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EFFICACY OF DISPOSAL WASTEWATER SLUDGE AS "CLEAN" FERTILIZER

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Extensive areas of irrigated soils are unproductive, due to the accumulation of salts in the soil profile occupied by root systems. It is estimated that about 15% of the total land area of the world has been degraded by salinization and soil erosion, which are among the major causes of desertification. The expected increase in the world's population (~10 billion by 2050) needs food productivity to step up within a few decades. Organic fertilization is highly sustainable when compared to other options to date when taken into consideration as a solution to the highlighted issues. It is possible to use biological soil properties for evaluating the effects of organic matter application on soil characteristics. Different approaches have been suggested to solve these issues of soil destruction. This study focuses on selected organic materials (e.g., different agro-industrial by products, and composts) as effective tools to improve different soil properties of soils. However, further experimental investigations are needed to validate this approach in a wider range of soils, also combining waste recycling with other sustainable agronomic practices. The same amendments could likely be considered for soil remediation in the affected areas due to their high organic matter content. In fact, organic matter has several beneficial effects on agricultural fields, such as the slow release of nutrients, soil structure improvement, and the protection of soils against erosion. Selected studies were focusing on the effects of application of various organic matters (i.e., different organic waste materials, mixture of green waste compost) to two soils. In particular, such effects can be referred to chemical, biological, and physical soil properties. The observed results offer powerful evidence on the potential of organic fertilizers in improving soil properties. Such results showed the improving soil structure, increasing different enzyme activities and soil organic carbon, total nitrogen and extractable phosphorus and increasing soluble and Exchangeable-K^+. Urease activity was increased by more than 150% in the mixed treatment, compared to the control. The incorporation of organic manure into the soil significantly increased soil phosphatase activity and soil respiration rate. 15 $g{\cdot}kg^{-1}$ of compost significantly improved soil physical-chemical properties, especially C and N contents. Enzyme activities were substantially promoted in presence of both amendments. However, there is no clarity whether organic matter, composts of organic wastes are as plant-friendly as the manure-based composts are believed to be. It is also not clear as to whether the action of green compost as a fertilizer depends on the species of plants being fertilized by it. This raises questions whether green organic composts are beneficial (or harmful) at all application rates or if there is a duality in their action which is a function of their level of application. The study reveals that, in general, organic matter composts of all are highly potent fertilizers.

***Keywords**: wastewater sludge, clean fertilizers, chemical, biological, physical soil properties*

INTRODUCTION

Fertilizers are organic or inorganic materials of natural or synthetic origin that are added to soil to supply one or more nutrients essential for the plant growth. Organic manure or organic fertilizers are fertilizers derived from animal or plant matter (e.g. compost, manure etc). Manure is any organic substance that is added to the soil to increase its fertility, soil quality and for enhancing plant growth

As a result of the linear economy, growing of global population, decreasing of resources especially the agricultural lands due to the climatic changes and increasing resource consumption, humanity is seriously challenged by the generation of waste in large quantities from various sectors. Organic waste (OW), animal waste (AW), and municipal solid waste (MSW) represent the major groups of waste generated by these sectors. Options of applying such organic waste streams as feedstock for producing clean fertilizers instead of chemical fertilizers. The respective integrated concepts have received significant attention in recent years as a sustainable alternative to agrochemicals and fertilizers applied to soils for increasing soil productivity and reducing soil pollutions.

In addition, agricultural activities have contributed to lowering the organic matter content. All the above has led to these soils losing a large part of their natural fertility [1].

Many agricultural soils have become loaded with nutrients, pesticides, and heavy metals as a result of intensive use of agrochemicals and fertilizers, changes in agronomic practices (also including the intensive use of soil) and to recycling of wastes [2]. Rehabilitation of a soil under intensive cultivation may be promoted by set-aside practice (as stated by Agricultural European Policy) which favours detoxification and microbiological activation of arable soil layers because of an increase of organic substrates [3]. However, long-term adverse effects, such as the mobilization and solubilization of adsorbed chemical compounds caused by the interaction between chemicophysical and biological processes, may occur.

The organic matter is responsible for adsorption–desorption mechanisms regulating the long-term fate of soil contaminants [4]. Soil organic matter can be divided into two major pools based on relative susceptibility to biological decomposition: 1. easily or readily, metabolised pool and 2. more resistant pool of humic substances [5].

Options are sought and required, to produce food and feed with other methods than traditional cultivation of agricultural land, and natural collection. Landless food systems are called for, e.g. in a paper aiming at securing the availability of food in Africa in 2100 by more circular and sustainable food chains (Rahmann et al. 2019)[6].

Studies should be initiated to design bioreactors utilising locally available sources of nutrients and organic matter, to make the bioreactors more sustainable and develop organic farming systems in a context of landless farming [7].

MATERIALS AND METHODS

Soil characterization, sampling and amendment

The soil samples were collected from the top 20 cm of chernozem meadow from the non-cultivated or treated sampling area from Szeged, Hungary. The soil samples were divided into two sub-samples: control soil and soil amended with disposal wastewater sludge (DWS) originated from the plant of wastewater treatment in Hódmezővásárhely, Hungary at 15, 30, 45 and 60% (w/w) rates. Table 1 represents some physico-chemical properties of used soil and DWS samples. Fifteen weeks after soil amendment in greenhouse. The following evaluations were carried out to study the effects of disposal wastewater sludge on soil biological activities.

Table 1. The physicochemical properties of used soil and municipal wastewater sludge samples

Parameters	Virgin sample of chernozem meadow soil	Municipal wastewater sludge
Clay and slit content (Li), %	51.7	n.d.
Soil plasticity (K_A)	53.07	n.d.
$pH_{(KCl)}$	6.02	7.8
Dry matter content, %	n.d.	42.9
Organic carbon content, %	2.87	20.4
Humus content, %	3.55	n.d.
Salt content, (%)	0.081	n.d.
$CaCO_3$, (%)	2	n.d.
Total N, mg/kg	334.7	43311

NO_3-N, mg/kg	39	n.d.
NH_4-N, mg/kg	4.5	n.d.
Mg, mg/kg	257	11860
Na, mg/kg	53	1441
AL-P_2O_5, mg/kg	378	20104
AL-K_2O, mg/kg	428	2908
Zn, mg/kg	1.1	1068
Cu, mg/kg	2.4	182.3
Mn, mg/kg	61	351.2
Fe, mg/kg	1094	13610
Cd, mg/kg	1.02	4.168
Pb, mg/kg	0.96	540.7

n.d.: Not determined, AL: Ammonium lactate soluble P and K

PHYSICO-CHEMICAL PROPERTIES

Determination of soil pH and moisture content: Soil pH was measured in 1 M KCl suspensions (1:2.5 w/v) with a glass electrode. Soil moisture was measured gravimetrically from drying soil sub-samples in hot air oven to constant weight at 105°C. The percentage of water holding capacity (WHC, %) was measured with known amount of soil and the volume of water relationship, to give a condition of 45% of the maximum WHC following the protocol proposed by MISHRA [12].

Determination of soluble nutrient element content: According to the Hungarian Standard MSZ 20135/1999 [13], the method describes the procedure of determination of Na^+, K^+, Ca^{2+} and Mg^{2+} in soil using the atomic spectroscopic techniques.

Determination of total soluble heavy metal content: According to the Hungarian Standard MSZ 21470-50/1998 [14], the standard describes the procedure for determination of Fe^{2+}, Mn^{2+} and Zn^{2+} content in soil by atomic spectroscopic methods after HNO_3/H_2O_2 extraction/digestion in microwave.

EVALUATION OF SOIL MINERALIZATION OF ORGANIC C, N, P AND S

Because the soil sub-samples had been stored at 4°C, soil sub-samples were pre-incubated as previously described to allow the microbial activity to restore and stabilize. Total organic carbon (TOC) content was determined by oxidation with potassium dichromate ($K_2Cr_2O_7$) in a concentrated sulphuric (H_2SO_4) medium and excess dichromate evaluated using Mohr's salt [$(NH_4)_2Fe(SO_4)_2$] according to WALKLEY & BLACK [15] and YEOMANS & BREMNER [16].
Organic carbon mineralization (C_{min}) was evaluated by measurement of soil CO_2 respiration. The C_{min} was expressed as mg CO_2-C released per kg soil weight and incubation time.

Determination of N mineralization and nitrification rates: Total N content in soil was determined by Kjeldahl digestion–distillation procedure [17]. Potential net N mineralization and net nitrification rates were determined by aerobic incubation of the soils. Nitrogen mineralization (Available N: AN), which includes NH_4^+–N and NO_3^-–N, was determined in 20 g of soil, which were extracted with 100 ml 2 M KCl for 1 h and filtered through Whatman quantitative filter paper. The soil clear filtrate was analyzed for NH_4^+–N at 660 nm and for NO_3^-–N at 540 nm using alkaline phenol according to CATALDO el al. [18] and DORICH & NELSON [19], respectively. The organic N mineralization rate was estimated by the sum of ammonification and nitrification rates. The C/N ration was computed by dividing the OC concentration by the TNC. The TOC, TNC, and AN records are presented on a soil dry weight basis. The net ammonification and nitrification rate was calculated as the difference of N-NH_4^+ and N-NO_3^- contents before and after incubation.

Phosphorus and sulphur mineralization was determined according to methods for P extraction and analysis in soils as detailed by OLSEN and SOMMERS [20]. Sub-soil samples were extracted in dilute NH_4F-HCl at the beginning and end of incubation period and the extracted P was estimated colorimetrically using the ammonium molybdate-stannous chloride blue colour method. Mineralized inorganic P was extracted with 0.5 M $NaHCO_3$ and was analysed by the ammonium molybdate–ascorbic acid method described in biomass P measurement.
Available extractable S was measured after the extraction with 0.01 M $CaCl_2$ and analysed according to SUBBA RAO [21]. The SO_4-S extracts were measured by converting them to barium sulfate by the addition $BaCl_2.2H_2O$ crystals; and the turbidity was measured at 340 nm on a UV-VIS spectrophotometer. Available S in soil sub-sample is expressed as SO_4-S in mg/kg.

Basal soil respiration
To determine the soil respiration rates, 50 g of soil samples were placed in hermetically sealed glass bottle, moistened at 45% and incubated in the dark at 28°C for 10 days. The amount of OC released as CO_2 and absorbed in vials containing 50 ml of 0.5 M NaOH placed inside bottle. The CO_2 emitted was measured as the Na_2CO_3 formed by titration with 0.1 M HCl.

SOIL MICROBIAL ACTIVITIES

Microbial characterization: Quantitative enumerations of mesophilic culturable populations of aerobic heterotrophs bacteria, filamentous fungi and actinobacteria were expressed by colony forming units (CFU) per gram dry soil. The populations were measured in 10 g of sieved soil was added to 90 ml of sterile saline solution (0.85%) in a 250-ml flask, and the suspension was shaken at 150 rpm for 30 min.
Ten-fold serial dilutions were made and 1 ml of 10^{-4}, 10^{-5}, 10^{-6} and 10^{-7} dilution was used to inoculate Petri dishes of different cultural media. Plates were incubated at 28°C for 2, 7 days for bacterial and fungal cultivation, respectively. Bacteria were determined on nutrient agar medium supplemented by filter-sterilized cycloheximide (100 µg/ml final concentrations) after autoclaving to prevent fungal growth. Fungal population was estimated on Rose Bengal-Streptomycin Agar [22] and modified potato dextrose agar (MPDA) supplemented with streptomycin (30 µg/ml) to inhibit bacterial growth according to ALEF & NANNIPIERI [23].
Actinobacteria were counted on Starch Casein Agar medium of KÜSTER & WILLIAMS (1964) [24] supplemented by cycloheximide (100 µg/ml) and modified by addition of nystatin and nalidixic acid which were used as antifungal and antimicrobial agent respectively in plates (WILLIAMS & DAVIES 1965) [25]. The plates were inverted and incubated for 7 days at 28°C. The results are reported as $\log_{10}$ of bacterial, fungal or actinobacteria CFU/g of dry soil.

Determination of soil microbial biomass: The most common technique used to estimate microbial biomass C, N, P and S were measured by the chloroform fumigation-extraction method. The MBC (C_{mic}), MBN (N_{mic}), MBP (P_{mic}) and MBS (S_{mic}) were measured by ethanol-free chloroform fumigation–extraction method. Briefly, 30 g soil for each sample was fumigated with ethanol-free chloroform for 24 h at 28°C after one week incubation at 45% WHC. Simultaneously, another unfumigated set was prepared and incubated under the similar conditions. After complete removal of $CHCl_3$, organic C and N from fumigated and non-fumigated soil sub-samples were extracted with 0.5 M K_2SO_4 with a soil:extractant ratio of 1:5 (w/v), inorganic P was extracted with 0.5 M $NaHCO_3$ (pH 8.5) with a soil:extractant ratio of 1:20 (w/v). Phosphate was measured by photospectrometry at 882 nm as described by JÖERGENSON et al. [26]. Also, S was extracted with 0.01 M $CaCl_2$ for 30 min on a rotating shaker [21]. MBC was calculated as: MBC = E_C/k_{EC}, where E_C = (organic C extracted from fumigated soils) − (organic C extracted from non-fumigated soils) and k_{EC} = 0.38 [27]. MBN was calculated as: MBN = E_N/k_{EN}, where E_N = (total N extracted from fumigated soils) − (total N extracted from non-fumigated soils) and k_{EN} = 0.54 [28]. MBP was calculated as: MBP = E_P/k_{EP}, where E_P = (total P extracted from fumigated soils) − (total P extracted from non-fumigated soils) and k_{EP} = 0.40 [29]. MBS was calculated as: MBS = E_S/k_{ES}, where E_S = (total S extracted from fumigated soils) − (total S extracted from non-fumigated soils) and k_{ES} = 0.35 [30]

Detection of phosphate-solubilizing microorganisms: One ml of homogenous soil sub-sample suspension of low dilution (10^5, 10^6 and 10^7) was plated on the surface of the agar plate containing a medium described by PIKOVSKAYA [31] and according to the procedure of GOLDSTEIN [32]. After incubation for 5 days at 28°C, colonies surrounding with clear zones were counted. Colonies showing solubilisation zones over 0.5 mm in diameter were counted.

Detection of cellulose-decomposing microorganisms: Microbial populations utilize cellulose as C source were detected by spread plate technique with 1 ml of soil suspension of low dilution (10^5, 10^6 and 10^7) on carboxymethylcellulose (CMC) medium according to HENDRICKS et al. [33]. Plates were incubated at 28°C for 2 and 5 days. The CMC plates were flooded with Gram's iodine which formed a bluish-black complex with cellulose but not with hydrolysed cellulose, giving a sharp and distinct zone around the cellulase-producing microbial colonies within 3 to 5 minutes. According to KASANA et al. [34] this is more rapid and efficient method than Congo red. The clear zone formed by isolates is used as indicator for cellulase activity.

DETERMINATION OF ENZYMATIC POTENTIAL ACTIVITIES

Hydrolysis of FDA was evaluated according to the methods of SCHNÜRER & ROSSWALL [35]. The enzyme potential activity is expressed as mg fluorescein /kg dry soil/h. ***Dehydrogenase*** was determined according to GARCÍA et al. [36]. ***Urease*** and N-α-benzoyl-l-argininamide (BAA) hydrolysing ***protease*** were determined following the method of NANNIPIERI et al. [37]. Urease and protease activities are expressed as mg NH_4/kg dry soil/h. ***Acid phosphatase*** was determined by spectrophotometry at 398 nm [38]. The enzyme activity is expressed as mg PNP/kg dry soil/h. ***β-glucosidase*** was determined using p-nitrophenyl-β-D-glucopyranoside as substrate. The amount of PNP was determined in a spectrophotometer at 398 nm [38]. ***Aryl-sulphatase activity*** was measured colorimetrically according to at 420 nm [39] and is expressed as mg PNP/kg dry soil/h.

RESULTS AND DISCUSSION

The application of bio-disposal wastewater sludge to soil can increase OM, pH of acidic soils [40], and soil microbial [43] and enzymatic activities [42] in the soil. The present investigations confirm the recent results mentioned above. The importance of the reuse of sewage sludge in agriculture is derived from its high nutrient content that can improve the soil characteristics crop production.

Changes in physicochemical properties

Our results clarified that disposal wastewater sludge enhanced the OM and biological characteristics e.g., the OC content and soil respiration were found to be higher in the treated soil sub-samples in comparison with the biodynamically properties of the control virgin soil. Table 2 shows that the application of DWS to the control chernozem meadow soil sample provided a good environmental medium for plant growth by increasing the pH and moisture content over the virgin control samples. The increases in soil moisture content will reduce the amount of water used in irrigation and the pH ranged between 6.19 and 6.71 creating a favourable medium for promoting plant growth.

Table 2. Application of disposal wastewater sludge changes the pH and moisture content of chernozem meadow virgin unfertilized soil samples.

Soil system	Various DWS rates (%)	$pH_{(KCl)}$	Moisture content (%)
Control untreated soil	0	6.02	**100**
Soil amended with DWS rates	15	6.19	**118.1**
	30	6.37	**132.76**
	45	6.50	**152.5**
	60	**6.71**	**165.4**

Our results are in an agreement with PRASANNA et al. [45] who pointed out those organic amendments are benefit for plant growth by increasing soil moisture holding capacity, improving soil texture, and providing plant nutrients such as N and P. Plant available macronutrients were affected by organic fertilizer application as the significantly higher of Na, K, Ca and Mg contents were found in soil under sludge treatment (Figures 1 - 4). The addition of disposal wastewater sludge to soil acts as nutrient reservoir. These nutrients released to the soil medium throughout the mineralization. The results showed higher nutrient contents of Na and K (Figure 1), Ca and Mg (Figure 2) and essential elements such as Fe as in Figure 3 and Mn and Zn (Figure 4) in DWS treated soil sub-samples in comparison with untreated control soil. The higher content of C, N, P and S indicates that OM can maintain the nutrients supply into DWS amended soil better than the control soil.
In general, soil treated with DWS had better soil properties than untreated soil sub-sample. The DWS amended soil had OC, total N, available P and S content higher concentration than in the control soil sample. Organic fertilizer is also known as a slow release nutrient source, so the nutrients can be effectively used for plant uptake, preventing nutrient losses from soil. Our results indicated that the significantly higher of Fe, Mn and Zn, in the investigated soil samples may also due to the higher content and type of DWS use. Our results are agreed with the findings of Singh et al. [46].

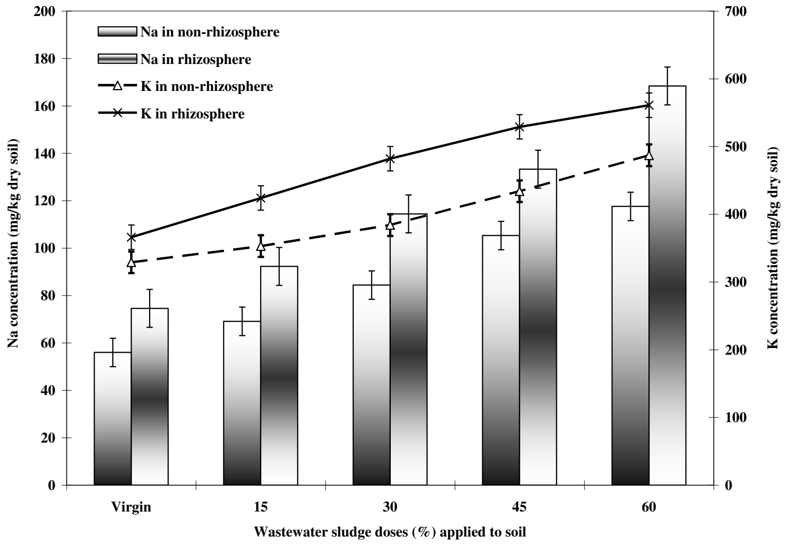

Figure 1. Effect of wastewater sludge on Na and K in bluk and rhizosphere soils

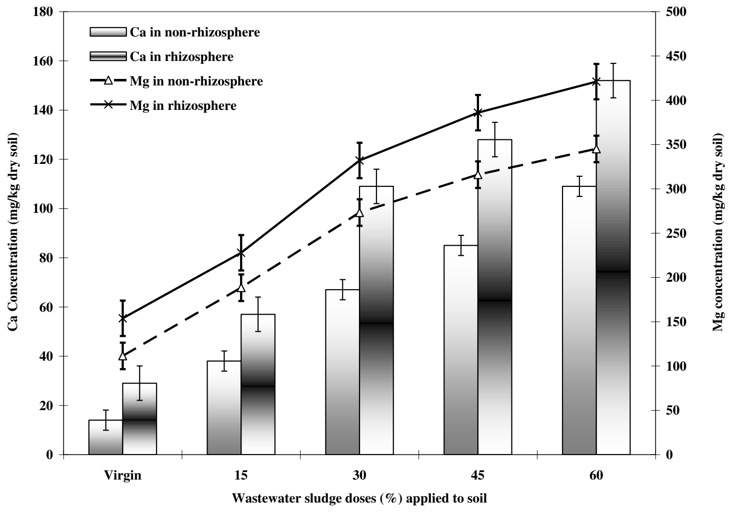

Figure 2. Effect of wastewater sludge on Ca and Mg in bluk and rhizosphere soils

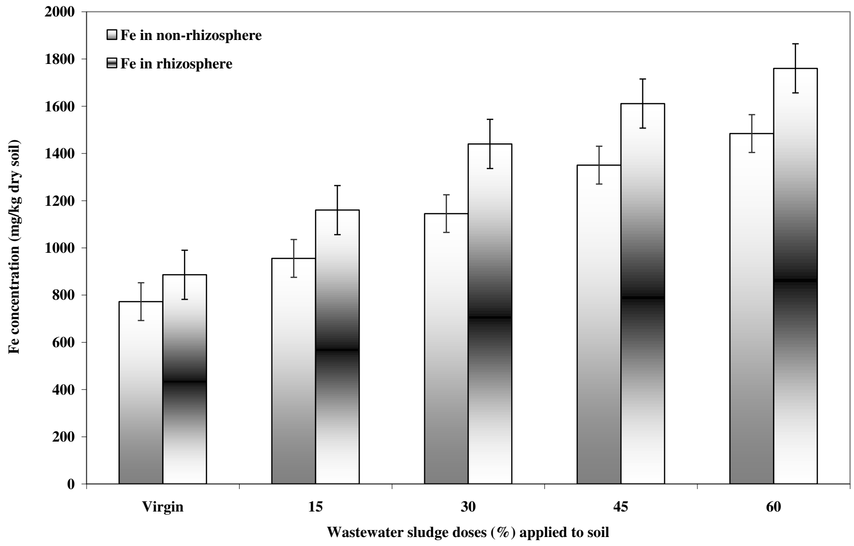

Figure 3. Effect of wastewater sludge on Fe in bluk and rhizosphere soils

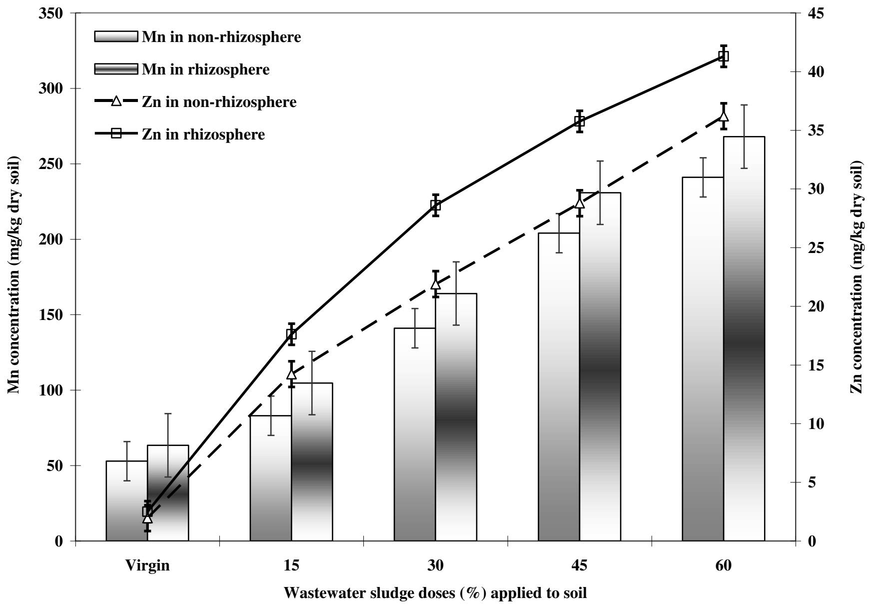

Figure 4. Effect of wastewater sludge on Mn and Zn in bluk and rhizosphere soils

Relationship between the microbial content and soil fertility

Microbiomes play a major role on decomposition of several organic compounds frequently used in agriculture, which directly affect the synthesis and decomposition of SOM [47].

In general, our results showed that higher microbial activity and potential activities of FDA and dehydrogenase occurred in soil samples amended with wastewater sludge (Figures 5 - 8), these indicating the impacts on the content and activity of soil microbiomes, which results in high nutrient recycling in the agroecosystem. The main microbial enzymes involved in the mineralization of SOM are cellulases, proteases, ureases and phosphatases [48].

Cellulase decomposers hydrolysed cellulose compounds present in fresh plant residues that are continuously deposited above soil [49]. Also, our results demonstrated that the quantitative counting of cellulose-decomposers in DWS amended soil was higher than those present in control soil samples (Figure 7).

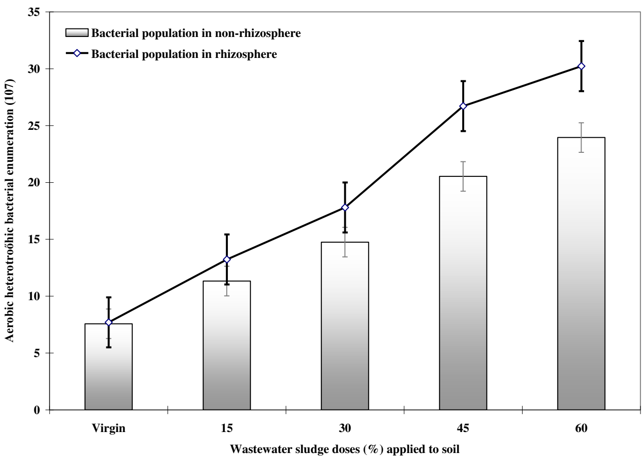

Figure 5. Effect of wastewater sludge on bacterial population in bluk and rhizosphere soils

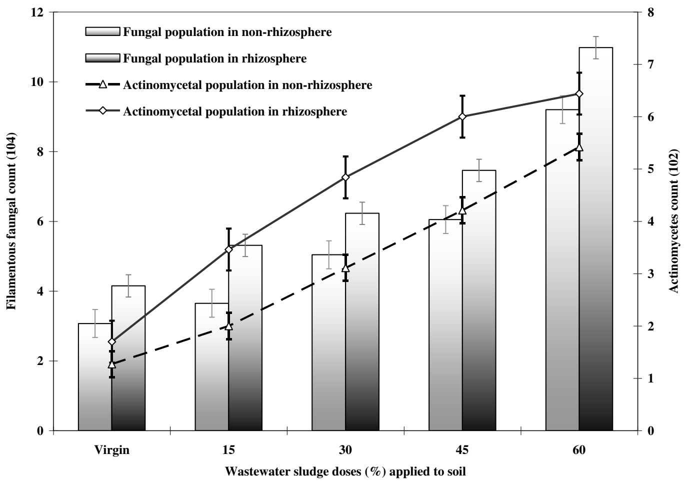

Figure 6. Effect of wastewater sludge on fungal and actinomycetes (actinobacteria) populations in bluk and rhizosphere soils

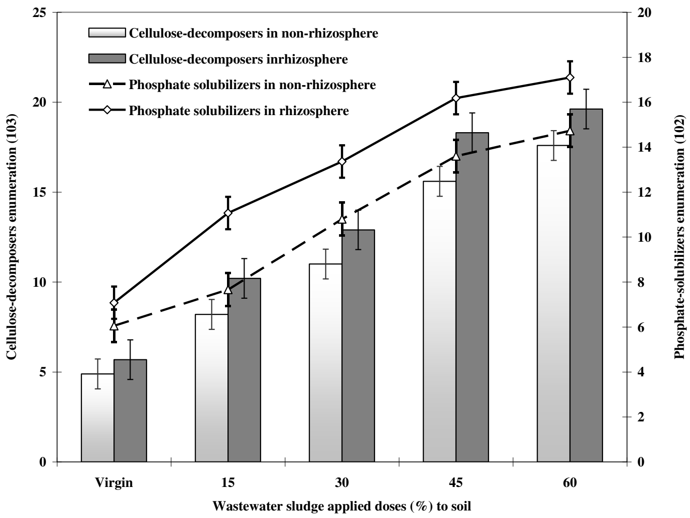

Figure 7. Effect of wastewater sludge on cellulose-decomposers and phosphate solubilizing microbes populations in bluk and rhizosphere soils

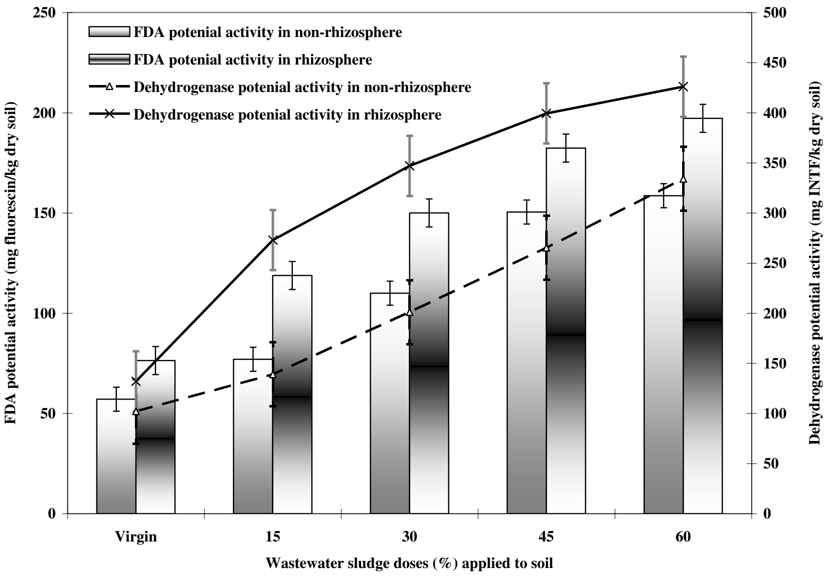

Figure 8. Effect of wastewater sludge on the potential activities of FDA and dehydrogenase in bluk and rhizosphere soils

Our results are agreed with SHENTU et al. [50] that soil biota is a significant component of soil quality as microbiomes play a vital role in soil ecosystem functioning related to soil fertility and primary production through OM decomposition and nutrient recycling.

Changes in microbial biomass C, N, P and S

Usually, larger differences were observed in the soil of higher DWS rates, for soil MBC and enzyme activities. Higher microbial activity was observed in the treated soil systems (Figures 9 - 10) than control soil samples. Dehydrogenase activity is directly linked with living cells associated with microbial oxido-reduction processes [51], which are important for OM degradation and transformation. Since, dehydrogenase activity is not active as extracellular enzymes in soil, it is considered to be a good indicator of overall microbial activity [36, 52].

Physiological and biochemical methods for estimating soil microbial biomass are usually calibrated against other methods and parameters. The estimation of microbial biomass can provide useful information on the changes in soil biological properties [53].

The strongest and most widely used calibration equations for quantifying microbial biomass are based on soil samples with a very wide range of biomass values [27, 54].

The potential activity of β-glucosidase in DWS managed treated soil was higher than the control soil. MOESKOPS et al. [55] reported significant correlation of β-glucosidase activity and SOC content with significantly higher β-glucosidase activity in organically managed soils. It has been shown that microbial activity and biomass is higher in fields with wastewater sludge amendments than fields with conventional fertilizers [56].

Furthermore, the microbial biomass reflects the contribution of soil microorganisms as both a source and a sink of C in soil ecosystem [57].

Soil microbial biomass, both source and sink of available nutrients plays a critical role in nutrient transformation.

As a consequence, our results are agreed that the microbiological properties, such as soil enzymatic activities have been suggested as potential indicators of soil quality because of their essential role in soil biology, ease of measurement and rapid response to changes in soil management [58].

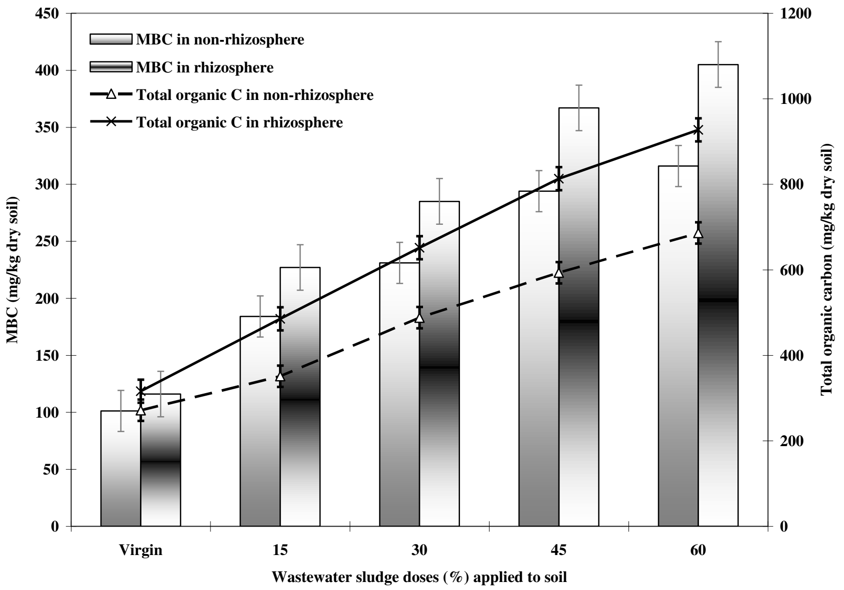

Figure 9. Effect of wastewater sludge on the MBC and TOC in bluk and rhizosphere soils

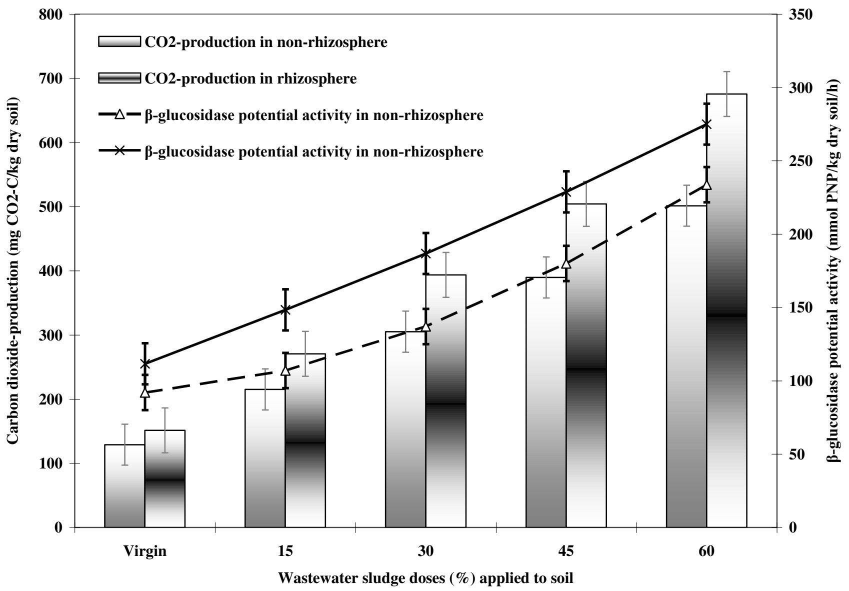

Figure 10. Effect of wastewater sludge on the CO_2 and β-glucosidase activity in bluk and rhizosphere soils

Our results showed that the application of wastewater treatment increases the MBN, TNC and the potential activites of urease and protease, and these stimulation effects were increased by increasing the application dose of DWS (Figures 11 and 12) in comparison with virgin soil samples.

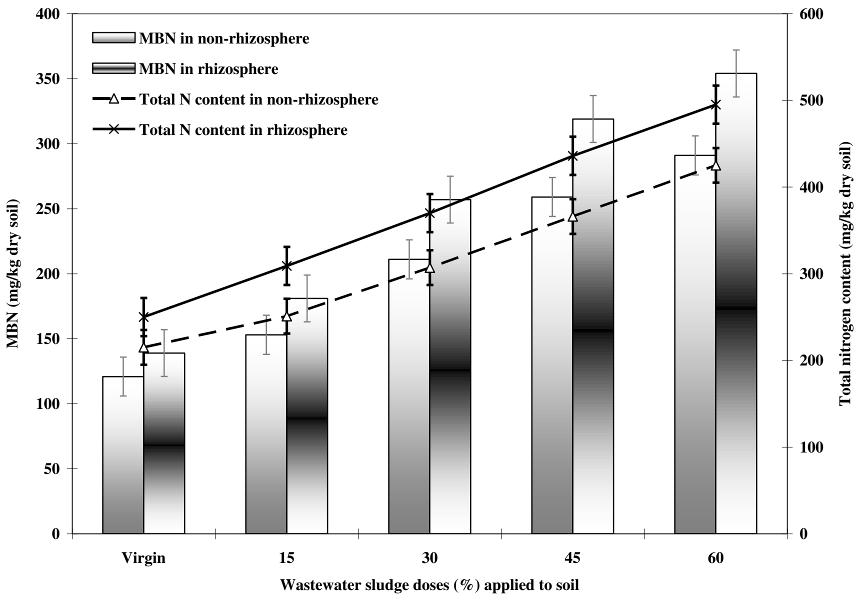

Figure 11. Effect of wastewater sludge on the MBN and TNC in bluk and rhizosphere soils

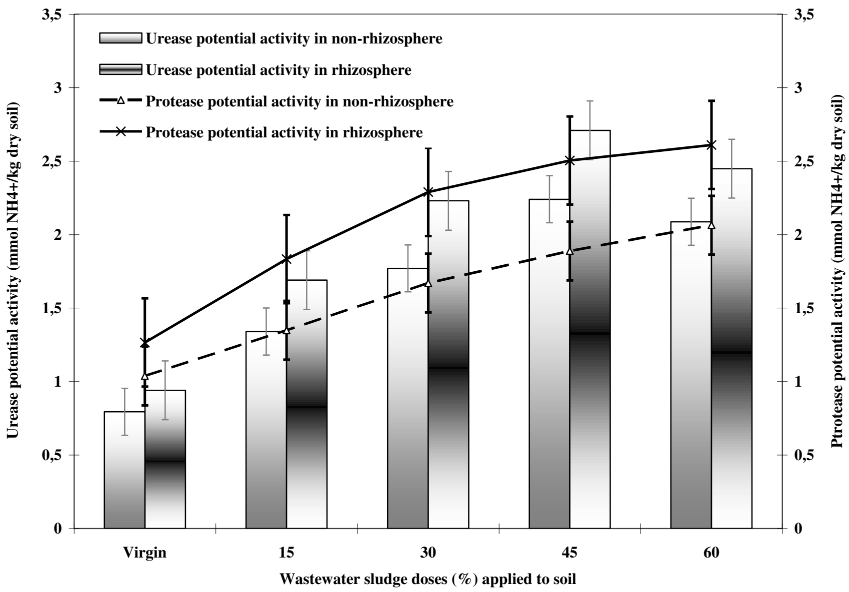

Figure 12. Effect of wastewater sludge on the potential activities of urease and protease in bluk and rhizosphere soils

Our results are in an agreement with the recent studies [59, 60], that soil is a highly complex biological system which is subject to dynamic changes under the effect of biotic and abiotic factors. The use of microbiological and biochemical properties of soil for the estimation of changes taking place in soil environment as a result of e.g., application DWS is fully justified. Nitrogen fertilization is the most important management strategy for the improvement of agricultural crops.
Urea is the most widely used source of organic N fertilizer in the world, which is easily hydrolysed to NH_4^+ and CO_2 by urease enzyme [61].
Organic N also affects directly the distribution and action of proteolytic enzymes in soils [62].
Figures 13 and 14 illustrate the effects of DWS on the MBP, TP, PO_4-P and potential activity of phosphatase under different treatments. It is clears that the addition of DWS increases the P content

in treated soil more the control soil. The stimulation of the P content was influenced by the application dose, too.

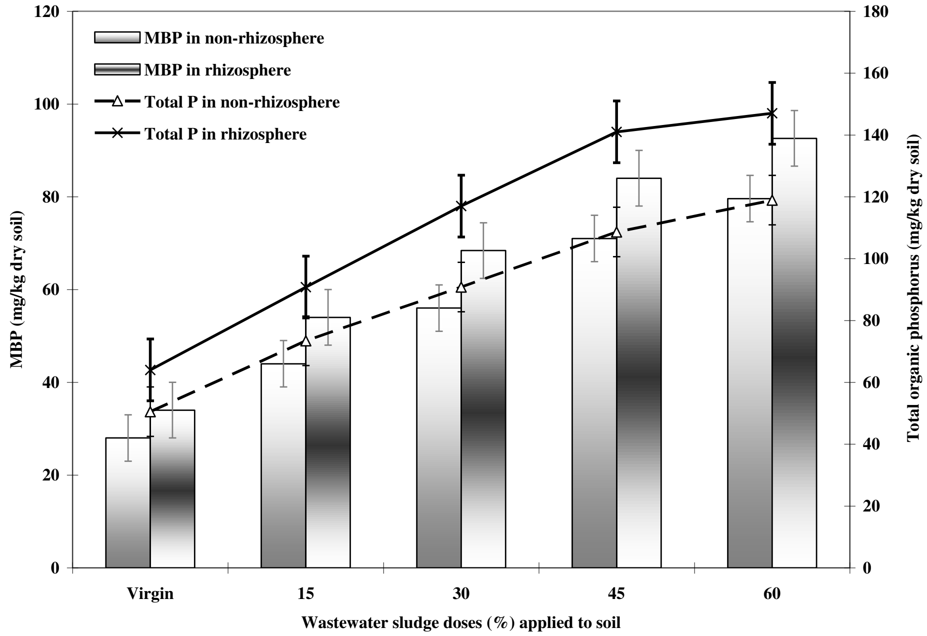

Figure 13. Effect of wastewater sludge on MBP and TP in bluk and rhizosphere soils

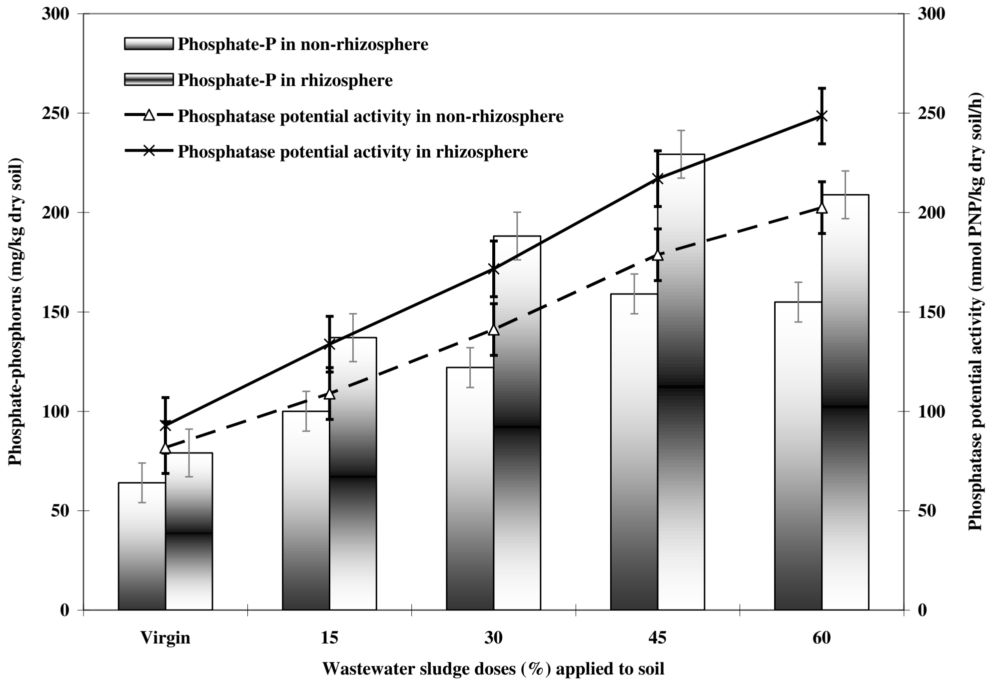

Figure 14. Effect of wastewater sludge on P and phosphatase activity in bluk and rhizosphere soils

Figure 15 demonstrates the effects of DWS on MBS and total S in treated soil samples. It was observed that by increasing the rate of applications, the investigated parameters increased

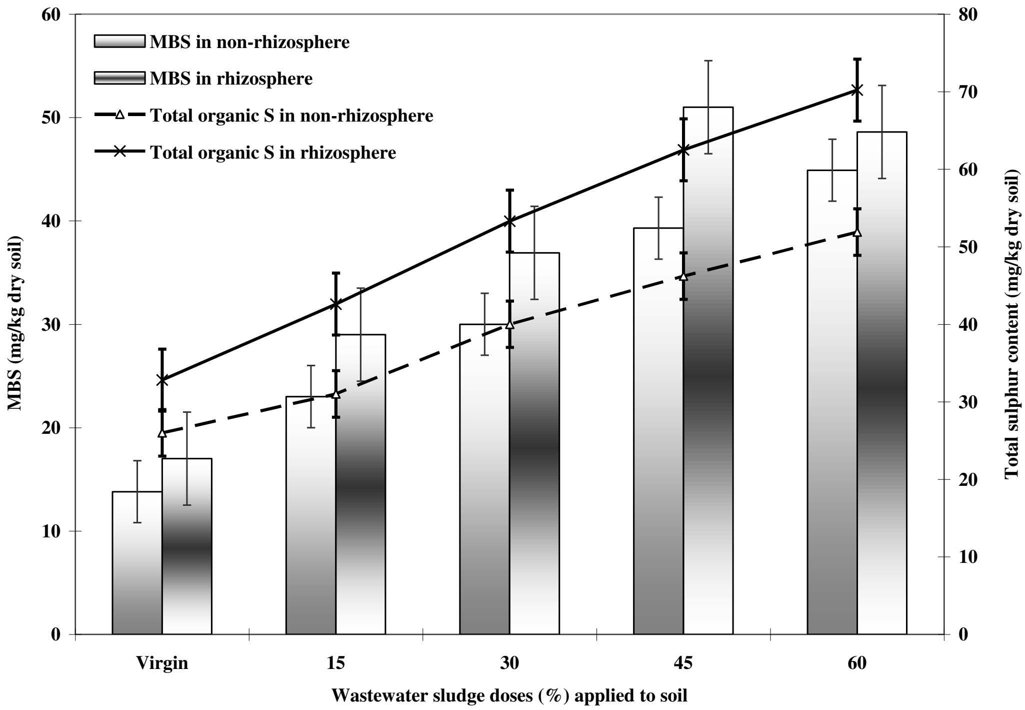

Figure 15. Effect of wastewater sludge on MBS and TS in bluk and rhizosphere soils

It is well established that the bulk of the S present in surface soils occurs mainly in organic forms and that it becomes available for plant uptake only if it is mineralised to inorganic sulphate by soil microorganisms. Microbial S values showed direct relationships with both microbial C and with total soil organic S. This result is in agreed with Banerjee and Chapman [30].

The results indicated that the enzymatic activities tended to be higher in soil treated with composted DWS than in samples without application of organic amendment. Although, our conclusion is in agreement with Vepsäläinen [63] in which soil enzyme activities are commonly correlated with each other, it is advisable in soil quality studies to measure a pattern of several enzyme activities simultaneously. Also, we are agreed with Roldán et al. [64] that soil enzyme activity can be used as an indicator of soil quality for assessing the sustainability of agricultural ecosystems.

Net N mineralization and nitrification

The concentration of NO_3-N in control soil amended with DWS was significantly affected by the interaction of DWS application rate. On the other hand, the control untreated soil produced the lowest concentration of soil NO_3-N, which was, however, not significantly different from that produced by the application of 15% of DWS (Figure 16).

Soil NO_3-N concentrations measured at the end of the experiment, which can be considered residual concentrations, increased as DWS rates increased.

In this study, the increase in DWS rates produced increases in soil NO_3-N concentration in soil amended with different rates of DWS.

Based on the results obtained, it seems that a control soil samples of the region studied, as a consequence of degradation processes originated mainly by the lack of vegetation cover and low organic matter content, can be considered as “poor” from a biological and biochemical point of view. Other parts of the study area (amended soil samples) may with time go the same way. It would, therefore, be of interest to study the regeneration of this type of soil to avoid desertification and to determine how regeneration affects the microbiological activity of these soils.

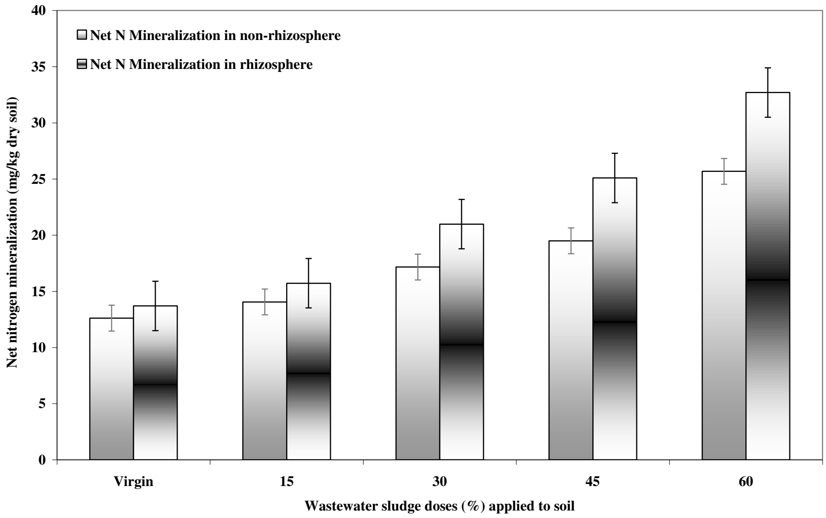

Figure 16. Effect of wastewater sludge on net N mineralization in bluk and rhizosphere soils

Organic manure (vermicompost, farmyard manure, etc.) is becoming an important component of environmentally sound agriculture. Recently, the use of organic materials as fertilizers for crop production has received attention for sustainable crop productivity (Arif et al., 2014)[65]. Organic manure act not only as a source of nutrients and organic matter, but also increase size, biodiversity and activity of the microbial population in soil, influence structure, nutrients get turnover and many other changes related to physical, chemical and biological parameters of the soil (Albiach et al., 2000)[66]. Nutrients contained in organic manure are released slowly and are stored for a longer time in the soil, thereby ensuring a longer residual effect and persistence of nutrient availability. Residual nature of organic sources makes them more value based for the whole system compared to individual crops (Arora and Maini, 2011)[67]. The judicious applications of organic manures not only improve the productivity but also make cultivation of crops more sustainable (Tiwari et al., 2002)[68].

Soil contains approximately 2344 Gt (1 gigaton = 1 billion tonnes) of OC globally and is the largest terrestrial pool of OC. Small changes in the soil OC stock could result in significant impacts on the atmospheric C concentration. The fluxes of SOC vary in response to a host of potential environmental and anthropogenic driving factors. Scientists worldwide are contemplating questions such as: What is the average net change in SOC due to environmental conditions or management practices? How can SOC sequestration be enhanced to achieve some mitigation of atmospheric CO_2? and Will this secure soil quality? These questions are far reaching, because maintaining and improving the world's soil resource is imperative to providing sufficient food and fibre to a growing population. Additional challenges are expected through climate change and its potential to increase food shortages. This further research work should highlight knowledge of the amount of C stored in soils globally, and the potential for C sequestration in soil. It also discusses successful methods and models used to determine and estimate C pools and fluxes. This knowledge and technology underpins decisions to protect the soil resource.

Finally, and according to the findings obtained, the authors are strongly recognize the following that organic wastes such as sewage sludge and compost increase the input of carbon and nutrients to the agricultural land. However, sewage sludge-applied heavy metals, and organic pollutants adversely affect soil biochemical properties. The addition of sewage sludge decreased soil pH if it is highly acidic and increased soil salinity if it contains hlgh amounts of Na, K, Ca, Mg, etc to a greater extent than the addition of compost. Both sewage sludge and compost increased significantly the values of the cumulative C mineralized, dissolved organic C, humic and fulvic acid C, microbial biomass C, and metabolic quotient (qCO_2), especially with increasing application rate. Compared to compost, the addition of sewage sludge caused higher increases in the values of these parameters. The values of dissolved organic C, fulvic acid C, microbial biomass C, metabolic quotient, and C/N ratio tended to decrease with time. The soil treated with sewage sludge showed a significant increase in the mobile fractions of Zn, Cd, Cu, and Ni and a significant decrease in the mobile fraction of Pb compared to control. The high application rate of compost resulted in the lowest mobility of Cu, Ni, and Pb. The results suggest that biochemical properties of calcareous soil can be enhanced by both organic wastes. But, the high salinity and extractability of heavy metals, due to the addition of sewage sludge, may limit the application of sewage sludge.

The application of chemical fertilizer can increase the yield of agriculture but excessive fertilizer application has become one of the important sources of agricultural non-point source pollution and how to control non-point source pollution is a thorny problem for developing countries in agricultural transformation and sustainable development. In the past 40 years, However, excessive fertilization has led to large-scale agricultural non-point source pollution, and agricultural non-point source pollution has surpassed the developed countries in both breadth and depth. As a sustainable development model, agricultural green development can improve the economic efficiency of existing resources and actively improve the current environmental efficiency without harming future resources.

CONCLUSION

A substantial increase in the quantities of soil microbial biomasses and enzymatic activities take place in the mineralization of OM present in the disposal wastewater sludge applied to the soil samples; however, there was a recovery of soil microbial biomass and enzymatic activities followed the use of soil organic fertilization practices. The biochemical indices selected in the present research can provide a reliable and useful indication of soil biological quality of soil fertility after application of disposal wastewater sludge. A greenhouse pot experiment is described for studying the changes in soil biodynamics after the application of disposal wastewater sludge. The result demonstrated that disposal wastewater sludge have a great potential to enhance soil OM, nutrient availability, microbial activity, microbial biomass and enzyme production. Soil biochemical and biological indicators of soil quality were generally higher in disposal wastewater sludge systems compared to control untreated soil system. High of soil enzymatic activities and microbial biomass C as affected by OM input in disposal wastewater sludge systems emphasize the important role of element recycling processes supported by an abundant and active soil biological community. The present research work highlights that a portion of C, N, P and S were increased in soil amended with higher rates of disposal wastewater sludge. Microbial interactions in the disposal wastewater sludge treated soil are the determinants of soil fertility and environmental health, our understanding of these interactions therefore has implications for sustainable soil management. However, the subject of agroecosystem is very complex and need more research to understand the interaction between the plant, the rhizospheric environment, and nutrient bioavailability.

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