POLYETHYLENE SLEEVES WITH FORCED AERATION FOR ON-SITE COMPOSTING: PILOT-SCALE EXPERIMENTS WITH MUNICIPAL SEWAGE SLUDGE AND OLIVE MILL WASTEWATER PRE-ABSORBED BY GREEN WASTE

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SUMMARY: Composting in polyethylene sleeves with forced aeration may be adopted in order to minimize odor emissions, vectors attraction, and leachates associated with open windrows. Advantages of this technology include simplicity in construction and operation. Moreover, because of the minimal infrastructure needs, it may not require building permits and be used on-site. A potential disadvantage, however, is the lack of mixing during composting, leading to the production of non-uniform and potentially immature compost. Thus, although potentially cheap enclosed technology, it must be ensured that compost quality is not inferior compared to that of classical open windrows. We explored the potential use of polyethylene sleeves for two different applications: One for composting municipal sewage sludge mixed with shredded green waste and the second for composting olive mill wastewater (OMW), the undesired stream associated with the olive milling industry. The latter was composted after pre-absorbing by green waste. Pilot-scale experiments were conducted using polyethylene sleeves of 1.5-m diameter and ca. 20-m long. The process within the packed sleeves was controlled by a programmable logic controller (PLC) that was connected to a blower, temperature sensors (PT-100) and oxygen electrochemical sensors. The blower operation (on/off) was controlled according to temperature and oxygen thresholds (55 °C and 10-12%, respectively), based on the average readings of all sensors. In two experiments with sewage sludge and green waste (1:1; v:v), thermophilic conditions (>45 °C) were maintained for two months, with successful control of oxygen levels and sufficient moisture. Emitted odors declined from $1.5\text{-}3.8\times10^5$ to $5.9\times10^3 - 2.3\times10^4$ odor units m^{-3} of air in the first 3 weeks of the process, emphasizing the need of odor control primarily during this period. Therefore, composting might be managed in two phases: (i) a closed sleeve for 6-8 weeks during which the odor is treated; (ii) an open pile with one or more turnings during which odor control is not necessary. Reduction of salmonella, *E-coli* and coliforms was effective

Proceedings Sardinia 2017 / Sixteenth International Waste Management and Landfill Symposium/ 2 - 6 October 2017
S. Margherita di Pula, Cagliari, Italy /

initially, meeting the standards of “Class A” biosolids; however, total and fecal coliforms density increased after opening the second sleeve of the sewage sludge compost and exceeded the standard of 1000 most probable number (MPN) per g dry matter. Either it could indicate regrowth potential of human pathogens under mesophilic temperatures, or it might reflect recolonization of the open piles by airborne pathogens or indicator microorganisms. Compost maturity was achieved in the open pile phase and the final compost was non-phytotoxic and beneficial as a soil additive. Composting of OMW was facilitated after soaking shredded municipal green waste in OMW for 72 h. The material was drained for 24 h and then readily shipped to the experimental site and packed in the sleeve. Thermophilic temperatures (>45°C) were maintained for one month followed by temperatures in the range of 35-40°C for a period of 3.5 months. The finished compost was non phytotoxic and was found suitable as an ingredient in peat/tuff - based growing media. This approach may be considered in some cases as a viable alternative for the recycling of OMW or other agricultural or food liquid wastes. The viability of this approach is strongly dependent on the absorption capacity of the vegetative waste.

1. INTRODUCTION

Compost in general is highly desired for sustainable agriculture, yet its manufacturing industry involves multiple environmental concerns. Most composting operations worldwide are based on open windrows technology of which odor control has long been recognized as a critical issue. Recognizing the reality that the formation of odorous compounds is an unavoidable outcome of biodegradation processes, the solution is either to maintain sufficient distance between such operations and potential receptors (Forgie et al., 2004) or to move into enclosed facilities with forced-aeration that are equipped with odor treatment. Maintaining sufficient distance is not always practical, especially in densely populated regions. On the other hand, moving into enclosed facilities may be not economical as considerably more capital investment is required than for open windrow technologies (Renkow and Rubin, 1998).

In Israel, odor regulations become a bottleneck, preventing the potential expansion of organic matter recycling. As in other regions of the world, increase in environmental awareness and transition of urban population to areas that were previously rural, led to increased number of odor complaints (Gostelow et al., 2001; Sweeten and Miner, 1993). Thus, although more expensive, enclosed composting facilities are in many cases recommended or enforced by environmental authorities. Compared to fully enclosed facilities or covered static piles with forced aeration (e.g. GORE® technology), the EURO Bagging or Ag-Bag commercial technology seems as a relatively cheap enclosed system that might be applied for some applications. Using this technology, the desired material is pushed into a plastic (polyethylene) sleeve while a perforated aeration pipe is laid on the bottom of the bag. Advantages of the system include simplicity in construction and operation. Moreover, because of the minimal infrastructure needs, this technology may not require building permits. A main disadvantage, however, is the lack of mixing during composting, which in turn may affect the homogeneity, stability and quality of the end-product.

We explored the potential use of polyethylene sleeves for two different applications: One for composting anaerobically digested sewage sludge mixed with shredded green waste which was recently published (Avidov et al., 2017); and the second was for composting olive mill wastewater (OMW), the undesired stream associated with the olive milling industry (Laor et al., 2011). The latter was composted after pre-absorbing by green waste.

2. MATERIALS AND METHODS

Pilot-scale experiments (both for sewage sludge and OMW) were conducted using polyethylene sleeve of 1.5-m diameter and ca. 20-m long. The process within the packed sleeves was controlled by a programmable logic controller (PLC) that was connected to a blower, temperature sensors (PT-100) and oxygen electrochemical sensors. The blower operation (on/off) was controlled according to temperature and oxygen thresholds (55 °C and 10-12%, respectively), based on the average readings of all sensors (Figures 1-2). An odor treatment unit (e.g. biofilter) may be installed at the ventilation exist (Figure 1C-D).

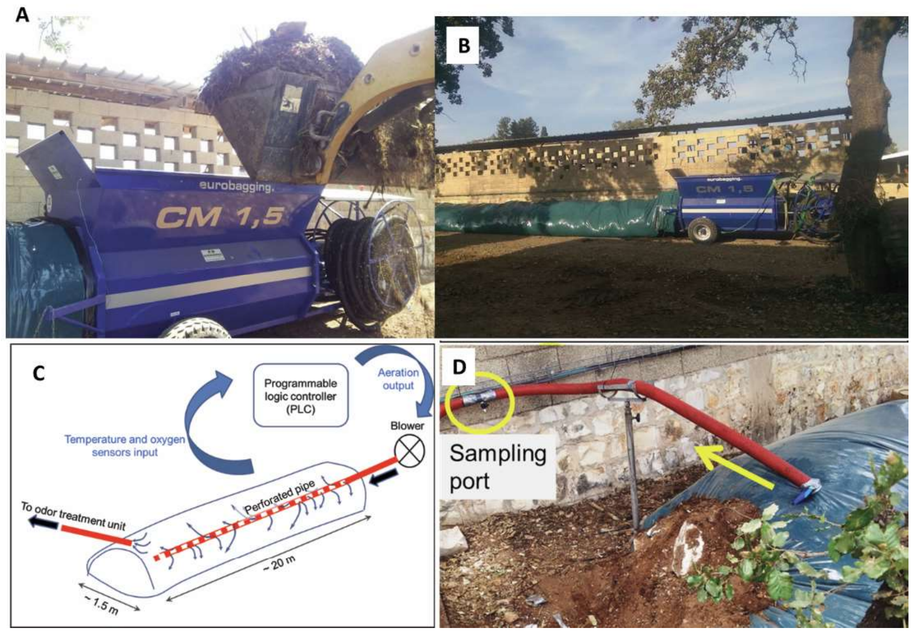

Figure 1. Experimental setup. The Euro-bagging machine during operation while the composting mixture is loaded and pressed into the sleeve **(A-B).** A scheme of the experimental design including the packed sleeve, a blower and a controller **(C)** and air sampling port at the sleeve exit **(D)**.

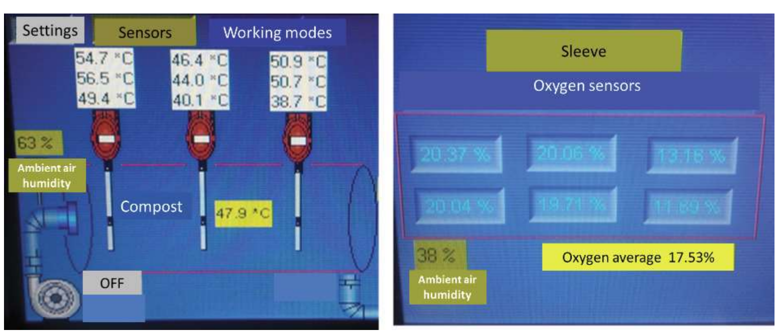

Figure 2**.** Aeration control display based on temperature (left) or oxygen thresholds (right). Another option is pre set on/off intervals.

Composting of OMW was facilitated after soaking shredded municipal green waste in OMW for 72 h. The material was drained for 24 h and then readily shipped to the experimental site and packed in the sleeve (Figure 3). To assess the absorption capacity of different kinds of vegetative wastes, we soaked waste samples in excess amount of OMW for 24 h and then drained the material for additional 24 h (Figure 4).

Figure 3. Preparation of OMW-green waste mixture: The OMW was brought to the site in 15 1-m^3 plastic cubes **(A-B)** and then poured into a container with shredded municipal green waste **(C)**, soaked for 72 h **(D)** and then drained for 24 h before used in the experiment.

Figure 4. Determination of the absorption capacity of OMW to different kinds of green waste: The waste was soaked in excess amount of OMW for 24 h **(A)** and then placed in fabric mesh and hanged up for another 24 h for drainage **(B)**.

Air samples were collected periodically in Nalophan bags through a sampling port at the exit of the sleeve (Figure 1D). The composting mixture was sampled at intervals from different locations and depths througout the sleeve using a soil auger (Figure 5). Temperature monitoring and sampling was managed also during the open pile phase after opening the sleeve.

Figure 5. Monitoring the composting of anaerobically digested municipal sewage sludge and shreeded green waste: Sampling the composting mixture along the process using a soil auger **(A-B)**. Following sleeve opening **(C),** temperature montoring was continued in the open pile **(D)**.

Phytotoxicity of the composting mixtures and the finished composts was tested in the lab based on germination and root elongation of cress *(Lepidium sativum L.)* seeds (Saadi et al., 2012) or in the greenhouse (Avidov et al., 2017).

3. RESULTS

3.1 Composting of anaerobically digested sewage sludge

In the two experiments with anaerobically digested sewage sludge and green waste (1:1; v:v), thermophilic conditions (>45 °C) were maintained for two months, with successful control of oxygen levels and sufficient moisture. The control of the process is exemplified in Figure 5: During the first 45 days of composting, the blower was controlled by temperature setting (<55 °C) where the amount of air required for removing heat exceeded the amount needed for oxygen replenishment. Thus, oxygen levels were near ambient atmosphere at this stage. Later, when heat production rate was reduced and temperatures did not increase beyond the set temperature, blower was operated according to oxygen settings (>12%).

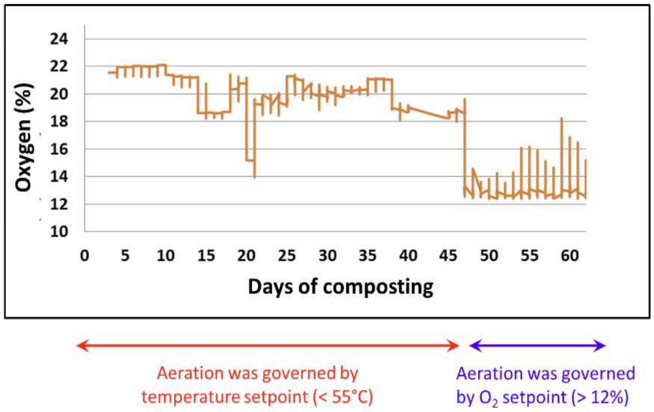

Figure 5. Oxygen levels during composting of anaerobically digested sewage sludge and shredded green waste.

Emitted odors declined from 1.5-3.8×10^5 to 5.9×10^3 – 2.3×10^4 odor units m^{-3} of air (OU/m^3) in the first three weeks of the process, emphasizing the need of odor control primarily during this period of time (Figure 6).

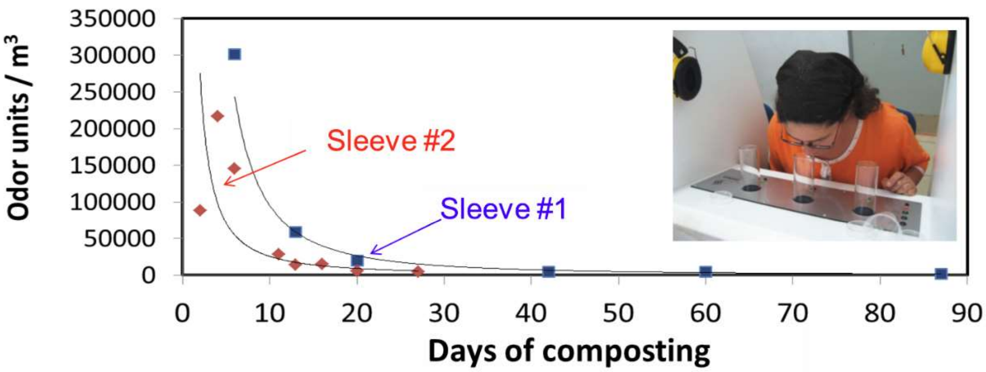

Figure 6. Odor concentrations at the sleeve exit (two experiments with anaerobically digested sewage sludge and shredded green waste).

Reduction of salmonella, E-coli and coliforms was effective initially, meeting the standards of “Class A” biosolids; however, total and fecal coliforms density increased after opening the second sleeve and exceeded the standard of 1000 most probable number (MPN) per g dry matter. Either it could indicate regrowth potential of human pathogens under mesophilic temperatures, or it might reflect recolonization of the open piles by airborne pathogens or indicator microorganisms (detailed in Avidov et al., 2017).

Compost maturity was achieved in the open pile phase and the final compost was non-phytotoxic and beneficial as a soil additive (detailed in Avidov et al., 2017).

3.2 Composting of OMW pre absorbed by shredded green waste

Thermophilic conditions (>45 °C) were maintained for one month followed by temperatures in the range of 35-40 °C for a period of 3.5 months (Figure 7). Considering future use of different kinds of vegetative wastes, the results showed that expected absorption capacity could be around 1 m^3 of OMW per 1 m^3 of dry vegetative waste. The specific type of vegetative waste as well as its initial water content will eventually determine the actual ratio between the co-treated amounts of liquid and vegetative wastes.

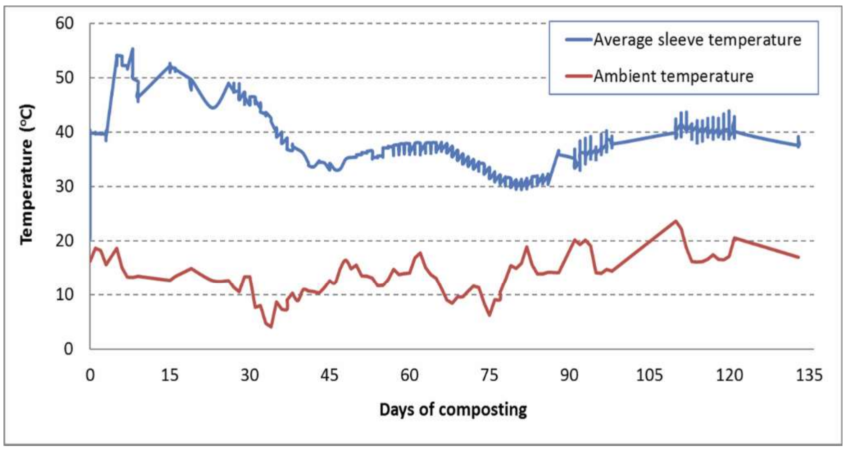

Figure 7. Temperature profile along composting of OMW pre absorbed by green waste (average of 6 sensors located througout the sleeve at different depths).

As opposed to composts based on municipal sewage sludge, composts based on vegetative wastes will potentially be considered for use in growing media due to its adequate physical properties and the higher economical value of this use. In the case of OMW, since its inherent phytotoxicity is well known (Aviani et al., 2009), the suitability of the finished compost was considered both in lab bioassay (Figure 8) and a greenhouse experiment with basil (Figure 9). The phytotoxicity of the composting mixture was reduced substantially during the first two months of the process within the sleeve and essentially remained non toxic thereafter (Figure 8). The finished compost showed comparable results to peat/tuff-based growing media in the greenhouse experiment with basil (Figure 9).

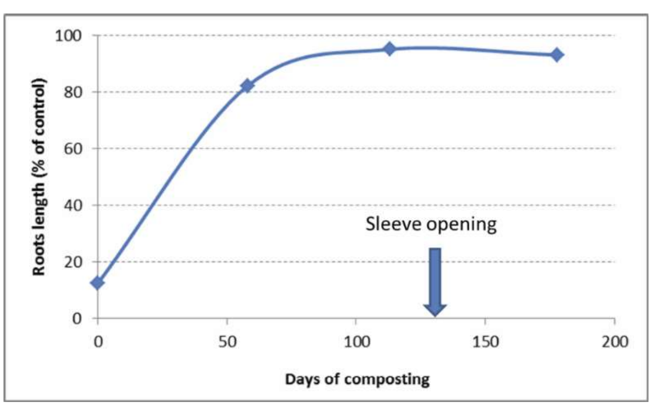

Figure 8. Phytotoxicity of OMW pre-absorbed by municipal green waste using Cress *(Lepidium sativum L.)* as a testing plant.

Basil growing experiment in a greenhouse

Treatment	Peat	Tuff	OMW compost
Control	60%	40%	-
OMW compost	-	40%	**60%**

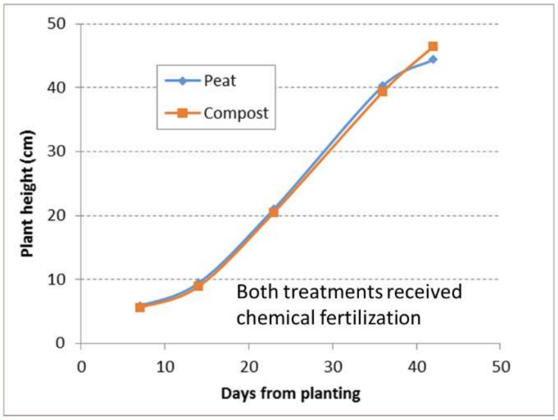

Figure 8. Use of OMW-based compost versus peat/tuff-based growing media for growing basil in a greenhouse.

4. DISCUSSION AND CONCLUSIONS

The results for anaerobically digested sewage sludge mixed with shredded green waste were discussed in detail in Avidov et al., 2017. Composting may be possible within the area of the wastewater treatment plant, thus eliminating the cost and nuisance odors associated with sewage sludge transportation. Notably, only Class A biosolids have been allowed in Israel since 2004 for all types of land use (i.e. the geometric mean of the density of fecal coliforms determined from at least seven samples should contain less than 1000 most probable number (MPN) per g of dry material or the arithmetic mean of Salmonella spp. determined from at least seven samples should be less than 3 MPN per four g of dry material; based on the definition of the U.S. EPA, 1993). Thus sanitary aspects are critical, especially since the material is not turned during the thermophilic phase. More research in deserved to interprate the observed increase in potential pathogens numbers. It could result from their incomplete elimination during the thermophilic phase and regrowth under mesophilic temperatures; or it might result from recolonization of the open piles by airborne pathogens. Based on odor measurements, it was suggested that composting might be managed in two phases: (i) a closed sleeve for 6-8 weeks during which the odor is treated; (ii) an open pile with one or more turnings during which odor control is not necessary.

For liquid composting in sleeves, the liquids should first be absorbed by the vegetative waste, drained, and then packed in the sleeve. These activities require some unique properly designed equipment. The economical and practical feasibility of this approach is much dependent on the possibility to maximize the amounts of liquids that can be absorbed and co-treated with the bulking material. It is therefore highly desired to select vegetative wastes with relatively low initial water content and large liquid absorption capacity. Specifically for the composting of OMW, the inherited phytotoxicity of the mixture is expected to diminish during composting, thus making the finished compost valuable as an ingredient in growing media.

AKNOWLEDGEMENTS

This study was supported by the ICA foundation [grant number 44/15, 2015-16]. We would like to thank Mr. Ilan Akiva, entrepreneur in waste management, and Mr. Zvi Wattenstein, vice president of Sharonim Recycling Co. Ltd, for their help.

REFERENCES

Aviani I., Raviv M., Hadar Y., Saadi I. and Laor Y. (2009). Original and residual phytotoxicity of olive mill wastewater revealed by fractionations before and after incubation with Pleurotus ostreatus. J. Agr. Food Chem., vol 57(23), 11254-11260.

Avidov R., Saadi I., Krassnovsky A., Hanan A., Medina Sh., Raviv M., Chen Y. and Laor, Y. (2017). Composting municipal biosolids in polyethylene sleeves with forced aeration: Process control, air emissions, sanitary and agronomic aspects. Waste Management.
http://dx.doi.org/10.1016/j.wasman.2017.05.035

Forgie D.J., Sasser L.W. and Neger M.K. 2004. Compost facility requirements guideline: How to comply with part 5 of the organic matter recycling regulation. Ministry of Water, Land and Air Protection. https://www.for.gov.bc.ca/hfd/library/WLAP/2004MR10.pdf (Accessed 20.7.2017).

Gostelow P., Parsons S.A., Stuetz R.M. 2001. Odour measurements for sewage treatment works. Wat. Res., vol 35 (3), 579-597.

Laor Y., Saadi I., Raviv M., Medina Sh., Erez-Reifen D. and Eizenberg, H. (2011). Land spreading of olive mill wastewater in Israel: Current knowledge, practical experience, and future research needs. Israel J. Plant Sci., vol 59(1), 39-51.

Renkow M. and Rubin A.R. (1998). Does municipal solid waste composting make economic sense?. J. Environ. Manage., vol 53 (4), 339-347.

Saadi I., Raviv M., Berkovich S., Hanan A., Aviani I. and Laor Y. (2013). Fate of soil-applied olive mill wastewater and potential phytotoxicity assessed by two bioassay methods. J Environ. Qual., vol 42(6), 1791-1801.

Sweeten J.M., Miner J.R. (1993). Odor intensities at cattle feedlots in nuisance litigation Bioresour. Technol., vol 45(3), 177-188.

USEPA. (1993). Standards for the Use or Disposal of Sewage Sludge; Final Rules. FR 058(32):9248-9415. Office of Science & Technology, Washington, D.C.