

## Effect of Utilization of Organic Waste as Agricultural Amendment on Soil Microbial Biomass

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### Authors' contributions

This work was carried out in collaboration between all authors. Authors RPS, AS, CS, PS, ARLM, LAPLN, ASFDA and WJDM managed the literature searches and wrote the manuscript. All authors read and approved the final manuscript.

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### ABSTRACT

The use of organic wastes, from municipal and industrial activities, as source of plant nutrients and soil conditioners increased worldwide. However, there is a concern with the environmental pollution.

Currently, these organic wastes are disposed in open dump in developing countries or in landfills in the developed ones. The main soil indicator used to evaluate the effect of organic wastes on soil is soil microbial biomass.

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Soil microbial biomass is very sensitive to environmental impact and there are already several studies evaluating the effect of organic wastes on soil microbial properties. Nowadays, the studies are focusing soil microbial diversity as the use of molecular biology tools. The current review addresses the effects of use of organic waste, from municipal and industrial sources, in agriculture and their effects on soil microbial biomass.

**Keywords:** Wastes management; agricultural soil; heavy metals; soil microorganisms.

## 1. INTRODUCTION

### 1.1 Wastes Management: A Need of Present Time

Organic wastes produced after wastewater treatment comprises discharges from domestic residences, commercial properties, industries, and agriculture [1]. Usually, it refers to the municipal and industrial wastes that contain a great number of contaminants resulting from the mixture of wastewaters from different sources [2]. Municipal and industrial wastes include domestic, municipal, or industrial liquid waste. The increasing in urbanization and industrialization has resulted in a strong increase in the volume of wastes produced around the world [3]. Generally, these wastes are release into the environment.

The main concern with the environmental quality has caused increase in organic wastes management, due to the necessity to find an ecologic way to dispose these wastes without environmental risks and, if possible, recycling the chemical elements present in these organic wastes [1]. An alternative method is the use of organic wastes as source of plant nutrients and soil conditioners, mainly, due the high content of organic matter, and plant nutrients [2] (Table 1).

However, these wastes present relative quantity of heavy metals (Table 2) that may have detrimental effects on soil quality and plant growth. Sewage sludge is originated from Wastewater Treatment Station (WTS) and for many years this residue was called biosolids [7],

**Table 1. Macronutrients in sewage, textile and tannery sludge and other organic wastes used in agriculture**

| Waste                               | C   | N  | P  | K  | Ca  | Mg | S  |
|-------------------------------------|---|----|----|----|-----|----|----|
|                                     | ----- g kg <sup>-1</sup> (dry basis)----- |    |    |    |     |    |    |
| Bovine waste <sup>1</sup>           | 486                                       | 27 | 18 | 32 | 30  | 9  | 3  |
| Chicken waste <sup>1</sup>          | 311                                       | 31 | 18 | 16 | 51  | 11 | 4  |
| MSW compost <sup>2</sup>            | 278                                       | 10 | 3  | 5  | 19  | 2  | 3  |
| Sewage sludge <sup>2</sup>          | 340                                       | 32 | 16 | 4  | 32  | 12 | 4  |
| Textile sludge <sup>3</sup>         | 222                                       | 52 | 16 | 6  | 21  | 17 | na |
| Textile sludge compost <sup>3</sup> | 365                                       | 10 | 87 | 34 | 139 | 43 | na |
| Tannery sludge <sup>4</sup>         | 407                                       | 23 | 2  | 6  | 46  | 27 | na |

MSW – Municipal solid waste; na = not available; <sup>1</sup> Arifin et al. [4]; <sup>2</sup> Melo et al. [2]; <sup>3</sup> Araújo and Monteiro, [5]; <sup>4</sup> Teixeira et al. [6]

**Table 2. Heavy metals in sewage, textile and tannery sludge and other organic wastes used in agriculture**

| Waste                               | Pb  | Cd       | Ni      | Cr      | Hg       |
|-------------------------------------|---|----------|---------|---------|----------|
|                                     | ----- mg kg <sup>-1</sup> (dry basis) ----- |          |         |         |          |
| Bovine manure <sup>1</sup>          | 1.52  | 0        | 3.0     | na      | na       |
| Hen manure <sup>1</sup>             | 38  | 4.4      | 4.4     | na      | na       |
| MSW compost <sup>2</sup>            | 1.3-2240                                    | 0.01-100 | 0.9-279 | 1.8-410 | 0.09-2.1 |
| Sewage sludge <sup>2</sup>          | 2-7000                                      | 0-3410   | 6-5300  | 8-40600 | 1-260    |
| Textile sludge <sup>3</sup>         | 71  | 5.6      | 104     | 111     | na       |
| Textile sludge compost <sup>3</sup> | 33  | < 0.3    | 30      | 73      | na       |
| Tannery sludge <sup>4</sup>         | na  | na       | na      | 43      | na       |

MSW – Municipal solid waste; na = not available; <sup>1</sup> Arifin et al. [4]; <sup>2</sup> Melo et al. [2]; <sup>3</sup> Araújo and Monteiro, [5]; <sup>4</sup> Teixeira et al. [6]

but more recently there has been a pressure to use the name sewage sludge, name adopted in Brazilian legislation.

Sewage sludge composition varies widely depending on the origin and the process used in the WTS [7,8]. It is still rich in organic matter which is important for soils in the tropical regions, which present low cation exchange capacity (CEC). This residue also contains all the macro and micronutrients. Sewage sludge can also contribute to improve soil physical properties as density, permeability, capacity of water retention, and water infiltration [7-9]. Consequently, it has been considered for use in agricultural soil in order to improve soil physical, chemical and biological properties and to supply nutrients to plants. But sewage sludge also contains heavy metals and other pollutants so that its application to soil represents a risk to the environment, to the plant growth and to the animals and human health [7,9]. Additionally, sewage sludge obtained from the treatment of domestic wastewater may contain higher concentration of pathogenic agents as helminthes eggs [9].

The use of sewage sludge in agricultural soils must be very criterions, subordinated to a very rigorous legislation based on data obtained during long-term field experiments and with a mechanism of annual evaluation that are able to detect any loss in soil quality. Some authors have developed researches on the use of sewage sludge as a mechanism for the reclamation of degraded areas which lost their organic matter or were contaminated by heavy metals [10-13]. In studies to evaluate the use of sewage sludge in agriculture, soil enzymatic activity may play an important participation, since it responses quickly to environmental alterations [10].

In this way, the use of organic wastes in agricultural soils needs of defined action, in order to not cause damage to environment, mainly to the soil biological properties. In recent years, soil microbial biomass has been seen to be early and sensitive indicators of soil stress and can be used to predict long-term trends in the soil quality [14].

## 1.2 Soil Microbial Biomass

Soil is a complex environment, where microorganisms play a crucial role in nutrient cycling and the degradation of different pollutants (for example, pesticides and industrial wastes)

contributing in this way to the maintenance of soil quality [5,14-16]. Additionally, the soil microorganisms performs others important functions, as to form symbiotic associations with roots, to act as antagonist of pathogens, to influence the weathering and solubilization of minerals and to contribute to soil structure and aggregation [14]. The role of the microbial fractions in mediating soil process, and their relatively high rate in turnover, suggest that the microbial fraction could be sensitive indicator and early predictor of the changing soil organic matter processes [17].

The soil microbial biomass comprises all soil organisms with a volume of less than about  $5 \times 10^3 \text{ um}^3$ , other than living plant tissue, and can thus be considered as the living part of soil organic matter [18]. The microbial biomass comprises about 1 to 4% of soil organic matter, being a important labile reservoir of essential plant nutrients, e.g. nitrogen (N), phosphate (P) and sulphate (S). Because it is living, the microbial biomass responds much more quickly to changing soil conditions, particularly decreases or increases in plant or animal residues, than does soil organic matter as a whole.

Out of the total soil microbial biomass, bacteria soil fungi are responsible for about 90% of the total energy flux of organic matter decomposition in soil [18]. The living component of soil responds usually more rapidly to changing soil conditions than that of most of the physical and chemical indicators [17,19]. Consequently they may be recognised as a sensitive indicator of soil conditions. As soil enzymatic activities are an expression of pedological amendments and soil properties and they have repeatedly been estimated to establish the indices of soil fertility [20,21]. Measurement of soil enzymes can also be used as an indicator for many soil biological processes.

Soil enzymes play a very essential role in agriculture and nutrients cycling as they are constantly being synthesized, accumulated, inactivated and / or degraded [22,23]. Soil enzymatic activities are indirectly affected by heavy metals via shifting the microbial community which synthesizes enzymes [24]. Each soil enzyme exhibits a different sensitivity to heavy metals due to the different chemical affinities of the enzymes in the soil system [25]. The effect of sewage sludge on soil biological activity can be used as pollution indicator [8]. Soil

microbial activity, soil respiration and soil enzymes activities are reported to increase due to sewage sludge amendment [26]. However, Fließbach et al. [16] have reported reduction in soil enzyme at longer incubation period with high heavy metal availability.

Urease (urea amidohydrolase), the enzyme that catalyzes the hydrolysis of urea to CO<sub>2</sub> and NH<sub>4</sub> ions by acting on C-N non-peptide bonds in linear amides [27], is an important enzyme in soil that mediates the conversion of organic N to inorganic N by hydrolysis of urea to ammonia [28]. Invertase ( $\beta$ -D-fructofuranosidase) is universal enzyme in soils [29]. For releasing simple C and N sources for the growth and multiplication of soil microorganisms the activities of urease and invertase are important in soil. According to Garcia et al. [15] sewage sludge contains high amounts of enzymatic substrates, which easily stimulates microbial growth and enzyme production.

### 1.3 Wastes Management and the Response of Soil Microbial Biomass

Several studies were conducted to evaluate the effect of wastes on soil microbial biomass [5,30]. In the laboratory study, Araújo and Monteiro [5] examined the effect of application of untreated and composted textile sludge on microbial biomass in a Brazilian soil. The soil was amended with untreated and composted sludge at rates equivalent of 6.4 ton ha<sup>-1</sup> and 19 ton ha<sup>-1</sup>, respectively, and was incubated for 60 days. The application of composted sludge increased significantly the microbial biomass and bacteria number of soil. There were not differences in the microbial activity and bacteria number among the control and untreated sludge amended soils. In conclusion, after 2 months of incubation, the effects of the two amendments on soil microorganisms were: microbial biomass, soil respiration and bacteria number were increased only in composted sludge treated soil.

Araújo et al. [30] verified the effect of tannery sludge on cellulose decomposition in soil. The amounts of tannery sludge were 0, 11, 22, 44, 88 and 172 ton ha<sup>-1</sup>. The authors observed that the waste applied in high rates inhibited the cellulose decomposition. The decrease in cellulose decomposition indicates that the waste reduced the fungi population, conform related by Akmal et al. [31].

Sewage sludge amendment have been reported to enhance soil microbial biomass by 8-28% at the sludge amendment rate of 0.75% (dry wt.), being greatest in the clay-loam and least in the sandy-loam soil [32]. The enzymes dehydrogenase, alkaline phosphatase and arginine-ammonification activities in soil were enhanced by 18-25%, 9-23% and 8-12%, respectively as compared to the unamended soils. The increase was reported to be greater in sandy loam than in loam, or clay loam soils.

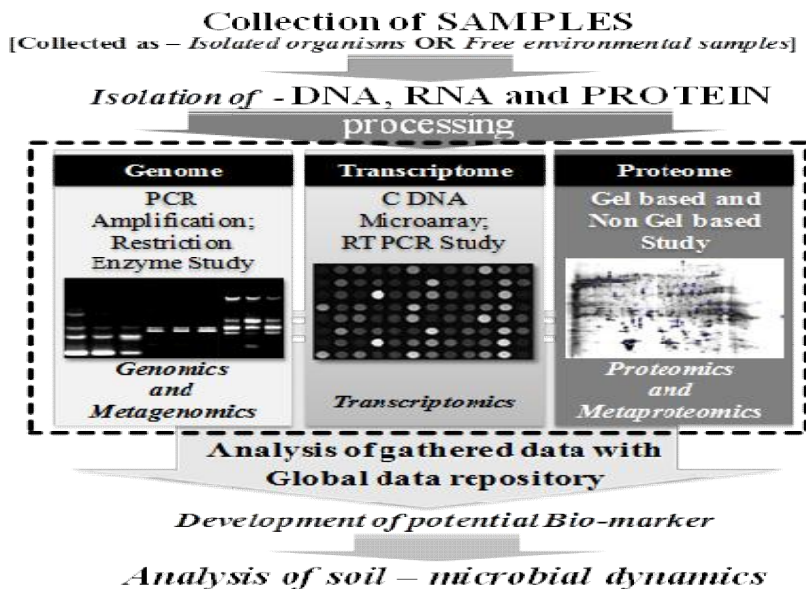
Although sewage sludge is also an important cause of soil pollution, soil fertility may increase due its use [11]. Some metals found in sludge, for example Cu, Ni, and Zn, are essential micro-nutrients for plants and microorganisms [33]. However, at elevated concentrations even these micro-nutrients may be toxic. Adverse effects of sludge derived metals on soil microorganisms result in a potential threat to soil quality, particularly through the nutrient cycling disruption. Reductions in microbial biomass [16,31,34] and enzymatic activity [35] have been found in soils contaminated with heavy metals in most of the studies. Reduction in microbial biomass due to heavy metal exposure have been owed to instantaneous death of microbial cells, disorder of important functions and change in population size and in viability or competitive ability of soil microorganisms [36]. The influence of heavy metals on soil respiration is less known. Some researchers have reported significantly lower CO<sub>2</sub> evolution in metal contaminated soils [35,36]. However, others have reported the contradictory results [16,34,37]. Moreover, a wide variety of studies have also indicated that respiration responses to metal inputs may differ with time since application [38]. Responses of microbes to variety of metals present in sludge may be synergistic, antagonistic or additive [14]. On account of such interactions, it is very hard to set up a least soil concentration for individual metals at which adverse effects on microorganisms occur [14]. Sensitivity of microbes to different metals may vary due to differences in their solubility in soils. Akmal et al. [31] reported higher reduction in biomass C with Cd than that with Pb and attributed it to higher Cd solubility than that of the Pb.

### 1.5 Waste Management and Soil Microbial Dynamics: Looking Through '-Omics' Approaches

Managing solid waste through agricultural utilization has been quite popular throughout the

world since last few decades [7]. However, very recent researchers have started studying its effects on soil health, especially soil – microbial interaction and dynamics. Modern days ‘-omics’ approaches, comprise of state of the art technologies, added a major outbreak in this initiative, and provided researchers a more comprehensive tool for the identification and evaluation of microbial diversity in soil, water and air [39]. Actually, in 21<sup>st</sup> century, we are running through the golden era of *genomics* (study of whole ‘genome’ is called ‘genomics’), especially for all microbial organisms; and also in position to use multiple parallel approaches for the functional analysis of genomes in a high-throughput manner. These parallel approaches surely result in an exceptionally swift and effective system for the analyses and deductions of gene(s) function in a wide range of living organisms, at the level of transcript (transcriptomics), protein (proteomics) and metabolite (metabolomics). All together these four approaches are commonly referred as the multi-parallel ‘-omics’ approaches in modern biology [40]. While in very recent times, researchers have also started working with ‘genome’ and ‘proteome’ samples directly isolated from environment, and termed those as – ‘metagenome’ and ‘metaproteome’ and their subsequent study as ‘metagenomics’ and ‘metaproteomics’. In total both of these *in vivo* and *in-vitro* ‘-omics’ approaches have

significantly contributed in the evaluation of soil – microbial dynamics at many ecosystems. Sanapareddy et al. [41] through metagenomics approach generated 3,601 sequences by pyrosequencing, using 454-FLX technology, of DNA samples collected from an activated sludge basin of a wastewater treatment plant in Charlotte, North Carolina, USA, and identified a significant amount of microbial community present in that sludge basin, and might be useful for the soil too. In another study, Wang et al. [42] through metaproteomics approach, using in depth 2-DE coupled with MALDI-TOF/TOF-MS, identified nearly 122 different proteins isolated from metaproteome of both plant and microbes complex existing in a crop rhizospheric soil, and indicated towards an intricate microbial dynamics. Chourey et al. [43] developed a novel direct protocol for metaproteome characterization of any type of soil, and showed a nice *in-vivo* identification method for microbe’s community. Other than these above reports, several other researchers also used ‘-omics’ approaches for evaluating microbial community dynamics in respective soil samples, and indicated their contribution for soil health [39,44,45]. However, following these studies, it was quite clear that, every ‘-omics’ workflow mainly target to develop a proper biomarker (that might be a gene or genes, protein or proteins) for the identification of microbial dynamics in the available environmental sample (Fig. 1).



**Fig. 1. Work flow for developing potential bio-marker for assessing solid waste management using ‘-omics’ technology**

Figure from the authors

## 2. CONCLUSION

Increasing solid waste in urban territory and its subsequent management through land filling or composting are of serious concerns worldwide. Land filling requires enormous landmass and is economically expensive practice. Also landfilling may also result in numerous environmental and health related problems. Our main conclusions are as follows- Although the agricultural utilization of urban waste may be beneficial, it also may contaminate the food chain, ground and drinking water.

Land applications of urban waste, e.g. - MSW, sewage sludge may result in transport of pathogens through aerosols to areas of human habitation.

Considering the foregoing, the physicochemical analysis of sewage sludge is necessary before a decision is made to use it for land application, and, Research is needed on application to different soil types and at urban waste amendment rates to evaluate effects on soil microbial biomass.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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