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IMPACTS OF COMPOST AND WASTEWATER SLUDGE ON SOIL BIOLOGIC ACTIVITIES

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Abstract

The use of agrochemical such as chemical fertilizers and pesticides has caused tremendous harm to the eco-environment. Organic matter (OM) addition to soil often leads to a rapid increase in the activities of various enzymes and reactivation of biogeochemical cycles in soil. One of the major concerns today in all over the world is the pollution and contamination of the soil. In fact hydrolytic enzymes are sensitive indicators of management induced changes in soil properties due to their strong relationship with soil organic matter (OM) content and quality. An experiment was conducted to study the impacts of combined fertilizer on soil properties in comparison with adding organic as solid waste compost (SWC) of plant origin or municipal wastewater sludge (MWWS) to sandy loam brown forest soil. Soil amendments were: control, 15 or 30 kg/ha dry organic fertilizer. Microbial compositions were determined by culture enrichment technique. Enzyme (β-glucosidase, cellulase, urease, and aryl-sulphatase) activities were estimated. Fluorescein diactate activity as well as physico-chemical properties as well as some microbial parameters were determined after 63 day of incubation under laboratory conditions. The results demonstrated that the SWC and MWWS significantly improved soil physico-chemical properties such as soil pH, moisture content, total C and N contents as well as biological properties. Accordingly, overall enzyme activities were substantially promoted in presence of both amendments and the higher increases were measured at 30% of SWC. Lower beneficial effects occurred at the combination of SWC and MWWS together at 30% possibly because of the increased the presence of trace elements through MWWS application. As a general response, SWC supplied at 30% seems to be a useful strategy to enhance biological activities of soil. Finally, soil biologic activities can be used as an index of soil fertility and organic fertilizer stimulates the natural soil microbiotas and reactivates the biogeochemical cycles.

Keywords: *biological activities, solid waste compost, municipal solid wastewater sludge, soil.*

1. INTRODUCTION

Soil is the major component of agroecosystems specifying the level of their biological productivity and transforming matter and energy fluxes. Current interest in examine the soil quality has been triggered by increasing awareness of soil as a component of the biosphere. Crop responses to wastewater sludge (WWS) application vary by source, application rate, plant species, soil type, climatic conditions, and management practices [1]. However, soil quality is defined as the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health [2].

Several factors make soil quality very difficult to define, because soils are inherently variable [3]. There is growing recognition for the need to develop sensitive indicators of soil quality in promoting appropriate soil management strategies for long-term sustainability of terrestrial ecosystems.

Monitoring is needed to encourage the use of wastewater sludge in agriculture and to regulate its use to prevent harmful effects on soil, crop, animal and man [4]. Therefore, treated wastewater sludge can be defined as biological, chemical or physical treatment of long-term storage or any appropriate process significantly to reduce its fermentability and the health hazards resulting from its use.

Organic fertilizer differs from chemicals in that they feed plants and adding organic matter to the soil. Organic farming technology is necessary to support the developing organic, sustainable and non-pollution agriculture. Excessive amounts of salts have adverse effect on physical and chemical properties and on biologically mediated processes in the soil, such as C and N-mineralization.

Due to climatic changes, global warming is considered to promote the decomposition of soil OM, and thereby to increase the C flux from soil to the atmosphere. Various organic treatments such as solid waste compost (SWC) or municipal wastewater sludge (MWWS) have been investigated for their effectiveness in acidic soil remediation. Meanwhile, the application of WWSs increases soil microbial biomass and some soil enzymatic activities such as urease and β-glucosidase linked to C, N, P and S soil cycles [5, 6].

In fact hydrolytic enzymes are sensitive indicators of management induced changes in soil properties due to their strong relationship with soil OM content and quality [7].

According to Rao and Pathak [8] and Liang et al. [9], the incorporation of organic treatments to soil stimulate dehydrogenase activity because the added material may contain intra- and extracellular enzymes and may also stimulate microbial activity in the soil. These parameters are the most sensitive to the changes which occur in acid-affected soil, and provide rapid and accurate information on changes in soil quality.

A simulated acidified experiment was performed in this study to examine the effects of MWWS and SWC incorporated in acid affected soil on the activity of some soil enzymes related to nutrient cycling such as aryl-sulphatase, phosphatase, dehydrogenase, β-glucosidase, urease and catalase.

Wastewater is a waste product produced at the end of municipal and industrial wastewater treatment processes and is being produced in gradually large volumes global due to increasing population and growing urbanization.

The application of WWS on soils has been widespread in agricultural areas. It depends on soil properties, HM levels and characteristics, plant species and climatic conditions.

Wastewater sludge is usually reflected as waste, the recycling and reuse of valuable nutrients contained in the WWS are currently being measured as important resources for sustainable development [10]. Treated WWS can be reprocessed in numerous ways including its use as fertilizer with important nutrient additions improving plant growth and as a soil conditioner for improving the physical and chemical properties of soils [11-13].

The estimated percentages of WWS applied to agricultural soils have been mentioned as 29% in the USA, 40% in the UK, 60% in France, 30% reuse potential in Russia and 230,000 ton/year in Japan [14-17]. In developing countries, the experience of using WWS application for agricultural purposes is often kept to communal farms. There is a supposed risk to the environment that prevented wastewater sludge from existence application to agricultural soils.

The utilization of WWS in agriculture and forestry is becoming a widespread practice. Municipal WWS are increasingly used as soil organic amendments, especially to agricultural lands with low OM content to maintain or improve soil quality. This practice can, however, increase the concentration of heavy metals and organic toxins in soil. Heavy metals can reduce soil microbial activities including respiration, ammonification, nitrification and enzyme activities.

Oxidative enzymes (especially dehydrogenase) were proposed as a measure of overall microbial activity. Dehydrogenase being an intracellular enzyme related to oxidative phosphorylation process that occurs in all intact, viable microbial cells [6]. Incorporation of both SWC and WWS stimulated dehydrogenase activity because the added material may contain intra- and extracellular enzymes and may also stimulate microbial activity in the soil [9].

In fact, some studies indicated that high doses of some organic materials can introduce into the soil toxic compounds such as heavy metals which could have a negative effect on enzyme activities [18].

The biological activity of soil may serve as an informative indicator of the ecological state of biocenosis. The aim of the present study was to examine the effects of SWC and WWS application on some soil biological activities such as the microbial content and enzymatic activities as well as soil pH, moisture contents, total organic carbon and total nitrogen content.

2. MATERIALS AND METHODS

In a greenhouse study, the soil samples used in pot experiment were clay loam brown forest collected from farmland surface layer (0–200 mm) of an agricultural area of Gödöllő (Hungary). One sample of WWS was selected depending on its low HMs content originated from Nyíregyháza wastewater treatment plant and the compost sample SWC was originated from garden plant residue. The main physico-chemical parameters of soil and WWS are shown in Table 1.

Fresh soil samples were sieved through a 4 mm sieve and mixed with WWS or SWC to form 10 and 30% (soil : Waste; w/w), and then placed into plastic pots with 42 cm in height and 23 cm in diameter. All treatments were designed in triplicates and submitted for statistical analysis. The study was conducted to determine the effect of WWS or SWC or in mixture on the biological activities of the soil after 4 weeks of incubation.

Table 1: Physico-chemical properties of soils and wastewater sludge samples

Parameters	Soil	Wastewater sludge
	Clay loam brown forest	
$pH_{(H2O)}$	5.12	7.99
Dry matter, %	22.4	74
Organic matter, %	1.27	25.6
Humus content, %	1.24	-
Salt content, %	0.74	-
$CaCO_3$, %	1.01	-
Total N content, mg kg^{-1}	84.11	75.700
NO_3-N, mg kg^{-1}	133.08	-
NH_4-N, mg kg^{-1}	410.69	-
Ca, mg kg^{-1}	856	5707
Mg, mg kg^{-1}	203	2810
Na, mg kg^{-1}	21	1290
AL-P_2O_5, mg/kg	121.31	9700
AL-K_2O, mg/kg	107	3120
Zn, mg kg^{-1}	38.1	453
Cu, mg kg^{-1}	22.9	100
Cd, mg kg^{-1}	0.18	1
Ni, mg kg^{-1}	0.064	15
Pb, mg kg^{-1}	15.1	30

AL: Ammonium lactate soluble P and K

Soil moisture content and pH were measured according to the method of Brzezinska et al. [19] and Pérez de Mora et al. [20], respectively. Total organic carbon (TOC) was analyzed by dichromate ($K_2Cr_2O_7$) oxidation and titration with ferrous ammonium sulphate according to Walkley and Black [21]. Total nitrogen content in soil was determined by Kjeldahl digestion–distillation procedure [22].

Determinations the enzymatic activities were carried as following:

Fluorescein diacetate (FDA) hydrolysing activity of the control and amended soil subsamples were determined by measuring the released fluorescein at 490 nm according to Alef [23].

Dehydrogenase activity was determined by the method of García et al. [24].

Urease activity was determined in 0.1 M phosphate buffer at pH 7; 1 M urea and 0.03 M N α-benzoylargininamide was used as substrate.

The activity was determined by the NH4+ released [25].

β-glucosidase activity was determined using p-nitrophenyl-β-D-glucopyranoside (PNG, 0.05 M) as substrate [26].

Similarly, aryl-sulphatase activity was determined as proposed by Tabatabai and Bremmer [27], after the soil incubation with p-nitrophenyl sulphate and measured at 400 nm.

Furthermore, the enumeration of microbial population in soil amended with SWC or WWS was done using the serial dilution plate method. The total colony forming units (CFU) of bacteria and fungi were recorded on Ken Knight and Munaier's agar [28] and Martin's Rose Bengal agar [29] media, respectively.

Enumeration of cellulose decomposers was determined according to Hendricks et al. [30]. For phosphate solubilized microorganisms, method of Goldstein [31] was applied. The plates were incubated at 28°C and microbial population densities were calculated and expressed as $\log_{10}$ of CFU x 10n g^{-1} air dried soil, where 10n was dilution factor.

3. RESULTS AND DISCUSSION

Utilization of WWS in agriculture increases the concentration of HMs in soil and HMs–rich MSS drastically reduced the biologic activity in soil. These critical limits depend on the source, WWS application rate and frequency.

Phyto- and rhizo-bioremediation using plants and related microorganisms are the promising approach to clean up the contaminated environment. Soil pollution by HMs is a serious worldwide problem and can be potentially harmful to human health via the food chain. The results of pot experiment illustrated the followings:

Table 2 shows that the effect of soil amendment with SWC and WWS on some important terms of soil characteristics from agriculture. It was found that application of SWC and WWS on soil pH has a positive influence, they significantly increased the pH and the combination of the two organic matters rose up the pH value better than in single application.

Similar results also obtained in term of moisture content and it is economically important to keep the soil more moisted for longer time too. In case of total organic carbon, the data of the experiment showed that the amount of TOC increased more when both organic matters were combined together. Also, the amount of total nitrogen content increased significantly more than they applied alone.

The best combination can be selected is 30% from SWC and 10% from WWS and in this case we reduced the risk of heavy metals effects on soil biodynamic properties.

The major factor affecting the productivity of the biocenoses is the level of the soil N supply, because N is the main element limiting the production of plant and animal food on the Earth.

Table 2: Effect of compost and sludge amendment on some physico-chemical properties of soil samples

Parameters	Compost (C)		Sludge (S)		Combination			
	10	30	10	30	10C+10S	10C+30S	30C+10S	30C+30S
pH	5.78	5.84	5.78	5.97	5.89	6.09	5.99	6.25
Moisture, %	10.5	20.7	12.8	22.4	14.7	23.5	22.7	25.9
TOC, mg/kg soil	0.89	2.15	0.96	2.42	1.28	2.11	1.73	2.65
TNT, mg/kg soil	35.6	57.4	35.1	68.2	36.2	62.4	65.8	72.1

Table 3 clarifies the important of the application of organic matter to the soil which increases the soil fertility and makes nutrients available for plant growth and development. The increasing enzyme activity in soil plays an important role for mineralization of organic matter, and in this case the soil quality will be increased.

Table 3 also, illustrates that the investigated enzymes are more active when SWC is in combination with WWS added to the soil. For more safety, 30% of compost matter in combination with 10% of sludge can prevent any contamination of the soil by heavy metals. All enzymes were more active when the soil was amended with both organic matters together.

Table 3: Effect of compost and sludge amendment on some enzymatic activities in soil samples

Parameters	Compost (C)		Sludge (S)		Combination			
	10	30	10	30	10C+10S	10C+30S	30C+10S	30C+30S
FDA	130	204	147	313	143	277	292	337
Dehydrogenase	139	306	171	326	151	332	351	355
Urease	1.79	2.91	1.88	3.67	1.87	3.12	2.71	3.89
β-glucosidase	130	228	142	304	139	304	325	348
Aryl-sulphatase	70	165	78	209	83	184	191	229

Soil OM has a great influence on the chemical and physical properties of soil and makes up, together with the clay, most of the cation exchange capacity and this is the key parameter describing the sorption and desorption of plant nutrients and contaminants from soil.

The major input sources of OM to soil are manure, litter-fall and crop residues, but the equilibrium content of soil OM is influenced by climate, land use and management, over time. Organic contaminants in WWS are not expected to pose major health problems to the human population when sludge is re-used for agricultural purposes.

Table 4 demonstrates the important of addition of organic matter to the soil as energy source and help the microbial content to be more active and established well in the soil. It was found that the microbial population increased by increasing the rate of application and in combination the population is more and it is important for soil fertility too.

Table 4 shows that the cellulose-decomposers and phosphate-solubiliers are more public in the combination of the two organic matters.

Table 4: Effect of compost and sludge amendment on some microbial population in soil samples

Parameters	Compost (C)		Sludge (S)		Combination			
	10	30	10	30	10C+10S	10C+30S	30C+10S	30C+30S
Aerobic heterotrophic bacteria (10^6)	9.54	28.7	13.5	36.2	10.8	30.8	35.3	41.3
Filamentous fungi (10^4)	5.95	23.6	7.65	31.4	7.21	29.67	29.4	33.4
Cellulose-decomposers (10^3)	5.5	16.5	7.07	20.3	6.84	18.71	22.57	26.6
Phosphate-solubilises (10^2)	4.4	22.1	4.5	26.9	5.21	24.61	27.3	30.19

It was found that WWS had a positive effect on the enzymatic activities. More studies are needed to deeper our knowledge of the effect of HM contamination on enzymatic activities. However, our results indicated that there are positively related correlation between the investigated enzymes and OM in the applied WWS or SWC or in combination. This indicates that an aggregate of multi-enzymatic activities may be better correlated with soil fertility than a single enzyme.

Particularly, the enzymatic activities in soil amended with WWS-LHM content were markedly higher than those in the soil amended with WWS-HHM content.

The soil microbial populations were far higher under WSS application than in case of the control and SWC treatments. Bacteria showed a marked increase in population size with increasing WWS mixing rate levels, other soil microbes; fungi in population size responded similarly to bacteria, although all treatments showed significant difference on population size in comparison between the WWS of LHM and SWC contents compared to control.

Further research is required with plant trials to test the effects of the WWS or SWC applied to different soil environments and measure the soil productivity under these applications as organofertilizer as well as soil conditioner.

However, as it seemed from the result of the experiment, that there is a good potential for using the WWS and SWC as soil improving agents. Considering the nutrient and soil conditioning values of the WWS and reusing them for agriculture is an economical and environmentally sound option and deserves given greater attention.

The results suggest that WWS addition induces a reactivation of soil quality and activity, as indicated by microbial content and enzymatic activities. According to this, our results are in good agreement with the results of Singh and Agrawal [32] who established that the mature municipal solid waste compost might be used as conditioner for clay soil, but not for sandy soil.

Monitoring soil quality by means of bioindicators can be helpful for the management and sustainability of soils that received WWS application. It should be concluded that the accumulative concentration of HMs in WWS amended soil should be calculated after every application of MSS.

Conclusion

In conclusion, both SWC and WWS affected soil physical and chemical properties and biological activities. The positive effect of the organic treatments on soil biological quality is due to the stimulation of microbial communities and growth and/or to the addition of microbial cells or enzymes with the amendment.

This hypothesis seems to be reliably supported by the increase observed for more than one soil enzyme activity that very likely behaved as valid indicators of soil biological activity. However, a balance between adequate fertilization and the possible environmental risks caused by over fertilization must be considered. Organic matter application increases soil microbial biomass and soil enzymatic activities linked to C, N, and S soil cycles.

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