# Long-Lasting Beneficial Effects of Slurry Application on Some Microbial and Biochemical Characteristics of Soil

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## Abstract

In this paper we report on comparison of microbial and biochemical properties of a loamy-sandy soil that 10 years earlier had been treated for 17 years with different rates of slurry or mineral fertilizers. Long-term fertilization of the soil with different doses of cattle slurry significantly improved microbial (biomass, respiration, numbers), biochemical (activity of dehydrogenase and phosphatases) as well as chemical properties (C and N contents, pH) of the soil as compared to the NPK-treated soil. Results of our study indicate that slurry application may cause long-lasting, beneficial changes in biological and physicochemical characteristics of soil.

**Keywords:** microorganisms, enzymes, soil, cattle slurry, mineral fert

## Introduction

Animal manure is a natural by-product of all types of livestock farming systems and in most cases, but particularly on large farms, it is stored as slurry. Slurry contains a lot of organic matter and plant-available nutrients, thus it has long been used as organic fertilizer incorporated into the soil [1-8]. Currently, in many European countries spreading of animal manures on agricultural lands is strictly regulated, both in terms of quantities and timing, in order to prevent nitrogen loss and ground water contamination with N and other nutrients [1, 2].

The direct effect of slurry application on crop yields is well documented [3, 5-8]. The influence of this manure on physical and chemical properties of soil has also been extensively studied, both in laboratory experiments and long-term field trials [8-11]. For example, Mazur and S'Hdej [8, 11] have shown in long-term field experiments that soils treated with farmyard manure or slurry had markedly higher organic matter contents, sorption capacity and the sum of basic cations (and % of saturation with these cations) than the untreated control soils or soils fertilized with NPK. With respect to biological properties of soil some short-term pot experiments showed temporal stimulation of some groups of soil microorganisms (total numbers of bacteria and fungi, proteolytic bacteria, urea bacteria) in soil amended with slurry as compared to soil treated with mineral fertilizers [12-14].

In this paper we report on a comparison of microbial and biochemical properties of a soil that 10 years earlier had been treated for 17 years with different rates of slurry or mineral fertilizers.

## Materials and Methods

In the autumn of 1972 a micro-plot experiment was established at the Experimental Station of the Institute of Soil Science and Plant Cultivation in Pulawy to study effects

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of different rates of slurry application on crop yields. Lyzimeter-like micro-plots (1m x 1m) had concrete walls to a depth of 1 m. The plots were filled-up with natural profile of soil, a loamy sand, containing in the plough layer 1.1% organic matter (OM), and 7% clay, pH ($H_2O$) = 6.1. Starting with the spring of 1973 until the spring of 1989 the plots were treated once a year with the following rates of liquid (slurry) cattle manure (in $m^3$ $ha^{-1}$): S1 = 25 $m^3$, S2 = 50 $m^3$, S3 = 100 $m^3$ and S4 = 200 $m^3$. The average composition of slurry and amounts of nutrients introduced into the soil with the lowest dose (25 $m^3$) of this manure are given in Table 1. For comparison, another set of plots was obtained for mineral fertilizers (MF) at four rates (in kg $ha^{-1}$): MF1 (100 kg N, 50 kg $P_2O_5$, 100 kg $K_2O$), MF2 = 2 x MF1, MF3 = 3 x MF1 and MF4 = 4 x MF1. Slurry was applied in April or in August in the years when spring or winter crops were planted, respectively. Both slurry and mineral fertilizers were incorporated into the soil by digging, usually 2 weeks before sowing of the crop seeds. During 1973-89 the direct influence of cattle slurry application on yields of different crops (as compared to the effect of mineral fertilizers) was tested. In 1990 slurry application was terminated and all the plots were treated with the same rates of mineral fertilizers (NPK) to test residual effects of slurry application on plant yields. The experiment was arranged as randomized block with 3 replicated plots for each treatment. More detailed information on this experiment is given in [3].

In the spring of 2000 soil samples were collected from the following treatments: slurry - S2, S3 and S4 and mineral fertilizers - MF2 and MF3. The samples were taken from the top-soil layer (0-20 cm), then sieved (2 mm mesh) and refrigerated. The soil samples were analyzed for: - total number of bacteria and fungi (colony forming units - cfu) using plate dilution method [15], - microbial biomass C (MBC) by fumigation-incubation method of Jenkinson and Pawlson [16] as modified in [15], - soil respiration ($CO_2$ released in the control, nonfumigated soil samples in the fumigation-incubation method), - acid and alkaline phosphatase activity [17], and - dehydrogenase activity [18]. Microbial biomass C was calculated according to the following equation: MBC = ($F_C$ - $UF_C$)/ $K_C$; where $F_C$ = $CO_2$-C released from fumigated soil samples during the 0-10 day incubation period; $UF_C$ = $CO_2$-C released from the nonfumigated (control) soil samples during the 10-20 day incubation period and $K_C$ = 0.45 (fraction of microbial biomass C mineralized to $CO_2$). Total N and organic C content in soil was measured by standard methods used in the certified Central Chemical Laboratory of the Institute of Soil Sc. and Plant Cultivation in Pulawy. Particulate organic matter (POM) content in the soil was analyzed by Cambardella and Elliot's method as modified in [19]. In this modification POM (0.053-0.5 mm fraction of organic matter) was physically isolated on a sieve after dispersion of the soil in sodium hexametaphosphate solution and then the content of organic matter in POM fraction was estimated by dry combustion at 450$^o$C.

## Results and Discussion

In this work we examined some microbial, biochemical and chemical properties of the soil that 10 years earlier had been treated once a year (1973 to 1989=17 years) with different doses of cattle slurry or mineral fertilizers. Results of the studies show that the examined characteristics of the soil amended for 17 years with slurry have changed significantly (Tables 1, 2 and 3) as compared to those of the soil treated with mineral fertilizers. Microbial biomass C (MBC) contents in the soil treated with different doses of slurry were similar, irrespective of the dose of this manure, but these MBC estimates were significantly higher than those in the soil treated with mineral fertilizers (Tab. 2). Activity of microorganisms, as measured by the amounts of $CO_2$ evolved, was also substantially higher in the soil amended with slurry than in the soil treated with NPK. Total numbers of microorganisms counted on different agar media (in Petri plates) are often used to characterize microbial status of a soil, though these plate counts are less reliable than, e.g. microscope counts or microbial biomass estimates, since only small portions of soil microorganisms are "culturable" on agar media [20]. In our study the numbers of colony forming units (cfu) of bacteria in the slurry-amended soil were markedly higher than in the NPK-treated soil and, with the exception of S4 treatment, the same was true for the numbers of cfu of fungi (Tab. 2). Thus, in this study all microbial parameters measured in the soil amended with slurry were significantly higher than those in the soil fertilized with NPK, even though slurry application ceased 10 years ago. Table 3 shows activities of the selected enzymes in the slurry- and NPK-treated soil. Similarly as microbial characteristics, activities of dehydrogenase and phosphatases were generally significantly higher in the soil amended with increasing doses of slurry than in the soil treated with the two doses of NPK. All the tested enzymes showed highest activity in the soil treated with 200 $m^3$ of slurry (the highest rate) while the lowest activities of these enzymes were found in the MF3 treatment (the higher dose of NPK). To our knowledge this is the first report showing long-lasting beneficial effects of long-term slurry

Table 1. Average contents of dry matter and nutrients in slurry and the amounts of these components introduced into the soil with the lowest dose 25 $m^3$ of this manure.

| Components | Percent in fresh matter | Amount kg $ha^{-1}$ $year^{-1}$ |
|---|---|---|
| Dry mass | 9.10 | 2325 |
| Nitrogen N | 0.31 | 79 |
| Phosphorus $P_2O_5$ | 0.16 | 45 |
| Potassium $K_2O$ | 0.41 | 102 |
| Calcium CaO | 0.23 | 58 |
| Magnesium MgO | 0.05 | 12.7 |

application on microbial and biochemical properties of the soil. It is of particular importance that these effects could be detected even after 10 years from the abandonment of the soil amendment with this manure.

Beneficial effects of the long-term slurry application on microbial and biochemical characteristics of the tested soil could be attributed mainly to increased contents of organic matter (OM), particulate organic matter (POM) and total N in the soil amended with this manure in comparison to NPK fertilization (Tab. 4). For example, in the NPK treatments the soil contained 1.29% - 1.37% OM while in the slurry-amended soil OM contents ranged from 1.59% in the S2 treatment (50 $m^3$) to 2.40% in the S4 treatment (200 $m^3$). In the S3 and S4 treatments total N content in the soil has also increased significantly as compared to the NPK treatments (Tab. 4). This resulted in a lower C:N ratio in the soil treated with S3 and S4. Higher pH of the soil amended with slurry as compared to the NPK-treated soil was probably another factor favorably influencing microbial populations and their activity in the slurry-treated soil. In 1983-84 Myśków *et al.* [21] examined biological and chemical properties of the same soil in the selected treatments of this experiment and found out higher activity of dehydrogenase, better development of bacteria and more organic matter in the soil treated with slurry than with NPK. Results of our analyses prove that the long-term slurry

Table 2. Microbial characteristics of soil treated 10 years earlier with different doses of cattle slurry and with mineral fertilizers (results expressed per 1 g of soil dry matter).

| Treatments* | Total number of bacteria, cfu x $10^6$ | Total number of fungi, cfu x $10^3$ | Respiration of nonfumigated soil µg $C0_2$-C | Microbial biomass C µg |
|---|---|---|---|---|
| S2 | 12.5 b** | 85.9 b | 84.8 a b | 179.1 a |
| S3 | 16.8 a | 124.9 a | 79.2 b | 180.3 a |
| S4 | 11.2 b c | 57.7 c | 92.0 a | 178.4 a |
| MF2 | 8.9 c | 69.0 b c | 49.6 d | 154.6 b |
| MF3 | 7.9 c | 50.6 c | 65.3 c | 137.9 c |

*Slurry: S2 = 50 $m^3$ $ha^{-1}$ $year^{-1}$, S3 = 2 x S2, S4 = 4 x S2; Mineral fertilizers: MF2 = 100 kg N, 50 kg $P_2O_5$, 100 kg $K_2O$, MF3 = 2 x MF2
**Values in columns with the same letter are not significantly different

Table 3. Activity of dehydrogenase and phosphatases in soil treated 10 years earlier with different doses of cattle slurry and mineral fertilizers (results expressed per 1g of soil dry matter).

| Treatments* | Dehydrogenase $mm^3 H_2$ | Acid phosphatase µg of p-nitrophenol | Alkaline phosphatase µg of p-nitrophenol |
|---|---|---|---|
| S2 | 6.0 b** | 41.8 c | 28.7 b |
| S3 | 7.1 a | 56.3 b | 31.2 b |
| S4 | 7.9 a | 65.4 a | 53.0 a |
| MF2 | 4.7 c | 43.4 c | 17.3 c |
| MF3 | 4.2 c | 24.3 c | 16.7 c |

*As in Table 2.
**Values in columns with the same letter are not significantly different

Table 4. Some chemical properties of soil treated 10 years earlier with different doses of slurry and mineral fertilizers.

| Treatments* | Organic matter % | POM % | Total N % | pH ($H_2O$) | C:N |
|---|---|---|---|---|---|
| S2 | 1.59 b** | 0.24 b c | 0.05 b c | 6.5 | 18.4 |
| S3 | 1.76 b | 0.28 b | 0.06 b | 6.2 | 17.0 |
| S4 | 2.40 a | 0.37 a | 0.08 a | 6.4 | 17.4 |
| MF2 | 1.37 c | 0.21 c | 0.04 c | 6.0 | 19.8 |
| MF3 | 1.29 c | 0.21 c | 0.04 c | 6.0 | 18.8 |

*As in Table 2.
**Values in columns with the same letter are not significantly different

application in comparison to mineral fertilization can cause beneficial and long-lasting changes in biological and physicochemical properties of the soil. It should be added, however, that the rates of 100 and 200 $m^3$ of slurry applied in the described experiment were large. According to the present regulations in some European countries so high rates of slurry are not allowed to be used on agricultural land for the reasons of the environment protection [1, 2]. The lowest rate of slurry (S2 = 50 $m^3$) tested in this experiment would be applicable in practice and, as our results show, it has also caused the long-lasting beneficial changes in the examined properties of the soil as compared to NPK.

The direct and residual effects of slurry on crop yields were also beneficial. For example, in 1989 (the last year when the direct effect of slurry was tested) the yields of potato tubers in S2, S3 and S4 slurry treatments were: 4.42, 5.90 and 8.78 kg per $m^2$, respectively, while in MF2, MF3 and MF4 (NPK treatments) 3.15, 2.82 and 4.45 kg per $m^2$, respectively. In 1999, when the residual effect of slurry application was tested, grain yields of corn in S2, S3 and S4 amounted to 0.92, 1.0 and 1.05 kg per $m^2$, respectively and in MF2, MF3 and MF4: 0.92, 0.91 and 0.91 kg per $m^2$, respectively. A detailed analysis of slurry and NPK fertilization effects on crop yields grown in this experiment has been performed in full by Maćkowiak [3].

## Conclusions

1. Long-term fertilization (17 years) of a loamy-sandy soil with different doses of cattle slurry has significantly improved microbial (biomass, respiration, numbers), biochemical (activity of dehydrogenase and phosphatases) as well as chemical properties (C and N contents, pH) of the soil as compared to the NPK-treated soil.
2. The above mentioned differences were detected 10 years after slurry application to the soil was abandoned. This would indicate that beneficial effects of slurry on the examined soil characteristics are long-lasting.

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