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DECENTRALIZED AEROBIC COMPOSTING OF URBAN SOLID WASTES: SOME LESSONS LEARNED FROM ASIAN-EU COOPERATIVE RESEARCH

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ABSTRACT
Composting of organic solid wastes is gaining in importance worldwide, in the frame of integrated municipal solid waste management and, in particular, the diversion of biodegradables from landfilling. At the post-consumer stage, this can be achieved by composting practices ranging from large-scale facilities to home (or yard) composting. Increasing costs for final disposal of MSW also point towards the use of composting technology as an alternative. This paper presents some results and conclusions from various small-scale composting activities implemented in Hanoi and Manila under different socio-economic settings, as well as a case study on a larger-scale composting scheme in the Prefecture of Pieria, Greece in the frame of a 2-year joint research project. It focuses on recommendations towards the Asian partners on how to improve their composting processes, on the basis of reviewing and assessing current composting practices in Vietnam and the Philippines, as well as some remarks on cost parameters for the Hellenic case study.

KEYWORDS: composting, local scale, ASEAN**,** organic waste.

1. INTRODUCTION

Solid Waste Management (SWM) is an important issue in Europe's environmental policy. Considerable effort has been made on the development of methods and policies in order to achieve waste minimization, recycling and treatment. Asian countries are also confronted with extensive SWM issues, since their population and resource consumption increase rapidly while the existing infrastructure does not keep up with the development in demands. This study was part of a project involving research and laboratory activities for examining composting schemes as residual waste minimization tools for selected communities in Vietnam, the Philippines and Greece. Asian countries have a large number of small and rural communities that produce large amounts of organic waste due also to agricultural activities. There is therefore a significant potential for composting activities with a direct market for applying the end product in these areas and, therefore, some attempts have already been going on for some time. In EU countries a number of home- and small-scale composting schemes have also been implemented, although large diversions are observed between member countries. Therefore, a critical mass of information was gathered for using the respective experiences for planning and improving composting schemes in selected communities in Vietnam and the Philippines. In parallel, the implementation of a large-scale composting scheme in Greece was examined by using the Asian best practices and after taking into consideration local technical, environmental and economic constraints.

2. BACKGROUND

The primary SWM objectives are to protect human health and the environment, as well as to conserve resources. In the case of developing countries, where public health issues related to absence or poor implementation of waste policies are still present, high-technology options for waste management are apparently excluded both for economical and local acceptance reasons (Brunner and Fellner, 2007). Moreover, the global issues of desertification and carbon sequestration also for mitigating greenhouse gas emissions, will have to be confronted by many developing countries. Therefore, the possibility of converting MSW to organic earth-like material by means of composting can provide a significant contribution to the solution (Linzner *et al.,* 2007). For the implementation of such organic SWM schemes in developing countries, the recently developed Clean Development Mechanism can support composting as it can help prevent methane production in disposal sites (Zurbrugg *et al*., 2007). In this sense, research results presented in this paper will be providing some added value towards informed decision making on organic SWM issues at the local level.

The problems of Vietnam's SWM system have been greatly magnified during the past decade, as a result of relatively strong economic growth rates and partially uncontrolled urbanization. Not only has there been an increase in the amounts of waste generated, but the composition of the waste has changed as well (Themelis, 2006). Solid waste generated in Vietnam has been increasing steadily over this last decade; in 1996, the reported generated amount was 5.9 Mt (Nguyen, 2005), whereas just eight years later, generated MSW alone for 2004 were reported at 12.8 Mt, with industrial and agricultural waste contributing another 2.2 Mt (Vietnam Environmental Monitor, 2004). Low collection rates and inadequate waste facilities characterize the current situation in Vietnam. Available literature points to a lower need for increased technological expenditures (such as an incineration plant) and an increased need for a greater understanding of social issues and well-informed education, awareness and community action programs (JICA 2000; Le Thi Huong, 1995). Given the high rates of organic matter (60%) with its very high (80-90%) moisture content, composting plants were assessed to be a potentially viable option by local stakeholders.

In the Philippines, SWM is currently acknowledged as one of the most pressing environmental problems too, with a total of 10.7 Mt generated in 2000. Philippinos living in urban areas are estimated to generate an average of 0.5 kg of waste per capita per day, while the average collection efficiency is only about 40%. To respond to this, local government authorities had intensified their efforts to make collection more efficient. Some have started to shift to sanitary landfills, as a more sanitary disposal system (JICA, 1998). Metro Manila alone generated 2.5 Mt of waste in 2000 with only 10.7 % (0.26 Mt) recycled or composted, while the rest was either hauled to the city's dumpsites, or dumped illegally on private land, in rivers, creeks and the Manila Bay, or openly burned. It is estimated that roughly 150,000 residents of Metro Manila live as scavengers and waste pickers.

Greece, in contrast is a developedcountry, member of the EU and has to implement the demanding and complicated body of the EU legislation on waste management. It has a population of 10.2 million with a population density of 79 inhabitants/km^2, half of the EU average. However, urban population accounts for 59% of the total, with nearly 50% living in the two largest cities, Athens and Thessaloniki. A continuous growth of MSW production is observed since 1990 and all predictions indicate further increase, despite moderately increasing waste prevention. MSW generation was 4.8 Mt in 2006 with the perspective of reaching 5.2 Mt in 2016; 91.2% is landfilled and 8.8% recycled, mainly from 3 composting plants supplied with mixed MSW and 14 material recovery facilities supplied with source separated packaging wastes and (1 with) WEEE, as well as via 8 other national-wide alternative management schemes for specific MSW and other SW fractions (batteries –portable and car-, oils, oil packaging, tires, cars, CDW) and -last but not least- still the informal sector, whereas Greece remains in 2009 the only EU25 country without any MSW Waste-to-Energy plants (with Ireland showing lately a similar attitude as well (ENDS, 2007)) also due to a still remaining (informal but clear) political exclusion standpoint. The same phenomenon of political scepticism towards integrating Waste-to-Energy plants in the waste management system has been observed surprisingly identical in the Philippines.

3. METHODOLOGY

Small-scale composting has been implemented successfully in Asian countries as a tool for reducing disposed MSW (Rothenberger *et al.,* 2006). This activity was found to be practised already quite extensively in Metro Manila at a kind of neighbourhood scale. From the scale point of view, this bears close resemblance to home composting, where compost is returned to the garden, creating a neat recycling loop and involving no transportation of waste (SWAN, 2000). The high organic content of MSW in developing countries but also the climate in wet tropical countries is ideal for composting (Hoornweg *et al.,* 2000). The raw materials which are most appropriate for composting include: vegetable and fruit waste; farm waste such as coconut husks and sugar cane waste; crop residues such as banana skins, corn stalks and husks; yard waste such as leaves, grass and trimmings; sawdust; bark; household kitchen waste; human excreta and animal manure. Parameters that influence the composting process include micro-organisms, C/N-ratio, pH, porosity, structure, texture, particle size, aeration and temperature. Based on preliminary research findings in the present work, various composting activities were performed both in Hanoi and Metro Manilla. In the Philippines a management scheme for sanitary waste from the campus of Miriam College (a purely feminine multi-level educational establishment) was planned and implemented, whereby various composting methods were tested with the aim to identify the optimum approach for managing sanitary waste in the entire campus. On the other hand, the composting activity in Vietnam focused on home-composting technologies for two selected areas in Hanoi, with parallel experiments and development of pilot composting equipment.

4. SANITARY WASTE COMPOSTING IN MIRIAM COLLEGE, THE PHILIPPINES

4.1 Sanitary waste generation

Used sanitary feminine napkins are usually considered as residual waste and end up in dumpsites and sewages. However, they can be composted since its main components are wood pulp and non-woven cotton, which are compostable materials. As an all-girl's school, Miriam College is faced with an everyday generation of used feminine napkins from mainly its Middle School, High School and College units. Based on a student population of about 3,800 females in the High School and College levels, it was estimated by a survey conducted in early 2004, that an average of 38,000 napkins are disposed of in the campus every month. However, the subsequent collection of used sanitary napkins indicated that the rate of generation was actually much lower, as students were initially thought to be in the campus five days a week; however, a closer actual inspection showed that students were not present in the campus on an everyday basis and, therefore, did not generate the initially estimated amount of used sanitary napkins.

4.2 Information and awareness campaign

To encourage the participation of students in the proper segregation of their used sanitary napkins, an information campaign was conducted among all Units of the School. Posters on segregation and composting were placed in each ladies' room, while signs were posted on the walls of each cubicle in the room (Figure 1). The objective of the information campaign was to raise awareness about the composting of used sanitary napkins and to obtain the participation of students and staff in the scheme.

4.3 Experimental methods and equipment

Within the grounds of Miriam College,experiments were organised both for *shredded* and *unshredded* sanitary napkins, whereas 2 activators (*Trichoderma harzianum* (Tricho) and Effective Microorganisms (EM)), were used, including also a Control group without any activators Different low-cost and low technology alternatives (figure 2) were implemented regarding composting containers such as compost pit, rotating drum, and rice sack (with 12 of each type used).

Figure 1. Signs of the information campaign in Miriam College

4.4 Experimental phases

Three experimental phases took place over a total period of 7 months. Each phase consisted of two stages, (stage 1:) application of activators to the napkins and (stage 2:) monitoring of the decomposition process. Each entire experiment lasted about 10 weeks. During the first week, activators were applied to both shredded and unshredded napkins, a control group was maintained where no activators were applied, whereas the parameters C/N ratio, pH, moisture content and temperature were monitored. The experimental set-up was organised both for shredded and unshredded samples (3-4). In the shredded samples, three composting vessels were employed and for each composting vessel, three set-ups were selected: (1) the control set-up with no activators used; (2) the Tricho set-up; and (3) the EM set-up.

Figure 2. Waste segregation and composting methods (left: bins; middle: pits; right: drums) used in Miriam College

Figure 3. Shredding of raw material

Figure 4. Weighing of sanitary waste

4.5 Experiments and results

The first experimental phase, conducted from mid July to mid September 2004, faced flooding during two consecutive typhoons that brought heavy downpour. This caused the overflow of water, particularly, in composting pits containing different activators, resulting in experiments' failure. In addition, temperature readings were only between 25 to 34^{o}C, thus far from the expected temperature range of 50-60^{o}C. It was confirmed that low temperature readings - the main problem during the composting process - were caused by the limited input of raw materials (i.e. sanitary napkins). Therefore it was suggested that organic wastes (such as green wastes) should be mixed with the sanitary napkins; additionally, soil (which was already used in the raw material) should be avoided. Furthermore, it was recommended that leaves and the tissue paper (which is generated by the school) should be added in order to facilitate further decomposition.

The second experimental phase was performed from mid October, 2004 to mid December, 2004. As suggested, used tissue paper was included to increase the volume of raw materials, while leaves were also added during the shredding process, in order to increase the level of nitrogen. The second experiment showed a slight increase in temperature compared to the first experiment. As of the 5th week in the rotating drums, the Tricho activators and the Control group showed faster decomposition than EM. Raw material in Tricho and Control groups was still present but in significantly lower levels compared to EM groups. The rotating drums showed faster decomposition compared to pits and sacks, mainly due to the frequent aeration that comes from turning the rotating drums twice each day. Notable decrease in the volume of raw materials was observed after 5 weeks (50%) in the rotating drums, while weather conditions did not cause any problems during this second (as well as the upcoming third) experimental phase.

The third experimental phase was conducted from early November 2004 until the first week of January 2005. Temperature, pH and C/N ratio were monitored during the experiment. Temperature readings were taken every day, except during weekends, whereas the pH values of each set-up were taken every week (Figures 5-7). The C/N levels were also tested (a) before the experiment started, (b) after its third week, and (c) after the composting was almost completed. General observations showed that the duration of the decomposition process in the Control and Tricho samples of the rotating drum were very similar, whereas the duration of the decomposition in the EM samples of the rotating drum was slower compared with the Control and Tricho samples. The samples in the sacks and the compost pits had slower rate of decomposition compared with the decomposition in the rotating drum, as drum rotation seemed to be more facilitating aerobic composting, also since mixing in the sacks and compost pits was not used. Results indicated that there is no need of activators for composting used feminine napkins, since the rotating-drum Control sample decomposed faster than the others.

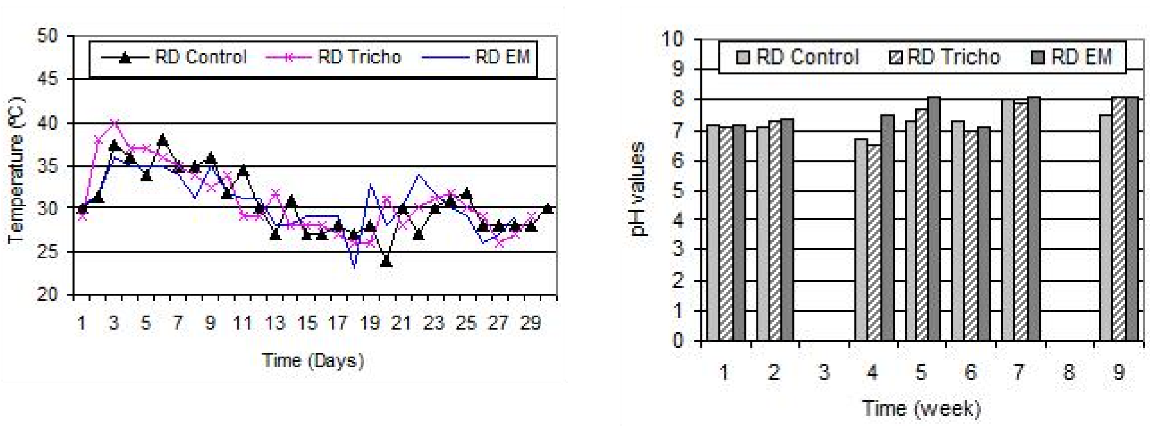

Figure 5. 3rd-phase experiment: Temperature and pH readings in rotating drums

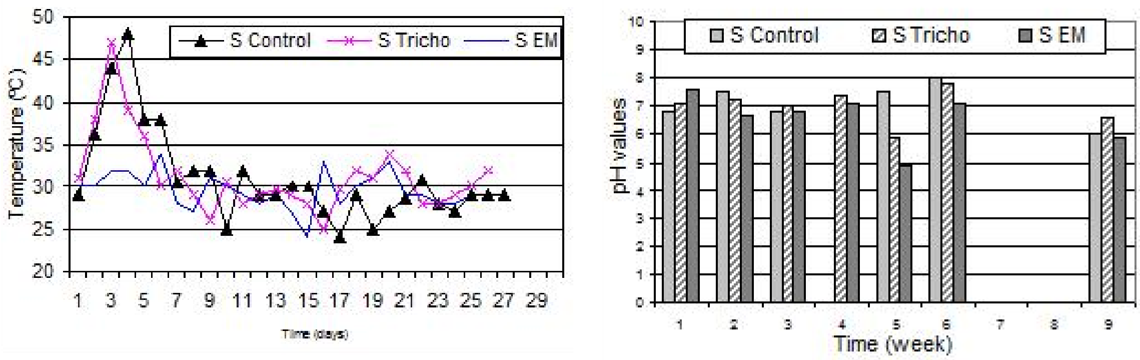

Figure 6. 3rd-phase experiment: Temperature and pH readings in sacks

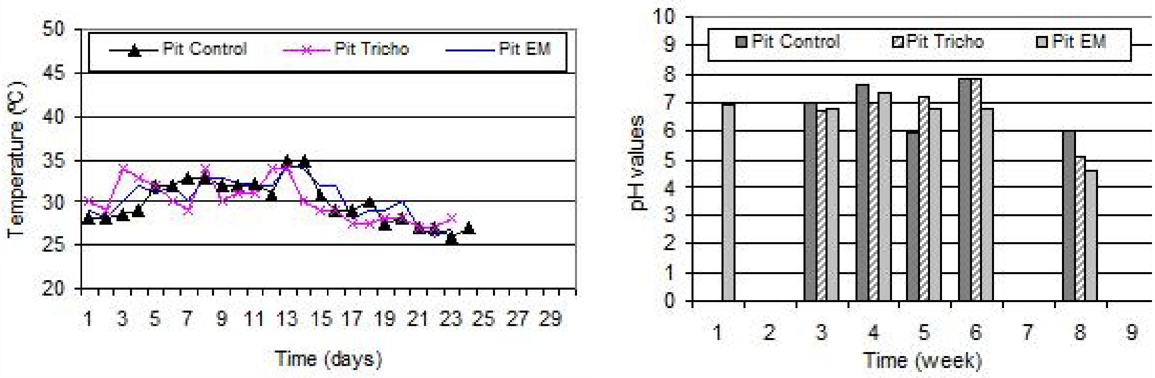

Figure 7. 3^{rd}-phase experiment: Temperature and pH readings in pits

5. COMPOSTING SCHEMES IN HANOI, VIETNAM

A home-composting scheme for two selected areas near Hanoi was organised, comprising of 4 individual stages: (a) selection of communities and data compilation, (b) selection of the composting technology, (c) conduction of experiments, and (d) assessment of the results.

5.1 Community selection and data compilation

Two communities were selected near Hanoi (Gia Lam and Phung with populations of approximately 353,000 and 132,000 respectively). They were considered appropriate for testing the implementation of home-composting schemes, as they are both semi-rural communities, producing large amounts of organic waste, while the main activity in the area is agriculture. The composition of solid waste in the selected areas was investigated in the field and yielded very low presence of metal and paper components, while the organic waste content ranged between 53 and 63% wt, with the organic waste's water content in the very high area of 80-90% wt and its C/N ratio in the relatively high range of above 60:1. Requirements and constraints for waste composting and proposals for the adoption of the Roll-Up or Drum composting method were provided. Moreover various technical issues were addressed concerning the adjustment of C/N ratio in the composting input, methods to ensure the required porosity and aeration of the material, the determination of the water content, as well as methods for the pre-processing of the input material. Furthermore, the pre-treatment of the raw material until a water content of 55 % and a C/N ratio of 30:1 in its organic fraction was provided as recommendation.

5.2 Selection of the composting technology

Based on laboratory results of the organic waste characterization, the composting technology selected was a Roll-Up system (in-vessel composting reactor). The reactor's technical features were: volume: 200 L; length: 1.2 m; diameter: 0.46 m; it also included a rolling and an aeration mechanical system. This system was assessed as the most suitable technology, although in operation problems came up related to the high moisture content of the waste and the resulting need for a pre-treatment of the input material.

5.3 Experiments and results

The selected Roll-Up system (Figure8) for household scale was designed to work under the following conditions: aeration regulation, leachate recycling, thermal and aeration control and effective micro-organism additives. The 1^{st} experimental phase included preliminary experiments in a stationary unit (Figure 99) with air supply and lasted 21 days. The whole process consisted of 3 experimental groups of input material (60 kg of organic MSW and 4 kg of straw). C/N ratio was measured, whereas the 1^{st} experimental group was subjected to an aeration velocity of 2 L min^{-1}. The 2^{nd} followed with an aeration velocity of 3 L min^{-1} and 4 L min^{-1}. Finally, the 3^{rd} group included leachate collection and recirculation through the organic mass of the composting pit. The second experimental phase used the Roll-Up system and the degradation process lasted 15 days. The material was rolled at 50 cycles/min and resulted to less odour generation compared to results of the 1^{st} experimental phase. Although the degradation process in the Roll-Up system was shorter than in a stationary unit (15 days instead of 21) and also gave fewer odors, several parameters in the Roll-Up system could not reach the appropriate standards of the process (e.g. temperature curve). The unit's fast rolling may have resulted to these problems and it was thus decided to reduce rolling speed to less than 50 cycles/min.

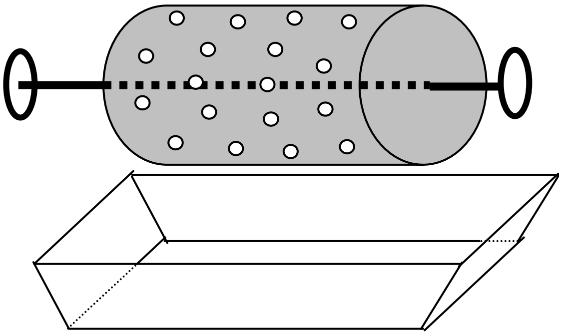

Figure 8. Roll-Up home-composting unit

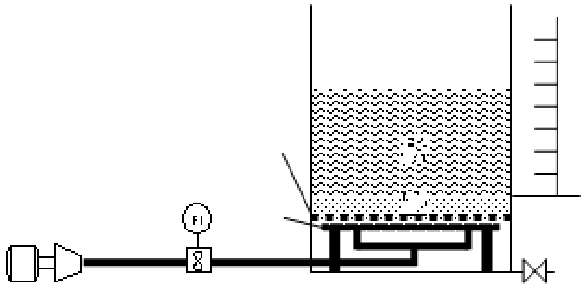

Figure 9. Stationary unit

6. A MASTER PLAN FOR AEROBIC COMPOSTING IN PIERIA, GREECE

In parallel to the Asian small-scale composting schemes previously analyzed, the investigation of a large-scale composting scheme in Pieria (a semi-rural area in north Greece with agricultural activities and production of large amounts of organic wastes) was studied. There has not been any prior experience in the production or use of MSW derived compost in this particular area (with the existing 3 composting plants in Greece located in Athens, Crete and Peloponnese) but the extended use of fertilizers in Pieria's agricultural region assured a stable market for quality compost. Based on a maximum estimated municipal organic fraction flow of 221000 Mg per year, a medium-scale composting plant was recommended where in-vessel technologies were excluded, as the cost of their installation and operation is considered too high by local decision makers and because they also require specialized personnel for operation. Moreover, the climatic conditions of Pieria with mild changes in temperature and medium-to-high humidity levels do not call for a technology to restrict heat and humidity, like in-vessel composting. Thus, passively aerated, turned windrow composting technology was recommended. Two groups of local master-plan scenarios were formulated, studied and simulated, resulting to a total of 10 scenarios. The first group of scenarios assumed no source separation of biowaste, while the second one considered biowaste source separation in specific regions of the prefecture. For each scenario waste flow analysis and cost elements for the collection, transport, processing and final disposal of waste were calculated using cost functions proposed in the available literature. The conducted analysis (which is presented in detail in Bilitewski *et al.,* 2005) indicated that the implementation of biowaste source separation (as well as home composting) schemes by also using low-cost solutions from the Asian parallel applications, can minimize the total system cost as low as 46% compared to mixed MSW composting. The range of the estimated cost for the considered scenarios ranged from 22,10 to 107 €/Mg of waste. Annual total cost per capita ranges from 7,24 to 35,06 € respectively. The operational cost of sanitary landfills was found significantly lower than the other system costs and varied in narrow range, while collection and transportation costs constituted a stable figure for every scenario.

7. DISCUSSION

During the experimental processes in both Asian areas, certain problems appeared due to weather conditions, quantity and composition of raw material, as well as the lack of previous experience in composting process. Collaboration between EU and Asian researchers resulted to an exchange of knowledge and experience on various SWM issues and on composting in particular. During the experimental phases, two were the main issues to be addressed; the quantity and composition of the raw material, as well as their retention time. The first issue was solved by adding green waste and by avoid using soil, which was traditionally added during composting. Leaves and used tissue paper were added in the input material in order to prevent plastic lining of the sanitary napkins from sticking on to the blades of the shredder and to improve the composting process by attaining the appropriate C/N values. All three experiments showed that sanitary napkins should be shredded prior to composting and that the use of rotating drums with either Tricho or no added microorganisms was the most efficient solution. Retention time was suggested to be increased, since it was determined on the field (both at the test sites, as well as on other facilities especially in Metro Manilla) to be initially very limited. This 'hurriness' to prematurely terminate the composting process –out of good will and often enthusiasm of course, but to the wrong result- is been practised widely in Asian areas as on-site visits showed. During and between the experiments, a number of neighbourhood composting facilities in Metro Manila were visited and examined by the research group, consisting of both Asian and EU experts. At these facilities, source separated organic MSW was mixed mostly with saw dust and introduced into elevated rotating drums for composting. However, a low-product quality was observed (rather 'enriched saw dust' instead of compost), which was attributed to low residence time, as the operators were in a hurry to take out the compost in order to produce more. Unfortunately, in this way, most of the material did not go through the final screen and was dumped.

The main setback in the composting activity in Vietnam was the high water content in the organic waste, which reached up to 90%. Therefore, a pre-treatment for controlling the water content was considered essential. To obtain input material suitable for composting, the organic waste of the selected communities needed to be mixed with other material (used paper and wood waste) in order to achieve the desirable C/N ratio of about 30/1; water content of approximately 55% and adequate aeration levels. Results indicated that the rotating-drum technology adapted well to the specific composting requirements and could be a good home-made solution to the pressing issue of SWM in Vietnam.

The sanitary napkin's composting scheme has become a permanent activity within the SWM programme of Miriam College, whereas Hanoi's environmental authority (URENCO) adopted the developed home composting technique for broader application in the city. The results from the Pieria case study, which learned a lot from the parallel Asian activities, confirmed that source separation of biowaste will result to better-quality compost and will minimize total system cost. Source separation schemes seem to be more acceptable considering cost, while scenarios assuming no waste treatment prior to final disposal are no longer politically acceptable due to the minimization of landfilling promoted by the EU waste management policy but were kept in the analysis as base cases for comparison reasons. Current prefectural planning (no source separation, large-scale composting facility combined with mechanical treatment of waste) leads to higher-cost systems, but the implementation of biowaste source separation (as well as home composting) schemes can significantly reduce the total cost and contribute in the production of better quality compost, thus enriching its added value and securing against final landfilling

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ACRONYMS

AUNP	ASEAN-EU University Network Programme	MSW	Municipal Solid Waste
EM	Effective Microorganisms	SWM	Solid Waste Management
ISTEAC	Integration of SWM Tools into specific settings of European and Asian Communities	Tricho	Trichoderma harzianum

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