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Article

Composting Used as a Low Cost Method for Pathogen Elimination in Sewage Sludge in Mérida, Mexico

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Abstract: Spreading sewage sludge from municipal wastewater (MWW) treatment on land is still a common practice in developing countries. However, it is well known that sewage sludge without special treatment contains various pollutants, which are (re)introduced into the environment by sludge landspreading and which might in turn have harmful effects on the environment and human health. This is more dangerous in places like Merida, Mexico, where soil is calcareous with fractures along the ground and thin layers of humus. Consequently, any liquid and semisolid wastes have the potential of percolating to the subsurface and contaminate the aquifer. The main aim of this work was using composting as a low cost process to eliminate pathogens contained in sewage sludge from MWW treatment in order to use the final product for land spreading in a safe way for both environment and human health. Two piles for composting process at real scale were settled using a mixture of sewage sludge from municipal waste water and green waste. Composting was carried out by windrow process and it was monitored during four weeks. Concentration of helminth eggs, salmonella and faecal coliforms were measured twice a week to observe its behavior and, as a control process, Temperature, Moisture Content (MC), and pH were also measured. After 30 days of composting sludge from municipal waste water system, salmonella was eliminated by 99%, faecal coliforms by 96% and helminth eggs by 81%. After 3 months compost reached GI = 160%, so did not show any phytotoxicity to seeds.

Keywords: sewage sludge; composting; pathogens; waste water

1. Introduction

The present work was developed in the city of Mérida, located on the Yucatán Península with 900,000 inhabitants approximately including its surrounding areas [1]. All area is formed by a very permeable karst surface[2]. Due to karstic conditions, there are a lot of fractures in the subsoil, the aquifer receives water from rainfall including any pollution that is picked up from the land surface [2,3]. The aquifer is also the unique source of water in the region. The main sources of pollution of the aquifer are the wastewater and sludge from the municipal wastewater system (septic tanks, small treatment plants and waste water from small industry).

The main goal of this study was to test the compost process as an economical and efficient method for pathogen elimination in sludge from a municipal waste water system. In the case of the city of Merida, Mexico, this process turns out to be important because at present the sludge from the municipal wastewater system does not receive any treatment before being deposited on soils, so it might represent a potential source to spread pathogens.

The composting process has shown to be an economic method, capable of eliminating or reducing the pathogenic microorganisms present in the material being treated by composting.

According to Epstein E. [4], composting is very effective in destroying pathogens, as a result of temperature—time relationship.

1.1. Background

Most houses in Merida have septic tanks as a sewage system. Once the septic tank is full, its content is collected and discharged into an oxidation pond system where sludge and water are separated by decantation. Separated sludge is discharged on the ground where it is sun dried. Endemic birds and insects like flies and worms have continuous contact with this waste. For flies, it becomes an ideal place for laying its eggs because of the amount of nutrients it has. As a consequence, they become a way of transporting pathogenic microorganisms with the potential of spreading human diseases.

As expected, municipal solid waste, sludge from municipal waste water (biosolids), food waste and yard waste, contain human pathogenic organisms.

Figure 1 illustrates an oxidation pond constructed in the city of Merida as a Municipal Waste Water System which is the only treatment available for wastewater in the area, for both household and micro-industry wastewater. The plant was designed to provide treatment to 9550 m^3 of wastewater per month; however, it receives between 10,000 and 12,000 m^3 [5].

Figure 1. Oxidation ponds system used in Mérida, Mexico as a Municipal Waste Water System.

Composting, if carried out properly, is an effective process to destroy contamination indicators and pathogens like faecal coliforms and Salmonella pp as a result of the relationship between time spent at elevated temperatures and pathogen destruction. For example, if the compost reaches a temperature of 60 °C during 30 min or 70 °C during 4 min, Salmonella in biosolids can be destroyed on the other hand total coliforms and faecal coliforms show great reduction when temperatures exceed 55 °C to 65 °C [4].

During the thermophilic stage of composting, an increase of temperature can occur through the sludge mass as a result of the microorganisms' activity. Thus pathogens content within the sludge could be destroyed. Temperatures above 45 °C characterizes this period of composting [4,6,7]. During the next stage temperature descends, causing a decrease of degradation speed. At the end of the composting process, resulting material looks similar to humus, and is free of easy available organic matter, weed seeds and pathogens.

Composting is an aerobic process, thus oxygen is essential element for the microbial activity. Sludge from waste water treatments usually contains large amounts of moisture which inhibits the free flow of air. Wood or bark chips, sawdust, yard trimmings and pruning trees have been tested like bulking agents providing free spaces for an adequate oxygenation [8,9]. For the current work yard trimmings were used. Composting by windrow has shown a good performance for sludge mixed with yard trimmings. According to Velazquez *et al.* [10], with this process, fecal coliforms were eliminated by 90% after a month.

The windrow composting method needs a lot of space and some mechanism for agitating the material (adding oxygen). For the city of Merida, the land is very cheap and oxygen can be added by manual turning of the pile. Therefore, composting can be achieved with only a small input of resources.

1.2. Research Objectives

- To test the windrow composting as a low cost process to eliminate pathogens contained in sewage sludge from municipal wastewater treatment.
- To observe the behavior of helminth eggs, salmonella and faecal coliforms during the windrow composting process.
- To obtain a final product that can be deposited on the soil safely in terms of environment and human health.

2. Methodology

2.1. Composting Process

Composting is not a common practice in the region; the present work was developed as a pilot experiment.

Two real size-composting piles were built for this work over a concrete slab nearby the municipal waste water system in Mérida, Mexico. In this city, the municipal wastewater system is an oxidation pond (See Figure 2). Each pile was constructed by a mixture of sludge from the municipal waste water system (40%) and green waste or yard trimmings (60%) which altogether added to 1000 L. Composting was made by windrow system, turning piles manually twice a week and using Temperature, Moisture Content and pH as control parameters. The temperature was measured everyday in 9 different points inside the compost matrix (30 cm depth) using a digital thermopar Tegam 871; the samples for the other parameters were taken after turning the piles. The pH was measured using a pH meter Thermo Orion with a range between 2 to 14 and an accuracy of ±2. Composting piles were monitored during four weeks for the active stage by analyzing, twice a week the concentration of Helminth eggs, Salmonella and faecal Coliforms. After the active stage, the composting material was tested twice a month during the following two months for the same pathogens and checking the germination index.

Figure 2. Composting piles at real scale using windrow system and manual agitation.

2.2. Laboratory Techniques

2.2.1. Salmonella and Faecal Coliforms

For salmonella and faecal coliforms tests, the procedures described by the NOM-004-SEMARNAT were used [11]. This methodology is based on the procedures described in the "Standard Methods for the examination of Water and Wastewater", where the techniques of Most Probable Number (MPN) were used. These procedures have been established by the Mexican environmental legislation specifically to indicate the possible presence of pathogens in sludge and also to establish the maximum permissible limits for these indicators in sludge to be deposited in soils safely.

2.2.2. Helminth Eggs

For determining helminth eggs concentration, the method described by Moodley *et al.* [12] was used. The method is based on three fundamental processes: washing, filtering one or more times, and then floating and sedimenting of the retrieved parasites. A flotation step is used for the isolation of helminth ova using density gradient centrifugation and a chemical solution that is saturated at a specific gravity of 1.3 so that all helminth ova having relative densities that range from 1.13 (e.g., Ascaris) to 1.27 (e.g., Taenia) are able to float in that solution. The deposit is transferred to one or more microscope slides and examined under the microscope to enumerate each species of Helminth ova using the 10x objective and the 40x objective to confirm any uncertainties.

2.2.3. Germination Index

Germination index was performed by a phytotoxicity bioassay, using a liquid extract of compost for watering radish seeds (instead of cress seeds), as described by the Methodology used by the Lab Staff at University of Leeds, UK [13] which is an adaptation of the method of Zucconi, *et al.* [14]. 30 g of screened sample were shaken with 300 mL of distilled water for 1 h. The suspension was centrifuged for 15 min at 3000 rpm and the supernatant was filtered through a Whatman No 6 filter paper. 10 radish seeds were placed on filter paper Whatman No 1 in a Petri dish of 10cm diameter. Two ml of the extract were added to the Petri dish. Two ml of distilled water were used for control. The test was run in triplicate. Petri dishes were left on laboratory bench and after 48 h, the total length of each cress root was measured. If the seeds did not germinate, their root length was considered to be 0 mm.

Results were calculated based on the following formula:

$$GI = (\text{Total Length of roots in test place} / \text{Total Length of roots in control plate}) \times 100$$

2.2.4. Control parameters

Values of potential of Hydrogen (pH) and Moisture Content were obtained according with the "Standard Laboratory Procedures for the Analysis of Compost" from Leeds University, UK [10,13]. and Federal Compost Quality Assurance Organization Manual, Germany [15].

3. Results and Discussion

After 30 days of composting sludge from municipal waste water system, Salmonella was eliminated by 99%, Faecal coliforms by 96% and Helminth Eggs by 81% (See Table 1).

Table 1. Results including pathogens reduction in time and control parameter behaviour.

Composting Time (days)	SalmonellaMPN/ g sludge	Faecal ColMPN / g sludge	Helminth Eggs / g sludge	Control parameters		
				T °C	MC%	pH
0	2.4×10^8	2.4×10^6	146	27	52.77	7.27
4	4.6×10^7	1.1×10^6	131	56	68.57	7.7
9	2.1×10^6	4.6×10^5	87	63.5	58.61	7.87
14	1.5×10^6	2.4×10^5	38	63.0	67.23	7.73
18	7.5×10^5	2.1×10^5	32	53.6	56.21	7.71
23	3.9×10^4	1.5×10^5	29	49.1	50.14	7.69
28	1.1×10^4	1.2×10^5	29	37.5	48.86	7.67
31	3.0×10^3	9.3×10^4	27	37.2	46.72	7.64
Max. Permissible limits for sludge C class* [11]	$\mathbf{3.0 \times 10^2}$	$\mathbf{2.0 \times 10^6}$	**35**			

* Sludge "C" class are allowed for forest, soil improvement and agricultural use; All values are the average of 3 replicates.

The potential risk of the presence of faecal coliforms in sewage sludge is because they are extremely resistant to certain conditions and their persistence for long periods of time. Therefore, faecal coliforms are used as indicators of the effectiveness of treatment processes in the destruction of bacteria, and regulate the quality of sewage sludge that can be used safely. They are also indicative of the concentration of Salmonella spp., bacteria that are usually associated with gastrointestinal diseases in humans and thus reducing faecal coliforms ideally reflecting a decrease in *Salmonella* spp. [16].

Although early in the process the sludge have had high levels of salmonella (higher than faecal coliforms), with increasing temperature during the composting process, the content of salmonella decreased to values lower than fecal coliforms. This experimental result is consistent with the nature of coliform group, which have higher rate of temperature–survival times than that of enteric pathogens like salmonella [4].

The concentration of Salmonella was decreased up to by 99%, but failed to reach the maximum levels of 300 NMP/g reported by the Mexican regulations for classification in Class C (For forest, soil improvement and agricultural uses) [11]. This may be due to the nature of the sludge which comes from domestic septic tanks and consequently contains high levels of faecal contamination. Faecal coliform levels were below 2,000,000 MPN/g corresponding to the class C according to the same Mexican regulation as above [11]. This indicates that the sludge can be disposed of safely in regard to fecal coliforms.

Helminth eggs, particularly Ascari, are very resistant to changes in environmental factors, which are stressful for other microorganisms, thus present an additional challenge for sludge treatment processes. The number of helminth eggs found after the composting process is a Class C according to Mexican regulation [11]. Several authors suggest that only the processe applying high temperatures (about 50 °C or more), reduce the density and the viability of different Helminth eggs [4,6,17], this coincides with the results, since the temperatures reached in the process of composting were higher at 60 °C.

For the germination index was only possible to sample every month, the samples were performed in duplicate and showed positive results (Table 2). The first month the germination rate was 65% on average, which is consistent with results reported by other researchers [10,18–20]. The last test performed strong in the third month and reported a GI = 160%. According to Manser and Keeling [14], values above 100% are indicative of positive influence of compost to the germination process.

Table 2. Germination index with time.

Composting time (months)	Germination Index (%) **
1	65
2	98
3	160

** All values are the average of 3 replicates.

However, these values as unique criteria are not enough to make a real assessment and it is important to clarify that this procedure is only focused in the initial germination phase and it cannot predict the behavior during the whole plant growth.

4. Conclusions

- After 30 days of composting sludge from municipal waste water system, Salmonella was eliminated by 99%, Faecal coliforms by 96% and Helminth eggs by 81%.
- The fecal coliform concentration decreased to levels below the maximum permissible limits
- The sludge can be disposed directly on the ground safely with respect to the concentration of fecal coliforms.
- Longer composting times and better control process are required for the elimination of Salmonella to achieve maximum permissible.
- Germination Index values indicate that the compost did not show any phytotoxicity to seeds, but the use as a soil amendment should be further tested.
- The results showed that a composting process is an efficient method for pathogens elimination in sewage sludge from municipal waste water.

5. Recommendations

- For future work, use longer composting times and a better control parameters
- For Merida city, it will be very useful to use composting for sanitazion of waste water sludge. There is no other system available at present in the area.

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Conflict of Interest

The authors declare no conflict of interest.

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