ORGANIC ON-SITE WASTE TREATMENT FOR HOUSES

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Abstract

Centralised treatment of domestic waste has been an accepted practice of management in urban and semi-urban areas in the developed world, in STP (Sewage Treatment Plants) for liquid wastes and sanitary land filling for MSW (Mixed Solid Wastes or Municipal Solid Wastes). Most of the waste that cannot be recycled is organic, and can or should return to nature from where it originated. Composting has been practised as the best way to do this from time immemorial. The procedure can convert all biodegradable waste into useful fertiliser as well as achieve pathogen reduction by thermal or biological process.

At the University of Western Sydney, projects are underway to design and test a composting (microbial and vermicomposting) technology to treat black water (toilet wastes) and organic solid wastes along with greywater treatment. The concept is to make the technology simple enough for laymen and appropriate for the rural and the developing world. A prototype of a modular composting system has been tested, and its management in view of a real world installation scenario and some of the test results are presented.

Keywords

Blackwater, greywater, risk management, residential wastewater, solid waste, vermicomposting.

1 Introduction

Managing the huge quantities of solid and liquid waste that humans create, due to its quantity and characteristics, is a major problem. Careless management of these wastes such as illegal dumping creates more problems, such as polluting the little freshwater available. Lack of space for land filling of solid wastes is creating problems in many places. Epidemiological problems abound in places without proper sanitation facilities. A more biocentric viewpoint is long overdue. Socio-economic or geographical differences have created different scenarios in the needs of waste management, nevertheless, the urgency is comparable everywhere.

Sustainability in waste management needs to be the focus of any emerging environmental projects if it relates to human habitation. Studies have shown that both private and public sectors are active in waste management in the developing world [Ahmed, 2003], whereas in the developed world it is mostly the private sector with controls from the public sector. Urban sprawl is more evident in the developing world than the developed world [UNESCO, 2003]; [WRI, 1997]. In light of this, the future of waste management in the developing world needs more options that can be adopted to the individual situations, rather than copying the technologies from the developed world, whether they have been successes or failures. This paper discusses a low-cost technology under study aimed at rural and developing worlds.

The ISWM (Integrated Solid Waste Management) hierarchy advises that all waste management options should work in conjunction with each other for the ultimate aim of optimum waste reduction and pollution control [Bluestem, 1997b]. It recommends the options of waste management, in the order of preference, as:

- Source reduction
- Maximum utilisation
- Reuse - recycling including composting
- Incineration with energy recovery
- Incineration without energy recovery and
- Land filling

Upon closer analysis, the most possible way to introduce better waste management at residential level can be 'reuse'. In the developed world, a majority of waste materials are reusable such as plastic and glass materials, whereas in the developing world most of the waste is biodegradable [Aranda, 1999]. Human wastes, including black waste (nightsoil) and other biodegradable waste, are sources of nutrients and energy that can be tapped, as demonstrated in many ancient cultures. It has been shown possible to extract fuel out of waste using anaerobic methods [Imura, 1995; Harremoes, 1997; Jefferson, 2000]. In the modern world, flushing toilets (discharging black water) and large volumes of 'greywater', flushed down the sinks [Hammer, 2001] have resulted in this resource of 'waste' being discharged into the environment, often at great social and environmental cost.

Composting is a traditional method for treating waste biologically. It has been in practise for different purposes around for many centuries. The process of composting creates heat and converts solid wastes into a material that can be used as a fertiliser [Haug, 1993; Hoitink, 1993]. Whether done with microbes (termed 'traditional composting') and/or worms (vermicomposting), the process goes through similar stages and the end results are mostly the same [Haddon, 1993]. The only difference between natural humus production and composting is that in the latter, the natural processes are taking place in a controlled environment and is mostly undertaken purposefully.

Approximately 4400 different species of worms have been identified, and quite a few are useful in vermicomposting [Fraser-Quick, 2002]. The most commonly used composting worms are Tiger worms (*Eisenia fetida*), Red Tiger or Red Wiggler (*Eisenia andrei*) and Red worms (*Lumbricus rubellus*). Vermicomposting is faster than microbial activity as actions by microbes and higher order creatures degrade the waste materials [Edwards 1988; DNR 2001].

The worms eat micro-organisms in the waste and the fine particles of waste itself. The digestive process at this time, converts the substrate into a stable material, termed vermicastings, enriched with nutrients in slow-release form. The strong indigenous microbes that are able to escape the digestive enzymes of worms are also added at this time. Pathogens within the waste mass usually don't escape this process [Eastman, 1999; Aston, 1988], given time for stabilisation of the process. Hence, vermiculture has the potential to reduce microbial contamination of organic matter. Red worms can consume, at the best, half their body weight of waste in a day, although this is controlled by many process variables such as temperature, moisture, porosity and quality of substrate [Dowdle, 2002]. Recent studies have shown various worm-stocking rates for a successful process, again depending on the above parameters [ROU, 2002].

At the University of Western Sydney, a residential onsite waste and wastewater treatment system using vermicomposting is under trial. The project's aim is to devise an economic method of treating sewage and putrescible waste fraction from kitchen, garden and other sources. The effluent from the unit is comparable to greywater and is treated with the greywater fraction using established methods, but with the addition of a vermicomposting unit as a grease trap. Studies are done on the real-world installation of such a system including the risk analysis and public perception. Studies [Bohm, 2003] have suggested that emotions by public cannot be avoided in the risk management of such issues. This paper deals with the issue of pathogen reduction in the concepts of technology as well as the public acceptance.

2 Materials and Methods

A prototype as shown in Figure 1 has been designed for residential waste generation of one-person equivalent quantity of black water, greywater and general solid waste including kitchen waste and paper shreds. Solid wastes also include garden waste, procured at site. Kitchen waste was collected from the nearby cafeteria. Blackwater was simulated by pig manure, collected at the University of Sydney Pig Farms. This source was chosen due to its comparability to human waste [Envirocycle, 2002; Aranda, 1999; CEEP, 1999] and lack of availability of the latter at site.

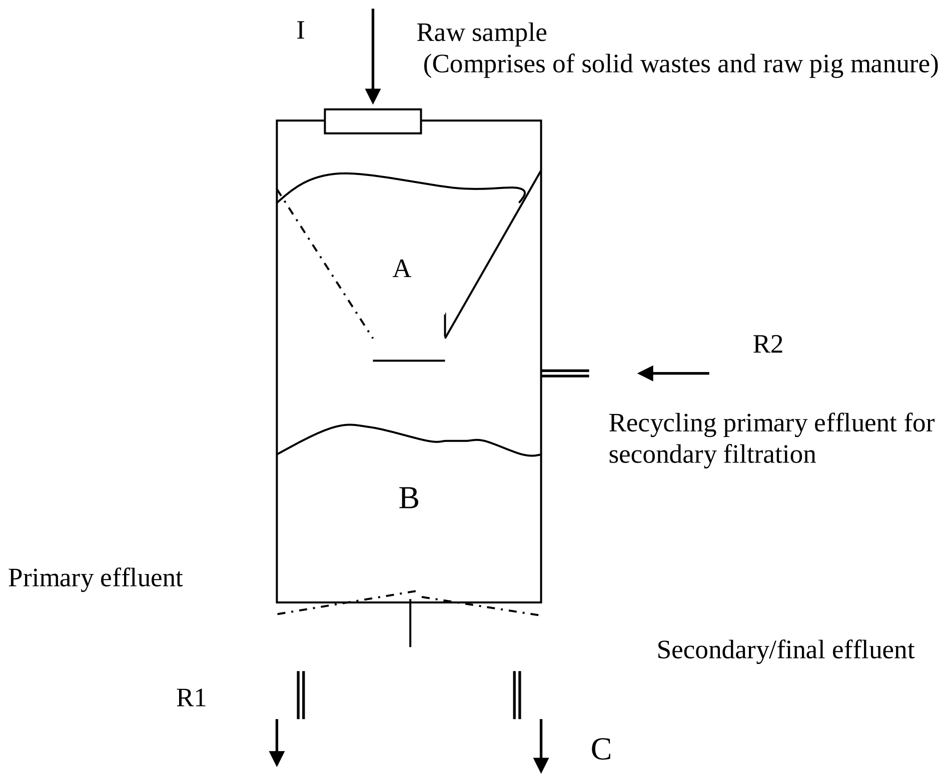

Figure 1. Schematic of the prototype with substrate flow directions and sampling points

A mix of Red Tiger, Red and Tiger worms were purchased from Eagle Creek worm farm, Nana Glen, NSW [Dowdle 2002]. The quantity of worms was finalised as 10 kg/m^3, after different trials of vermiculture tests based on studies elsewhere [ROU 2002]. The worms were then carefully collected from the vermiculture boxes, their biomass determined, then added to the prototype. A base of 125 mm of mature vermicastings was prepared in chambers A and B prior to adding the worms. Addition of moistened wastes followed this and black water addition began once the worms were settled into their new environment. This was verified by observing the actions by worms.

The design of the prototype allowed free fall of size-reduced waste materials from chamber A to chamber B under gravity and thus there was no need of manual labour for the purpose. The perforated sides and bottom break-bar of the chamber A allowed free passage of filtered black water into the left side of chamber B where it received further filtration. This liquid was then recirculated from R1 to R2 via peristaltic pump or manual method allowing a tertiary filtration on the right hand side of chamber B. The total hydraulic retention time was a minimum of 3 hours, depending on the moisture content of the degrading solids within. The final effluent was then collected at point C in a tank fitted with level- switch controlled bilge pump, that pumps the effluent to the greywater tank. Sampling points were at the entry point I, R1 and C. However, for the purpose of this paper, only points I and C are considered.

The total solid retention time achieved was two months, because the composting cycle comes to a stable-state at that time. At this time, the materials from the chamber B are removed for curing stage, materials from chamber A are moved down to B and the cycle is repeated. Mature castings are used as bedding for the worms in both chambers at the start-up. Tests are conducted for pH, temperature (solid temperature is measured by bimetallic thermometer), conductivity, total dissolved solids, total suspended solids, turbidity, BOD_5, nitrogen, phosphorous, faecal pathogens and *E.Coli*. The micro-organisms are measured in CFU/100 mL at the Australian Government Analytical Laboratories.

3 Results and Discussions

The on-going tests have revealed satisfactory results in terms of most parameters such as pathogen reduction, solids reduction and BOD_5 reduction.

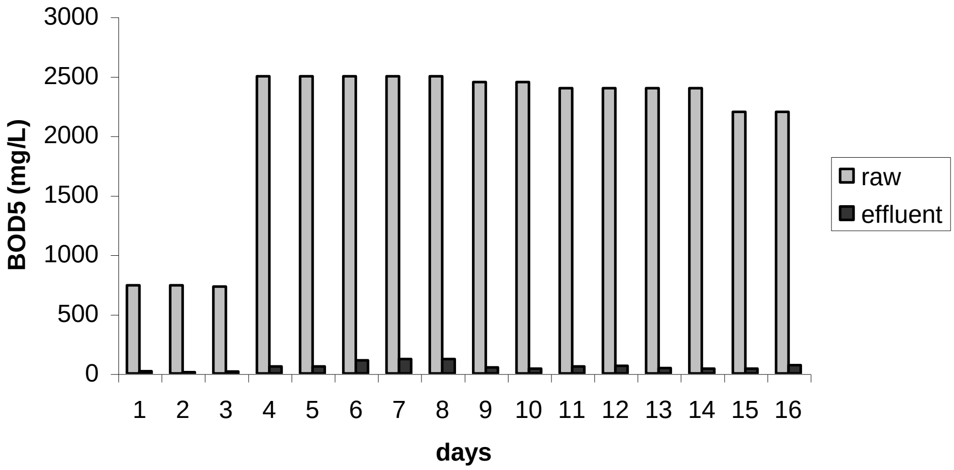

Figure 2. Reduction in BOD_5

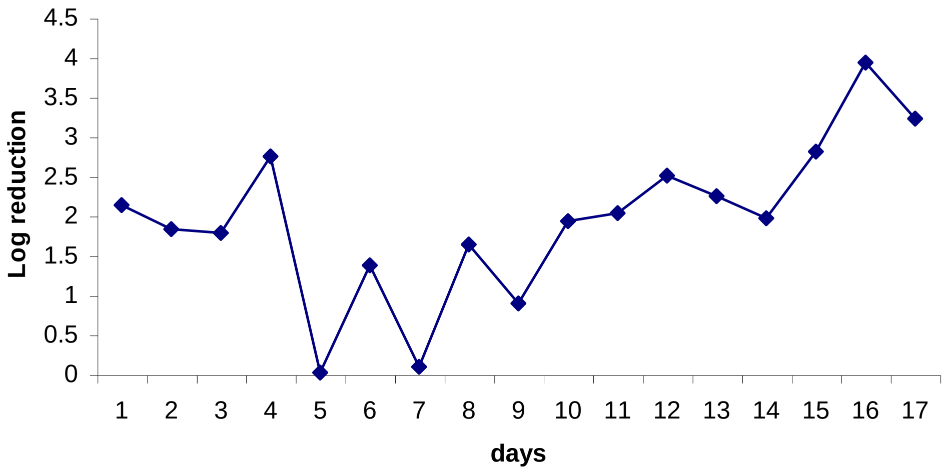

Figure 3. Log reduction of Faecal Coliforms – comparison of raw (R1) and effluent (C)

The data in the charts presented are from the second trial, and agree with the results of the first trial. Reduction in BOD_5 (Figure 2) and solids (Figure 4) give very satisfactory levels, whereas reduction in pathogens (faecal coliform – Figure 3) is encouraging. The chart in Figure 3 gives log-reduction levels. On an average, a log reduction of approximately 2 is achieved in faecal coliform colony counts. This could be due to the small amount of solids and worms used; a larger scale application can be expected to give better results. A log reduction of 3 refers to a reduction to 1/1000th of original value. The drop in efficiency between 5th and 8th days in the chart could be due to application of matter with high pathogen levels. The faecal coliform colony counts were reduced below detection levels during application of the effluent to greywater tank, perhaps due to the chlorine and soap content in it. A real world application with random waste composition and varying pathogen levels can provide different data, as the tests mentioned in this report are from controlled condition with measured waste materials and black water. As can be seen in the chart for TSS (Figure 4), the reduction was good and the turbidity reduction was also excellent.

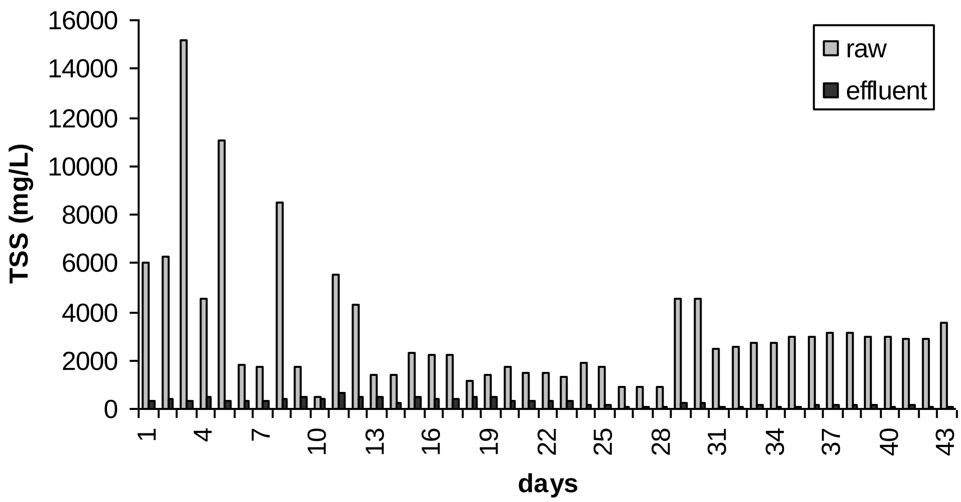

Figure 4. Reduction in Total Suspended Solids

The compost releases nutrients into the effluent, and thus Total Dissolved Solids (TDS) was found to increase. Trials with plants onsite showed that these could be plant nutrients, further chemical analysis is currently underway to determine what chemical elements cause this. It is speculated that the nitrogen and phosphorous content from pig manure contribute to this. A detailed analysis on the solid residue, which is vermicastings, for the nutrient levels in it is also underway.

3.1 Future of domestic waste management

In the rural and developing world, centralised waste management is not an option. Individual households can treat their wastes better, with resource recovery. The practised technologies of the developed world, such as land filling and STPs (Sewage Treatment Plants), will not work in the developing world, as demands on space and available funds create a different set of priorities. Poorer economies find it difficult to opt for centralised treatment, so do rural communities in the richer world. With the number of Mega cities growing around the world, urban waste management needs to find urgent alternatives that are appropriate to the economy yet conform to required standards [Li, 2003].

With backyard gardening in many households, the householders in rural and developing world can be expected to be interested in activities such as composting. A mentality of responsibility can also be created/developed with the results of one's own initiation. But there are inherent risks in a complete waste treatment system such as the one discussed in this paper, due to the inclusion of black water. Blackwater contains many harmful pathogens that can cause diseases that can spread fast. A risk study was conducted for the project to compare the risks involved in the current practices of waste management in the developing world.

Public awareness was seen to be the key in safe risk management. As the project of black water treatment can be adopted to single households as well as small communities and apartment buildings in densely populated areas, acceptance by the community as a whole was seen to be an important parameter [Panikkar, 2003]. The most important areas of hazard identification, public awareness and user education were seen to be key in the success of any decentralised sanitation project.

4 Conclusions

This paper discusses a project aimed at finding a low-cost alternative to waste and wastewater treatment at the residential level, particularly in the rural and developing world. It identified some issues and discussed the project with some encouraging results. Further studies are required to validate the results and optimise the technology of black water treatment for trials in villages or households, for the real world scenario. The most important parameter of pathogen reduction was seen to be addressed to satisfactory levels, and many other parameters such as solids reduction and BOD_5 reduction were seen to be commendably reduced. Ongoing trials and tests are hoped to produce better results. The discussed black water treatment system in conjunction with a greywater treatment system will provide an economic alternative to waste management at households, including organic solid wastes and wastewater.

References

Ahmed, S. A., & Ali, M. (2003), 'Partnerships for solid waste management in developing countries: linking theories to realities.' *Habitat International*, vol. *accepted for publication*.

Aranda, E., Barois, I., Arellano, P., Irissón, S., Salazar, T., Rodríguez, J., & Patrón, J. C. (1999), 'Vermicomposting in the tropics', in *Earthworm management in tropical agroecosystems*, ed. Lavelle, P., Brussaard, L. & Hendrix, P., CAB International Publishing, Oxon, UK.

Aston, R. J. (1988), 'The case of temperature control in vermiculture', in *Earthworms in waste and environmental management*, ed. Edwards, C., & Neuhauser, F., SPB Academic publishing, The Hague, pp. 135-143.

Bluestem (1997b), *Integrated Solid Waste Management*: Bluestem solid waste agency; Available: [www.bluestem.org/ISWM.html] Accessed: 15-09-2001.

Bohm, G. (2003), 'Emotional reactions to environmental risks: Consequentialist versus ethical evaluation', *Journal of Environmental Psychology*, vol. 23, no. *accepted for publication*, pp. 199-212.

CEEP (1999), *Phosphate precipitation from nightsoil*: SCOPE Newsletter - Centre Européen d'Etudes sur les Polyphosphates; Available: [http://www.ceep-phosphates.org/scope/articles/scope30/scope30-10.htm] Accessed: 1-11-02.

Dowdle, R., & Dowdle F. (2002), 'Personal Communication', Camphor Creek worm farm, Nana Glenn, NSW 2450.

Eastman, B. (1999), *Achieving pathogen stabilisation using vermicomposting.*: worm world inc.; Available: [www.gnv.fdt.net/~windle/refrence/index.htm] Accessed: 24-7-01.

Envirocycle (2002), *C/N Ratio of Compostable Materials*: Envirocycle Systems Inc. (Canada); Available: [http://www.envirocyclesystems.com/canada/CDN_EN.CNRatio.html] Accessed: 1-11-2002.

Fraser-Quick, G. (2002), 'Vermiculture - a sustainable total waste management solution', *What's new in Waste Management*, vol. 4, no. 6, pp. 13-16.

Haddon, F. (1993), *A practical guide to composting*, Simon& Schuster Australia., NSW, Australia.

Hammer, M. J., & Hammer, M. J. (Jr.). (2001), *Water and Wastewater technology*, Prentice Hall, Inc., USA.

Harremoes, P. (1997), 'Integrated water and waste management', *Water Science & Technology*, vol. 35, no. 9, pp. 11-20.

Haug, R. T. (1993), *The Practical Handbook of Compost Engineering*, 2 edn, Lewis publishers, CRC Press Inc., Florida, USA.

Hoitink, H. A. J., & Keener, H.M. (ed.) (1993), 'Science and Engineering of Composting: design, environmental, microbiological and utilisation aspects.' The Ohio State University, Renaissance publications., Ohio.

Imura, M., Sato, Y., Inamori, Y. & Sudo, R. (1995), 'Development of a high-efficiency household biofilm reactor', *Water Science & Technology*, vol. 31, no. 9, pp. 163-171.

Jefferson, S., Laine, A.L., Judd, S.J. & Stephenson. T. (2000), 'Membrane bioreactors and their role in wastewater reuse', *Water Science & Technology*, vol. 41, no. 1, pp. 197-204.

Li, H. (2003), 'Management of coastal mega-cities - a new challenge in the 21st century', *Marine Policy*, vol. 27, no. *accepted for publication*, pp. 333-337.

Panikkar, A., Shrestha, S., Hackney, P., & Riley, S. (2003), 'A residential black water and municipal solid waste treatment system - safety issues and risk management', in *ORBIT 2003*, ed. Prathap, P., Murdoch University, Perth, Australia.

ROU (2002), Vermiculture in Organics Management - The Truth Revealed (Seminar in March 2002), Recycled Organics Unit, UNSW, Sydney.

UNESCO (2003), *Water for people, water for life*, The United Nations World Water Development Report: Executive Summary, UNESCO publ.

WRI (1997), *World Resources Report 1996-1997*, World Resources Institute, Oxford University Press, New York.