic wastes on the changes in organic substance of the soil on which maize, a plant that exerts a negative effect on the humus balance, was grown.

## MATERIALS AND METHODS

A three-year experiment was carried out in the Institute of Agricultural Sciences in Zamość, Agricultural University of Lublin. In the spring of 1996, pots with 8 kg of control soil (light loamy sand) were once supplemented with: (1) sugar-beet washing earth from Werbkowice at a dose of 100 g kg$^{-1}$ dry soil (equivalent to 280 Mg ha$^{-1}$ dry weight, i.e. an optimum amount for field fertilization as established in other experiments [8]); (2) ash from a straw combustion furnace in the amount of 0.31 g DM kg$^{-1}$ dry soil (equivalent to 0.9 Mg DM ha$^{-1}$, i.e. an average amount remaining after one heating season in a farm which uses a PM-35 heater); (3) a mixture of both of the above wastes in the amounts given above. The substrata so obtained were enriched with a 2 and 5% doses of sewage sludge, with a "zero" variant containing no sludge. The obtained combinations are presented in Fig. 1.

<table>
<tr><th>0<br>with no sewage sludge</th><th>2%<br>sewage sludge</th><th>5%<br>sewage sludge</th></tr>
<tr><td colspan="3">soil</td></tr>
<tr><td colspan="3">soil + sugar-beet washing earth</td></tr>
<tr><td colspan="3">soil + ash from a straw combustion furnace</td></tr>
<tr><td colspan="3">soil + sugar-beet washing earth + ash from a straw combustion furnace</td></tr>
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**Fig. 1.** Outline of the experiment.

In the experiment, lime stabilised sewage sludge was used. According to Sloan and Basty [9], it is better suited for farming purposes than fermented sludge. It was produced in a sewage treatment plant in Zamość. The amounts applied (i.e. 20 and 50 g DM sludge $kg^{-1}$ soil) were followed standard agronomic doses and corresponded to 56 and 140 Mg DM $ha^{-1}$. The content of heavy metals as well as the sludge sanitary condition allowed for its use in farming.

Maize was grown in the pots protected from rain and watered with distilled water in a three-year monoculture. It was harvested in the early dought stage.

The level of organic carbon (according to Tiurin) [6], and its fraction soluble in 0.1 M $Na_4P_2O_7$+0.1 M NaOH and 0.05 M $H_2SO_4$ (Kononowa-Bielczikowa's method) [6] were determined at the beginning and at the end of the experiment. Humic and fulvic acids, and humins were used for the interpretation of results meant the compounds obtained according to the methods of humus fractioninig. Strictly speaking, they were not only carbon compounds of the humus, but also carbon compounds of the organic matter added into the soil and having the same solubility in the extraction solutions used. Characteristics of the organic matter used in the experiment: soil, washing earth, and sewage sludge are presented in Table 1.

Additionally, at the end of the first vegetation season the number of heterotropic microorganisms (basing on the number of colonies grown on agar media), and intensity of microbial respiration measured as the amount of the released $CO_2$ (Maciak's method) were determined. Soil analyses were carried out according to the standard procedures of agrochemical laboratories. Total heavy metal content was analysed by flame atomic absorption spectrometry (AAS) after hot *aqua regia* digestion of the solid sample.

The present study was carried out according to the split-plot model in three replications; the results were analysed statistically.

**Table 1.** Organic matter characteristics in the control soil, washing earth and sewage sludge

| Substrata | C:N | Total organic C ($g\ kg^{-1}$ soil) | Percentage of C in total organic C | | | | |
|---|---|---|---|---|---|---|---|
| | | | extracted with 0.1 M $Na_4P_2O_7$+0.1 M NaOH | | | Extracted with 0.05 M $H_2SO_4$ | $E_4$:$E_6$ humic acids |
| | | | HA | FA | non hydrolysable C | | |
| Soil | 16 | 6 | 11.5 | 32.4 | 56.1 | 11.1 | 3.9 |
| Sugar-beet washing earth | 10 | 15 | 10.4 | 37.7 | 55.4 | 6.2 | 4.4 |
| Sewage sludge | 7 | 256 | 4.7 | 37.4 | 57.9 | 8.8 | 6.1 |

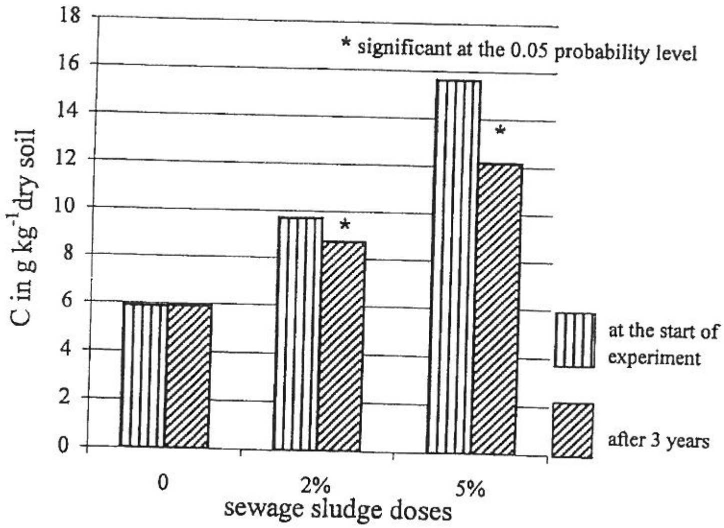


**Fig. 2.** Changes in the content of organic C in the substrata a result of sewage sludge.

## RESULTS AND DISCUSSION

Addition of sewage sludge rich in organic matter (Table 1) to the soil had a double effect. It increased the organic carbon level in the substrata proportionally to the dose, simultaneously, but to a lesser degree, intensifying mineralisation processes. This is why after three years of the experiment, the amount of carbon in the combinations with the sludge lower dose was higher by 50%, while in the combinations with its higher dose, by 100%, even though carbon losses in those pots were the highest. The observed intensification of decomposition processes resulted from an increase in the soil microbiological activity, usually took place after addition of fresh organic matter [5,10,12]. Lime stabilised sewage sludge decomposes only slightly before its application, so it contains large amounts of oxidable organic carbon [9] which is a good culture medium for microorganisms. This is why their numbers and also the intensity of microbial respiration increased so significantly in the pots containing sewage sludge (Fig. 3).

Addition of sludge containing a biomass of heterotrophic organisms with a characteristic, narrow C:N ratio resulted in an understandable narrowing of the carbon to nitrogen proportion in the substrata (Tables 1 and 2). Its values show a tendency to become closer to the values characteristic of humus substances

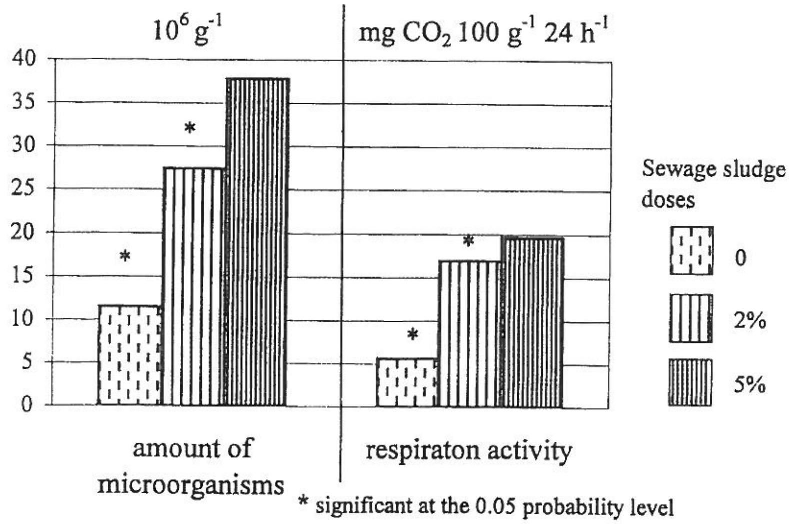


**Fig. 3.** Effect of sewage sludge on some indices of microbial activity in the substrata.

T a b l e 2. Effect of sewage sludge on some organic matter characteristics in the studied substrata in 1996 and 1998

| Rate of sewage sludge (%) | C:N | | $E_4:E_6$ humic acids | | 0.05 M $H_2SO_4$ extractable C | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | g kg$^{-1}$ soil | | % total org. C | |
| | 1996 | 1998 | 1996 | 1998 | 1996 | 1998 | 1996 | 1998 |
| 0 | 10.0 | 11.8 | 5.5 | 3.8 | 0.65 | 9,53 | 11.3 | 9.1 |
| 2 | 8.9 | 11.1 | 6.6 | 3.7 | 0.83 | 0.53 | 8.7 | 6.2 |
| 5 | 8.6 | 9.1 | 6.4 | 4.0 | 1.24 | 0.67 | 8.1 | 5.6 |
| Mean | 9.2 | 10.7 | 6.2 | 3.8 | 0.91 | 0.58 | 9.4 | 7.0 |
| $LSD_{0.05}$ | | | | | | | | |
| between years | 0.8 | | 0.4 | | 0.06 | | 0.6 | |
| years x dose of sludge | - | | 0.6 | | 0.10 | | 1.2 | |

already after three years. That allows us to presuęing processes had already started. Additionally, heteropolymodepends on the amounts of its components and proportions between them. According to Kononowa [5], free substances and substances associated with calcium or with silicate-free $R_2O_3$ forms are the most active components of the humus. They make up a sum of humic and fulvic acids which are extractable with a mixture of 0.1 M $Na_4P_2O_7$ + 0.1 M NaOH. In our experiment, the absolute amount of such carbon compounds clearly increased as an effect of sludge addition, but its percentage decreased (Fig. 4). Because the level of humic acids (HA) rose at a slower rate than the level of fulvic acids (FA), the already unfavourable relationship between got even worse, i.e.: from 0.30 in zero variants to the average of 0.24 in the combinations with sludge.

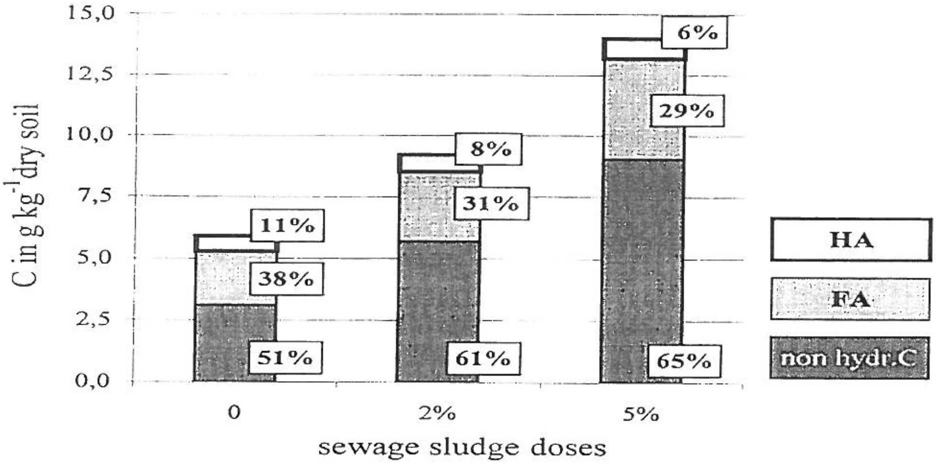


**Fig. 4.** Effect of sewage sludge on the contents of carbon fractions extracted with 0.1 M $Na_4P_2O_7$ + 0.1 M NaOH.

In our climate, fulvic acids predominate in the humus [12]; they are formed in acidic soils which are poor and show low biological activity. Such a soil was also used in our experiment. Fulvic acids are often regarded as the youngest humus fractions, which can undergo mineralisation or, in favourable conditions, be transformed into humic acids [1,5,11,13]. It is, therefore, a possible that at least a part of the fulvic acids added to the sewage sludge would be transformed in this way, as the trophic conditions and the pH of the soil improved significantly. Additionally, macromolecules of humic acids became more condensed with time; the fraction of aliphatic chains decreased in favour of aromatic units. This was indicated in the lowering of the $E_4$:$E_6$ colour index (the ratio between extinction at 465 and 665 nm - Table 2). Such changes are characteristic of humification processes [5,11].

Addition of sludge resulted not only in an increase of the concentration of non hydrolizable C, but also in the increase of its fraction in the total organic carbon content (Fig. 4). This could have been due to the stabilising effect of the lime added to the soil together with the sewage sludge as it not only reduces the solubility of the humus, but also changes the inner structure of its molecules [1].

Proportionally to the sludge dose, the content of low-molecular carbon compounds extracted with 0.05 M $H_2SO_4$ also increased, while its fraction in the total organic carbon content decreased (Table 2). This was especially noticeable after three years. It is understandable as those substances, similarly to other simple aliphatic acids, amino acids, sugar acids, and polyphenols, are very liable to microbial degradation [3,11,13]. Additionally, as was noted by Sloan *et al.* [10], organic matter added with sewage sludge stabilises with time, and the level of soluble organic compounds of carbon goes down.

Other wastes modified the results to a much lesser degree. Washing earth and its mixture with ash stimulated an increase of the organic carbon content in the soil (Table 3). While ash from straw lowered the level of organic carbon, it increased the proportion of its most active fractions, including humic acids. However, they were characterised by a worse structure as indicated by an increase of

**Table 3.** Changes of some organic matter properties as an effect of washing earth and ash from straw (average from 1996 and 1998)

| Combinations | Total organic C (g kg$^{-1}$ soil) | Percentage of C: soluble in pirofosfate (% org. C) | Percentage of C: humic acids (% org. C) | $E_4$:$E_6$ humic acids | Content of C fulvic acids (g kg$^{-1}$ soil) |
|---|---|---|---|---|---|
| | with no sewage sludge | | | | sludge 5% |
| Soil | 5.8 | 46 | 8 | 3.9 | 4.0 |
| + sugar-beet washing earth | 6.7 | 44 | 9 | 4.2 | 3.4 |
| + ash from a straw | 4.8 | 58 | 17 | 5.5 | 4.4 |
| + sugar-beet washing earth+ash from a straw | 6.1 | 47 | 10 | 4.9 | 4.3 |
| $LSD_{0.05}$ | 1.3 | 8 | 3 | 0.8 | 0.5 |

the $E_4$:$E_6$ ratio. Washing earth also reduced the increase in the fulvic acid content resulting from the addition of a 5% dose of sewage sludge (Table 3).

The use of sewage sludge resulted in an increase in the concentration of soluble organic compounds in the soil [9,10]. Those substances regulate availability of nutrients, and also affect solubility of heavy metals in the soils [4,9,10]. In the experiment presented here, strong correlation between the content of various organic matter fractions, nutrients and metals levels in the substrata, as well as plant yield was observed. Sorptive capacity, total N, and available forms of P, K, Mg, as well as the majority of heavy metals (with the exemption of Cr and Fe) were positively correlated with the content of carbon in the compounds soluble in both extraction solutions (Table 4). What is more, the level of many indices correlated significantly stronger with the content of carbon in fulvic than in humic acids. This can be explained by the fact that fulvic acids have more carboxyl and acid hydroxyl groups capable of forming chelates with metals [11,13]. In the case of sorptive capacity, N, P, and Mg, a stronger relationship was established between

**Table 4.** Correlation indices between the levels of various carbon fractions and plant yields and some substrata properties (n=72)

| Parameter | | C extracted with | | | | Significant differences between modules of correlation coefficients | | |
|---|---|---|---|---|---|---|---|---|
| | | 0.1 M $Na_4P_2O_7$+0.1 M NaOH | | | 0.05 M $H_2SO_4$ | | | |
| | | HA | FA | Σ | | | | |
| | | a | b | c | d | | | |
| Yield | | 0.42*** | 0.52*** | 0.65*** | 0.35* | | | |
| Soil | CEC | 0.59*** | 0.86*** | 0.89*** | 0.76*** | b>a | | c>d |
| | Total N | 0.53*** | 0.90*** | 0.92*** | 0.79*** | b>a | c>a | c>d |
| | Available P | 0.58*** | 0.92*** | 0.95*** | 0.82*** | b>a | c>a | c>d |
| | Available K | ns | 0.54*** | 0.52*** | 0.40** | | | |
| | Available Mg | 0.59*** | 0.92*** | 0.95*** | 0.81*** | b>a | c>a | c>d |
| | Cd | ns | 0.60*** | 0.58*** | 0.63*** | | | |
| | Cr | ns | ns | ns | ns | | | |
| | Cu | 0.61*** | 0.89*** | 0.93*** | 0.85*** | b>a | c>a | |
| | Fe | 0.44** | ns | ns | ns | | | |
| | Mn | ns | 0.59*** | 0.55*** | 0.53*** | | | |
| | Ni | 0.57*** | 0.51*** | 0.57*** | 0.45** | | | |
| | Pb | 0.61*** | 0.82*** | 0.86*** | 0.78*** | b>a | c>a | |
| | Zn | 0.59*** | 0.89*** | 0.92*** | 0.88*** | b>a | c>a | |

*, **, *** Significant at 0.05; 0.01, and 0.001 levels of probability, respectively. ns - not significant.

their level and the carbon content determined in the alkalic pyrophosphate than in the sulphuric acid extract.

## CONCLUSIONS

Our results do not allow to draw any general conclusions, as they were obtained from a three-year pot experiment. It can be stated, however, that the processes of forming humus from the sludge organic matter had started and they proceeded in the right direction. Firstly, because there was an improvement of the carbon to nitrogen ratio, secondly, maturing of humic acids, and thirdly, a decrease in the proportion of mobile forms (fulvic acids, and also compounds extracted with sulphuric acid) with a simultaneous increase in the proportion of more stable structures. This allows to presume that lime stabilised sewage sludge from Zamość can be a source of humus-forming substances, and its quality can be improved by mixing with washing earth or ash from straw.

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