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Waste Management
IMPLEMENTING REGIONAL ECOLOGY CENTERS IN THE VISAYAS REGION, PHILIPPINES: NETWORKING TO ENHANCE SECTOR DEVELOPMENT AND SOLID WASTE MANAGEMENT

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ABSTRACT
Local government units (LGUs) are primarily tasked by law to implement solid waste management (SWM) in the Philippines. But as in other developing countries, technical and financial constraints and limited political tenure delay SWM enhancement. Nevertheless, the law mandates the creation of multisectoral Regional Ecology Centers (RECs) that serve as platform for public participation, capacity development, knowledge transfer and networking. In partnership with Environmental Management Bureau (EMB), the first RECs were established in Region 6 (Western Visayas) and Region 8 (Eastern Visayas) with development support from the German International Cooperation (GIZ). Upon formulation of mission and vision statements, signing of Memorandum of Commitment and creation of working committees, the RECs pioneered in conducting annual regional SWM summits for sharing of best practices and by strengthening networking and sector development.

Keywords: Regional ecology center, Networking; Knowledge transfer, Sector development

Introduction
In the Philippines, various forms of participatory arrangements had been tested and supported by development projects to demonstrate benefits of multisectoral empowerment and alliances in increasing environmental management systems. Many such networks had proven to complement traditional forms of government control, fill gaps and tackle emerging issues in a more holistic and efficient approach [1].

In 2000, the Philippines’ Ecological Solid Waste Management Act or Republic Act (RA) 9003 has placed the responsibility of managing municipal wastes onto LGUs. However, many LGUs still struggle to adjust to increasing public duties while balancing its available financial and technical resources. This was acknowledged by RA 9003, which mandates the creation of support structures to assist LGUs and other stakeholders in SWM implementation. Among these are the National Solid Waste Management Commission (NSWMC) for national oversight and policy prescriptions, and the RECs for capacity development and networking services at the local and regional levels [2]. The Philippines is administratively divided into 17 regions, whereby each region hosts offices for various national government agencies (NGAs) and non-government organizations (NGOs). The establishment of RECs is stipulated under RA 9003 to establish a structure that is easily accessible to SWM stakeholders. REC as a multi-stakeholder assembly aims to enhance SWM capacities by tapping and synergizing available expertise and potential resources of NGAs, NGOs, academe, media, and other concerned stakeholders. It shall serve as platform for public participation/networking and shall ensure that all information generated, collected, and stored is accessible to the general public [2].

Development Process and Methods
The actualization of the role of the REC in supporting SWM sector development was initially tested in the Western Visayas (Region 6). Its membership, roles and responsibilities and its operational mechanisms were proposed and defined. Regions 7 (Central Visayas), 8 (Eastern Visayas), 13 (Caraga, Mindanao), and others in the country later adapted this model in institutionalizing their own RECs.
Processes for REC Establishment

RA 9003 did not specify a REC structure but mandates EMB regional offices to lead REC with its regional director in his/her *ex officio* capacity. In Region 6, an initial meeting of participating agencies was held in 2006 to clarify REC targets and to review roles of involved agencies based on RA 9003 as well as to agree on vision and mission statements as shown in Figure 1.

![A net is as strong as its weakest mesh](image)

Figure 1. “*A net is as strong as its weakest mesh*” to introduce a workshop for formulating mission and vision statements

An *ad hoc* technical working group was tasked to draft conceptual and operational framework for REC-6. To promote a cohesive organization, participation and sharing of resources, REC member agencies then entered into a Memorandum of Commitment (MoC).

In Regions 6 and 8, members acknowledged that for the REC to be more functional and to perform the individual mandates, an organizational structure within thematic work committees is needed. Hence, the REC was grouped into the following three committees: (a) environmental education and awareness (b) technology transfer and public-private partnership and (c) LGU support and networking. Committee work is a crucial pre-condition for REC assembly to come up with agreements and resolutions. One of the early challenges observed during pilot REC operations was that the involved agencies appeared inefficient in sustaining self-organized committee work. Possible factors identified were top management commitment, policy gaps, multiple staff assignments and deviating targets of individual member agencies. Hence, various organizational analyses were conducted in order to analyze strengths and weaknesses of the organization and to better define roles, functions and responsibilities of REC members as well as standard procedures and monitoring/evaluation systems.

Based on the made experiences, a corresponding REC guideline and manual of operations was developed and submitted to the NSWMC for later national policy issuance. This guideline proposes how to organize, operationalize and sustain the REC, including the use of various instruments, procedures, and financial and staffing requirements needed to make it functional [4].

Results and Discussion

Being pioneers in REC establishment and mobilization, the Visayas regions have undergone cycles of tests, evaluation and learning which led to enhance and streamline REC operations in various aspects. The signing of MoC by REC’s participating agencies proved to be a valuable tool in ensuring organization-based representation and institutional continuity. REC-6’s model MoC was later adapted by RECs in Regions 7, 8 and 13 and adjusted to the local conditions. A three-committee REC proved to be ideal in streamlining its activities while still encompassing all the roles and functions that RA 9003 downloaded to the RECs. The impact of REC could be measured by how strong the ‘buy-in’ was from its target clients and beneficiaries. Since 2008, RECs 6 and 8 had been conducting annual SWM stakeholder needs assessment surveys to monitor and evaluate SWM sector development and to adjust interventions, work plans and capacity development for local actors accordingly. A further undertaking is the annual conduct of REC summits per region. Each year, different thematic SWM topics are featured to update stakeholders on emerging issues, policies and technologies. The summits also serve for sharing of local best practices and for showcasing
products and equipment from private sector partners. To enhance knowledge management, RECs 6 and 8 and SWM4LGUs had been jointly documenting inspiring LGU initiatives into two-page fact sheets and other forms such as articles, news clippings, posters and peer-reviewed conference papers. To reach a wider audience, REC and its partners currently set up an electronic database (www.swm4lgus.net) with support of GIZ-AHT.

The legally mandated regional SWM database for monitoring LGU compliance to RA 9003 has not yet been realized due to a wide array of available formats that needed harmonization in terms of ease of use while managing to pool sufficient data. Nevertheless, regional EMB offices have been consolidating information gathered from LGU monitoring and from various REC members, which are featured in the annual State-of-the-Brown-Environment status reports compiled nationwide.

Through the REC’s mandate in establishing an accreditation program for SWM trainings, GIZ-AHT supported the development of a 17-module toolkit that encompasses the essential elements LGUs need to know to enhance their local SWM systems. Its adaption by the NSWMC for a standardized accreditation system is currently being reviewed while parallel efforts are in the pipeline to convert this SWM toolkit into a university curriculum as well.

Conclusions

The pioneering participatory approaches to establish RECs in the Visayas Region of the Philippines has engaged the supporting agencies to design and implement RA 9003-relevant programs in a more cohesive manner. The experiences of this multi-stakeholder assembly in steering SWM sector development, particularly in pilot Region 6, had been challenging. Yet the lessons learned in REC 6 made it easier for other RECs to benchmark their own. The functionality of RECs as portal for public information, capacity building, knowledge management and joint learning had been demonstrated by enhanced interest from its target beneficiaries. The quality of REC services provided to LGUs may not be perfect as of the moment, but continuous buy-in of stakeholders provides further motivation for this multi-sectoral body, not only in creating synergies and linkages to support local SWM implementers, but to buffer any gaps created by frequent local political transitions as well.

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References

APPLICATION OF MULTI-CRITERIA ANALYSIS IN MANAGEMENT OF MUNICIPAL WASTE IN CHOSSEN REGION IN POLAND

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ABSTRACT The main purpose of managing municipal waste is creation of technical conditions under which they can be processed in most eco-efficient way. Considering the present state of science and technology, it is possible to develop a technical system, which operates quite well, causing the lowest impact to the environment, but such a system would be costly. Economic aspects of the system are essential and very often they constitute the decisive factor in the selection of a given system. The best technical solutions will not operate properly if its functions are not accepted by society. It is therefore necessary to persuade the society to provide increased the financial outlays to be spent on the entire system. Analysis of all these elements leads to many difficulties. In this paper, a complex evaluation that was made using multi-criteria analysis of the possible solutions for municipal waste management in some Polish region is presented.

Keywords: Multi-criteria analysis, Waste management system, Waste incineration plant

Introduction

The main purpose of managing the municipal waste is creation of technical conditions to process them. Considering present state of technology and science it is possible to find a quite well operating technical system with its lowest impact to environment, but that system will be expensive. Economic aspects of the system are very essential and very often they are the decisive element of selection of a given system. The best technical solutions will not operate properly if the actions are not accepted by society. Thus it is necessary to convince the society what will increase financial outlay to be spent to the whole system. Analysis of all those elements leads to many difficulties [5, 6, 10]. In the paper complex evaluation made with multi-criteria analysis of the possible solution of municipal waste management in Cracow was presented.

Calculation: Multi-criteria Analysis of Waste Incineration Plant Location

The key problem in decisions concerning management the wastes and application of multi-criterion methods is objectiveness and fairness of an evaluating person. The goal of this analysis was to compare the calculation results with use of various multi-criteria methods applying the same assumptions and output data for calculations, the same evaluating criteria and their value.

Calculations were made on the example of waste management system in Cracow to determine the best location of municipal waste thermal processing plant. The necessity of its existence was assumed for calculating purposes, as one of the basic elements of a whole system in Cracow. Three possible hypothetical locations were analyzed:

Thermal-electric power station Cracow – Łęg (s1),
Agglomerating plant in HTS (old location) (s2),
Power plant in Skawina (s3).

Thermal-electric Power plant Cracow – Łęg is the biggest producer of heat operating in the city. It is also very important that it supplies heat for a whole year. This is very important, considering the possibility of wastes thermal processing location in that site. But at present there are no detailed information and details about such possibility of location of incinerating plant. Second possible location as being considered, concerns the parcel in South-East part of HTS Steel Company, close to Agglomerating Unit 2. That is the industrial area, preliminary prepared for ore waste dump. Currently significant part of that area was reinforced and prepared for investment purpose. There are the detailed conditions for area development, in
terms of investment i.e. municipal waste thermal processing too. Third potential location was Skawina Power Plant Co. Despite of production of electric energy and heat the plant runs auxiliary activity including utilization of waste from food industry. That plant is located in west part of Skawina town ~13 kilometers from Cracow centre. The area close to power plant in particular in its southern part is used as the industrial area, in conformity with local area development plant.

The same technology of incineration and treatment of process products waste was applied in all three cases assuming that it will be no influence the calculations results. The considered evaluation was not applied for measurement or for evaluation of technological solutions.

Used evaluation criteria for location of wastes incinerating plant in Cracow have been formulated in four presented groups:

**Technical–law Criteria:** conformity with area development plan and with plans of wastes management of higher levels, area and investment possibilities, existing infrastructure, distance from heat using cities centers.

**Environmental Criteria:** conditions of impurities emitted into the environment, possibilities and conditions of liquid waste collection, distance form final wastes dump (emission from transport), distance from the town (supply of waste, emission), possibility of use of the products (energy and by-products), use of renewable energy sources.

**Economic Criteria:** price of the building sites, investment outlays for infrastructure, costs of waste and products transport.

**Social – political Criteria:** living houses close to that area, possibility of social conflicts occurrence, political conditions.

As it is seen, there are many criteria and sometimes they present the contradictory goals. To have a clear picture and easier selection of location it is required to include in assumptions all the possible criteria. It is not easy because for example, in economic criteria, to define the price of a building sites in the place of incinerating plant location. These prices may change depending on time and many factors during the investment process. All the economic criteria mentioned above may be substituted with one i.e., cost of incineration of 1 ton of waste per one inhabitant per year. Such criterion will be useful for all the system users, but on the basis of current data and assumptions it is not possible to be evaluated. Thus it would be easier to take to calculations the series of partial criteria in all the groups and analyze their values for individual locations of incinerating plant.

All the evaluation indexes should give full picture describing each location and enabling to compare the individual solutions. Thus selection of evaluation indexes and finding of their measures was the most difficult task in complex evaluation of wastes incinerating plant location. Index measures are not presented in this paper, but exactly the same their values were taken for each of multi-criteria methods. The purpose of calculations was to compare the results with use of various methods and with the identical assumptions [1-4, 9-10].

Three multi-criteria methods have been selected for calculation:

bord method– ordering the location categories separately in relation to the evaluation criteria and next aggregating of partial evaluations into a final order selecting the best strategy of location,

the method of weighed sums – ordering the location strategies as a distance of individual strategies from a nadir (the least advantageous solution),

the method of compromise programming.

**Bord Method**

The following formula defines the principle of aggregation of partial positions in final ordering in relation to all the criteria:
\[ D_n = \sum_{m=1}^{M} D_{nm} \]  

(3)

Where:

\(D_{nm}\) – position of strategy \(s_n\) in the order settled in relation to criteria \(k_m\); \(D_n\) – “summation” position of location strategies including all the criteria. The final order of strategy is from the most advantageous to the least favorable is settled according to the increasing values \(D_n\):

\[ s_i \rightarrow s_j \iff D_j < D_i, i, j = 1, \ldots, N \]  

(4)

The best strategy \(s^*\) is defined as:

\[ s_j = s^* \iff D_j = \min \{D_n\}; n = 1, \ldots, N \]  

(5)

**Method of Weighed Sums**

That method uses the idea of ordering of individual strategies, depending on their distance from a settled nadir (the least advantageous solution in relation to all the criteria). Usefulness of strategy \(s_n\) in relation to all the criteria may be expressed as:

\[ U(s_n) = \sum_{m=1}^{M} w_m \cdot (r_{nm} - x_{m}^{**}); m = 1, \ldots, M \]  

(6)

Where:

\(x_{m}^{**}\) - \(m\) – coordinate of nadir (the least advantageous solution)

Searching the most advantageous strategy is performer according to:

\[ s_j = s^* \iff U(s_j) = \max U(s_n); n = 1, \ldots, N \]  

(7)

The results and final ordering of individual strategies of location of incineration plants are presented in table 1.

Bord method gives a univocal answer. Strategies \(s_1\) and \(s_2\) are equivalent and they take the same position in selection of unit location.

Method of weighed sums gives the more complicated results, because of the possibilities of weights relating to individual criteria. Various weights (as presented in the Table 1) have been used for calculations and depending on taken weights – various results of calculations have been obtained. Criteria weights are related to their individual groups: technical-law, environmental, economic and social-political criteria. Designation 1:1:1:1 assumes that number 1 relates to each of criteria, while designation 1:5:1:1 assumes that each of environmental criteria is marked as 5 and the next criteria as 1. On the basis of calculations according to this method, it was confirmed that:

In most cases, independently on taken hierarchy of criteria values- the most advantageous strategy relates to location Cracow – Łęg (\(s_1\)).

The analysis was made considering what values of weights should be taken for individual groups of criteria, to change location \(s_1\) to another one location. For example in case of technical-law criteria, no matter what value of weight relates to it, strategy \(s_1\) will always be selected; in case of environmental only weight 14 will be attributed with other criteria weight on the level 1 what indicated that location strategy \(s_3\) is selected. Such analysis enables to investigate the sensitivity of calculations result depending on importance of individual criteria take by a decision-maker.

Method of compromise programming similarly as the method of weighed sums gives the complicated results which have to be analyzed.
As a result of multi-criteria analysis, a half of cases concern the strategy s1 - location Cracow – Łęg. Similar analysis was made for strategy changing, depending on importance of used criteria. That analysis was very similar to that made in weighed sums method.

Table 1. List of individual strategies according to the selected multi-criteria methods

<table>
<thead>
<tr>
<th>Multi-Criteria Method</th>
<th>Calculations Results</th>
<th>Orderings of an incinerating plant location strategy</th>
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<td></td>
<td>1:1:1:1</td>
<td>s1 → s3 → s2</td>
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<td></td>
<td>5:1:1:1</td>
<td>s1 → s2 → s3</td>
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<td>1:10:1:1</td>
<td>s1 → s3 → s2</td>
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<td>1:14:1:1</td>
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<td>1:1:5:1</td>
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<td>1:1:4:1</td>
<td>s1 → s2 → s3</td>
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<td>1:1:1:5</td>
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<td>s1 → s3 → s2</td>
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<tr>
<td>Compromise Programming</td>
<td>Hierarchy of importance of criteria (technical, law, economic, social, political.) (α =2)</td>
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<td>1:1:1:1</td>
<td>s1 → s2 → s3</td>
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Conclusions

Multi-criteria decisive methods are the mathematic tool enabling to evaluate waste management in many fields and aspects. They enable to perform objective evaluation of waste management system, replacing intuition evaluations of those requiring the expert’s opinions. They also enable to evaluate the system, in conformity with requirements of environment management even in case of goal change or change of conditions in a described region. Decision in the area of waste management system is difficult considering various, often contradictory goals and tasks. Thus the most difficult and the most essential element of calculation is correct and full description of a problem, depending on type of decision that could to be taken.

References


ABSTRACT The global effort to fight climate change through emission trading mechanism has been under scrutiny for its efficiency in reducing green house gasses (GHG) and asymmetric participation. Low income communities who are the largest part of the world’s population are left behind to benefit from the lucrative market share. The Programme of Activities (PoA) of the Clean Development Mechanism (CDM) has arisen to address participation of very small projects. A case study on registration of the PoA KIPRAH for a pro-poor carbon financing project explores the opportunity of KIPRAH to benefit from CDM. KIPRAH, an abbreviation of “Kita-Pro-Sampah” which means “we’re concerned about waste” is a decentralized community-based solid waste management plant which serves up to 1500 households and manages approximately 1-3 tons of waste per day. The high potential of GHG emission reduction and the social benefits makes PoA KIPRAH a promising way for pro-poor financing.

Keywords: CDM, PoA KIPRAH, Solid waste management, Community, Sustainability, Small scale

Introduction
The Indonesian national statistics 2008 illustrated that 43% of the waste generation in Indonesia in 2006 came from households wherefrom 69% was collected and brought to the final dumpsite while the rest were buried (9.6%), composted (7.15%) and burned (4.8%) [1, 2]. Apart from a few CDM waste projects in final dumpsites [3] most of Indonesia’s final dumpsites don’t have any treatment for the waste brought in, resulting not only in health, safety, and aesthetic problems but also climate problems from its methane emission.

Community-based decentralized solid waste handling which involves composting, is one of the ways to respond to these waste management problems as it reduces the amount of waste brought to the final dumpsite and avoids methane emission from organic waste through composting. The PoA scheme allows very small projects like community-based decentralized solid waste management plants to participate in CDM. If it is successfully registered, it will be the first community-based project ever registered as a CDM project, marking the participation of low income communities in the global effort of fighting climate change and economically benefiting from it.

By analyzing the first year experience of designing the project and going through the registration process of PoA KIPRAH, the study portrays the potential and challenges of community-based projects to be part of CDM scheme.

Materials and Methods
This study is based on two applied researches in Indonesia held by the Bremen Overseas Research Development and Assistance and the International Development Research Centre; “Decentralized Urban Solid Waste Management in Indonesia” (2006-2009) and “The Carbon Market and Integrated Waste Solutions: A Case Study of Indonesia” (2009-2012). The method is a case study approach with 15 case studies in 6 cities across Indonesia. In addition, literature research was conducted by means of documents from the Ministry of Environment of Indonesia and articles on emission trading.

Results and Discussion

Decentralized Solid Waste Management
The enactment of the Indonesian Waste Management Law 18/2008 remarks the shifting of paradigm in waste management from “collect-transport-dispose” to reduce-reuse-recycle (3Rs), putting more responsibility to the waste generators to handle their waste [4]. KIPRAH is a decentralized solid waste
management project which arose as a response to the change in law and the targeted urban poor communities.

KIPRAH includes two vital components, 1) the installation of a community-based material recovery facility (MRF) where waste is separated and composted. An MRF serves maximum 1500 households manage 1-3 tons waste per day, employs 2-6 local workers and 2) the creation of a community-based organization to manage the MRF. The KIPRAH model consists of building partnerships and multiple financing by the community, government agencies, Non Governmental Organization (NGO’s) and the private sector. The Governments providing funds for the MRF, NGOs are facilitating communities, communities are paying and managing the MRF through community-based organization and the private sector is buying recyclables or compost. The lessons learnt from KIPRAH implementation from 2006-2009 are that a strong community-based organization, financial stability, and regular assistance are the key factors of sustainable community-based solid waste management facilities. Nevertheless funding is needed to assure good composting and operational of MRF; therefore options of financing need to be taken into consideration.

Potential in Carbon Financing for KIPRAH Projects

Indonesia has ratified the Kyoto Protocol and since has hosted 48 CDM projects where nine (9) are waste projects; six (6) are “Methane recovery and utilization” and three (3) are “Methane avoidance”. The Programme of Activities (PoA) is a natural evolution of Clean Development Mechanism (CDM) to address issues of asymmetries of participation, especially in very small-scale project activities due to low volume of reductions against high transaction costs [5]. Since its adoption by United Nations Framework Convention on Climate Change (UNFCCC) in 2007 there are six (6) registered PoA’s (http://cdm.unfccc.int/ProgrammeOfActivities/registered.html) compared to total 2777 registered projects (at the time of writing: Jan 2011) and none of them are community-based projects. PoA mechanism has allowed small projects like KIPRAH to be registered at the concept level without specifying beforehand all its constituent activities, but one CDM Project Activities (CPA) which in this case is a group of MRFs. Once PoA is registered, other CPAs can be added under the umbrella of PoA without having to be registered. Thus, PoA gives the chance for many MRFs to be included and receive carbon funds from the sales of the Certified Emission Reduction (CER).

The estimated emission reductions of a typical MRF with an annual load of 500 tons of organic waste and a fossil fuel consumption for waste processing of 2 liters per HHs per year is 132 tons CO2-e annually. With an average price of 18.7 US$ per CER in the European Union Emission Trading Scheme in 2009 [6], the break-even point of a CPA operational cost will be reached with a minimum number of 15 MRFs per CPA.

Challenges in CDM-Registration Process for Community Based Projects

The PoA KIPRAH registration process is now at the stage of validation. During the first year experience of the project design development and registration process some challenges are encountered, recognizing the extent of CDM complexity and high cost for a small scale community project:

a. Different paradigm in waste management between UNFCCC and community: UNFCCC is referring to the proven reductions of GHG as criterion for project eligibility. Therefore the monitoring requirement is rigid and sophisticated regardless of who runs the project, either big companies or the community. On the other hand, the community sees emission reduction as one small part among waste related social problems.

b. Monitoring mechanism required by UNFCCC is challenging to be implemented for community based projects: KIPRAH applied the methodology AMS.IIIF which consists of tools to determine methane emitted from disposal of waste by monitoring organic waste load and characteristic, oxygen content measurement during the composting process, and strict documentation at a MRF site. These monitoring are challenging to be managed by low educated MRF workers and community-based organization members.

c. High costs of registration process: PoA KIPRAH design and validation cost at almost USD 80,000. Without donor or external financial support, community projects wouldn’t stand a chance to benefit from CDM.
d. Small profit with high risk investment: Regardless of its high social components, PoA KIPRAH is unattractive from the investment point of view. Apart from the small numbers of CER generation, KIPRAH doesn’t involve sophisticated technology and professional employees like any other CDM composting projects, which leads to higher uncertainty in achieving certified emission reduction.

e. Gold Standard, the only premium standard for which gives higher price for projects with high social component is still limited to renewable energy projects.

Conclusion

Can the community benefit from global emission trading?

The total transaction value of the global CDM market in 2009 was 20,200 million US$ [6]. PoA, which was launched to address the asymmetric participation of very small scale projects, should help the community projects to benefit from this huge market. Yet, the number of registered PoA projects since its adoption by UNFCCC in 2007 are only 6 (six) compared to total 2777 registered projects (at the time of writing: Jan 2011). The high potential of GHG emission reduction in the waste sector and the communities social benefits from decentralized solid waste management makes KIPRAH projects a promising way for pro-poor financing. PoA may have opened the door for community projects but without further improvements of PoA through simpler methodology and lower cost of registration, community projects will remain alienated.

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We would like to thank the community-based organizations and operators of the KIPRAH plants and the Bremen Overseas Research and Development Assistance Indonesia partner organizations: LPTP, BEST and BALIFOKUS for supporting the process of registration. Also thanks to the donating organizations of International Development Research Centre and Bremen Overseas Research and Development Assistance Indonesia for financing the case study.

References

ABSTRACT Municipal solid waste (MSW) category classification represents a change in MSW management in China. Detailed investigations on the physical composition and properties of MSW in the experimental districts revealed that high moisture and high percentage of kitchen waste are the main limiting factors in the recovery of recyclables. On the basis of the investigation, a new category classified system, according to which MSW was classified as kitchen waste, other waste and ash waste, was proposed of South Beijing. In addition, a corresponding MSW treatment pattern that involves all compost for kitchen waste, incineration for other waste and landfill, for ash waste and residues of composting and incineration were constituted to promote efficiency of waste disposal. Performance results showed that the recycling rate, benefit cost ratios and the production rate of compost were improved about 65.0%, 31.6% and 82.9%, respectively. But the landfill capacity was reduced by 81.6% for the category classified MSW as compared with mixed collected pattern.

Keywords: Municipal solid waste, Category classification, Kitchen waste, Other waste, Comprehensive treatment pattern

Introduction
In China, about 180 million tons of MSW are disposed in 2007 with an annual growth rate from 8% to 10%, and have caused serious pollution to urban environment [1]. Integrated waste management is considered to be the key towards successful MSW treatment [2]. Waste separation is a critical component of a successful integrated waste management system. Previous reports [3] have proposed many MSW classification systems, but those unsuitable for China MSW classification in the early stage. In 2009, the government of Beijing setting a goal for MSW disposal that is “enhances the disposal capability, adjusting structure, promoting reduction”. According to this objective, the MSW ratio for incineration, composting and landfill will achieve 4:3:3 and, the separation ratio of MSW in Beijing will achieve 65% by 2015. The purpose of this study was to establish a new category classification system and the comprehensive treatment pattern which suited to the MSW management of South Beijing.

Materials and Methods
MSW for the experiment was collected from four districts, located in the south part of Beijing. At present, the mixed collection and transportation of MSW is practiced in Beijing as shown in Fig.1. In this study, the MSW was collected from 3 collection stations for each district, the waste samples were classified manually as kitchen waste, plastic, paper, wood, metal, ash, fabrics, rubber and glass, the percentage and the low heat value of each component were computed [4].

Results and Discussion

Physical Composition and Category Classification of MSW
The mean percentage of kitchen waste, paper and plastic were 59.5%, 13.8% and 19.2%, respectively (Table.1). The content of rubber, metal and glass were quite small, below 2%, and these components could be sent to recover system after sorting. Ash waste plays little role in MSW, which contributed only 2.7% in total MSW. The mean moisture content and low heat values were 59.9% and 1988.1kJ/kg for the mixed MSW of four districts, respectively. For the existing collection pattern, because of high moisture content in the mixed MSW, recyclables such as paper and fabrics would be inevitably contaminated by the wastewater from the kitchen waste, which would make them impossible to be recovered. According to the composition and characteristics of MSW, the mixed MSW can be category classified for kitchen waste, other waste (which contains the composition of paper, fabric, plastic and wood) and ash waste in south Beijing.
Table 1. MSW physical composition of different districts in South Beijing

<table>
<thead>
<tr>
<th>District</th>
<th>Kitchen waste</th>
<th>Paper</th>
<th>Plastic</th>
<th>Fabric</th>
<th>Wood</th>
<th>Rubber</th>
<th>Metal</th>
<th>Glass</th>
<th>Ash</th>
<th>Moisture</th>
<th>Low heat value (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ChongWen</td>
<td>63.0±2.9</td>
<td>12.2±1.6</td>
<td>18.5±1.5</td>
<td>1.5±0.2</td>
<td>0.3±0.2</td>
<td>0.3±0.3</td>
<td>3.1±0.4</td>
<td>0.9±0.6</td>
<td>61.3±4.7</td>
<td>1813.7±242.1</td>
<td></td>
</tr>
<tr>
<td>ChaoYang</td>
<td>57.3±2.6</td>
<td>13.1±3.0</td>
<td>19.3±2.9</td>
<td>1.9±0.4</td>
<td>2.2±0.1</td>
<td>0.1±0.3</td>
<td>1.4±0.4</td>
<td>0.3±0.6</td>
<td>58.1±4.7</td>
<td>2046.8±251.7</td>
<td></td>
</tr>
<tr>
<td>XuanWu</td>
<td>65.6±3.2</td>
<td>12.6±3.0</td>
<td>16.1±1.6</td>
<td>0.2±0.1</td>
<td>1.6±0.5</td>
<td>0.3±0.3</td>
<td>0.9±0.4</td>
<td>2.2±0.6</td>
<td>63.9±3.7</td>
<td>1618.2±251.7</td>
<td></td>
</tr>
<tr>
<td>FengTai</td>
<td>52.2±3.2</td>
<td>17.1±3.0</td>
<td>23.1±1.6</td>
<td>1.1±0.1</td>
<td>1.1±0.1</td>
<td>0.1±0.4</td>
<td>0.1±0.4</td>
<td>3.8±0.6</td>
<td>55.8±3.7</td>
<td>2477.7±251.7</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. MSW characteristics after category classification

<table>
<thead>
<tr>
<th>District</th>
<th>Moisture</th>
<th>Low heat value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kitchen waste</td>
<td>Other waste</td>
</tr>
<tr>
<td>ChongWen</td>
<td>58.1±5.4</td>
<td>24.7±1.5</td>
</tr>
<tr>
<td>ChaoYang</td>
<td>67.9±2.4</td>
<td>28.1±2.8</td>
</tr>
<tr>
<td>XuanWu</td>
<td>65.9±4.6</td>
<td>24.9±1.3</td>
</tr>
<tr>
<td>FengTai</td>
<td>62.5±2.5</td>
<td>30.4±1.6</td>
</tr>
</tbody>
</table>

The Characteristics of MSW after Classification

After category classification, the mean moisture content of kitchen waste, other waste and ash waste were calculated as 63.6%, 27.7% and 17.1%, respectively. Almost all water in MSW mainly comes from the kitchen waste, once the kitchen waste is isolated from the mixed MSW, the water content of the waste can be reduced dramatically. The mean lower heating value for kitchen waste, other waste and ash contents were -381.6kJ/kg, 5021.9kJ/kg and -102.6kJ/kg, respectively. It showed that category classification of the MSW not only reduced the water content, but also increased the heating value of the combustible waste fraction.

The Recovery Potential and Disposal Pattern after MSW Category Classification

The kitchen waste was characterized with easily biodegradable, high moisture content and low heating value. Therefore, composting could be considered as the suitable method for kitchen waste recycling,
and the composting residue can be used for incineration purpose. But the main limiting factors during composting of kitchen wastes were mainly high moisture content, higher leachate production and lower temperature profile reported earlier. Therefore, it could be co-composted with dry straw. The characteristics of other waste were low moisture content, high heat value, which higher than 3344kJ/kg (could reach more than 5000kJ/kg). Hence, incineration could be considered to recycle other waste streams, and there should not add combustion improver during incineration process. The characteristics of ash waste were stable and easily stocking, therefore, this part of waste can be separately collected and directly transported to the landfills for final disposal.

**Destinations of MSW after Category Classification**

Table 3 showed the destinations of MSW after category classification, and as control of existing treatment pattern. The total amount of MSW collected in south Beijing was 2000 tons per day. After category classification, the amount of kitchen waste was 1190.4 tons a day, other waste and compost residue (more than 25mm) were 1093.2 tons a day. The amount of incineration residue, solidification of fly ash and ash waste was 309.0 tons a day. The computing method of incineration residue, fly ash and electric energy production were consulted the references \[5-7\].

<table>
<thead>
<tr>
<th>Item</th>
<th>Category classification amount (ton/day)</th>
<th>Mixed collection Amount (ton/day)</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total amount of mixed MSW</td>
<td>2000.0</td>
<td>2000.0</td>
<td></td>
</tr>
<tr>
<td>Compost material</td>
<td>1190.4</td>
<td>646.7</td>
<td>Compost material</td>
</tr>
<tr>
<td>Compost production</td>
<td>217.8</td>
<td>64.7</td>
<td>Agricultural application</td>
</tr>
<tr>
<td>Compost residue</td>
<td>337.3</td>
<td>324.2</td>
<td>Incineration</td>
</tr>
<tr>
<td>Other waste</td>
<td>755.9</td>
<td>—</td>
<td>Incineration</td>
</tr>
<tr>
<td>Incineration residue</td>
<td>187.1</td>
<td>—</td>
<td>landfill</td>
</tr>
<tr>
<td>Incineration fly ash</td>
<td>47.7</td>
<td>—</td>
<td>Landfill after solidification</td>
</tr>
<tr>
<td>Electric energy (kWh/day)</td>
<td>317688</td>
<td>—</td>
<td>Electric energy production</td>
</tr>
<tr>
<td>Landfill amount</td>
<td>309.0</td>
<td>1677.5</td>
<td>Final disposal</td>
</tr>
</tbody>
</table>

Compared with the existing pattern, the amount of composting material increased from 646.7 tons a day to 1190.4 tons a day, and therefore the compost productive rate increased up to 82.9%. The amount of compost residue was 337.3 tons a day, which had lower moisture content (25%~30%) and higher calorific value and can be incinerated with other combustible fractions. Electrical energy production was about 317688kW.h a day during incineration process. The materials for landfill mainly include incineration residue, solidification fly ash and ash waste, the amount was only 309.0 tons a day. While in existing pattern, the material for landfill including compost residue, the waste of less than 15mm and more than 80mm, total amount was 1560.8 tons per day. After category classification, it avoided the predicaments caused by landfill of less than 15mm and more than 80mm waste which used to cause a serious waste of resources and produced a large amount of leachate pollution. By the category classification pattern, the rate of resources increased from 97.3% to 32.3%, and the landfill capacity was reduced by 81.6%, saving a lot of land.

**Economic Assessment Results**

In China, all of the waste disposal costs supported by the government, the costs for composting, incineration and landfill are 20.5, 30.4 and 8.4 USD per tons, respectively. The costs include five parts, i.e., the cost of collection, transport, pre-treatment (RTS), treatment and environmental pollution control. The benefits for MSW treatment include tow parts, i.e., sell the compost and the electrical energy from incineration process. The price of the compost is about 9.1 USD for the category classification pattern and is about 7.6 USD for
the mixed collection pattern. In general, about 25% electric energy was used for incineration plant, the remaining electric energy for grid-connected, and 0.08 USD/kWh. The original data in benefits and costs calculated was extracted directly from Table 3.

Table 4. Comparison of financial cost and benefit of different collection system (USD /day)

<table>
<thead>
<tr>
<th>Item</th>
<th>Category classification</th>
<th>Mixed collection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost</td>
<td>Benefit</td>
</tr>
<tr>
<td>Composting</td>
<td>24414</td>
<td>1985</td>
</tr>
<tr>
<td>Incineration</td>
<td>33216</td>
<td>18099</td>
</tr>
<tr>
<td>Landfill</td>
<td>2582</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>60212</td>
<td>20084</td>
</tr>
<tr>
<td>Benefit cost ratio (%)</td>
<td>33.4</td>
<td>1.8</td>
</tr>
</tbody>
</table>

The cost benefit assessment is presented in Table 4. Results showed that the total cost of the category classification pattern tow times as large as the total cost of mixed collection pattern, but the total benefit of the category classification pattern is more than forty times than the total benefit of mixed collection pattern. After category classification of MSW, the benefit cost ratios increased from 1.8% to 33.4%. Based on the calculation, the category classification pattern was superior to the mixed collection pattern.

Conclusions

The high percentage and high moisture content of kitchen waste in MSW are the main limiting factors in the recovery of recyclables. With category classification pattern, the recycling rate, benefit cost ratios and the production rate of compost were improved about 65.0%, 31.6% and 82.9%, respectively, but the landfill capacity was reduced by 81.6% as compared with the mixed collection pattern. It was showed that the category classification pattern was superior to that the mixed collection pattern.

Acknowledgements

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References

WEB-BASED DECISION SUPPORT SYSTEM FOR ECONOMIC EVALUATION OF MUNICIPAL SOLID WASTE MANAGEMENT

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ABSTRACT The rapid rise in the quantity of MSW has made a great impact on the environment of cities, so various processes have been developed in order to select both environmentally friendly and economically viable methods for waste management. The alternative methods of treating waste range from the old-fashioned landfill, to more modern methods such as incineration, materials recovery, energy from waste, mechanical biological treatment, anaerobic digestion and more specialised methods, such as pyrolysis and gasification. In this paper, an evaluation model is developed to assist the economic assessment of different methods of MSW management, which uses incremental Net Present Value (NPV) to compare alternatives and select the best solution from economic point of view and Decision Support System (DSS) have been developed.

Keywords: Solid waste management, NPV, Decision support system

Introduction

China generated over 150 million tons of municipal solid waste MSW annually. Over the past ten years in China, the annual average rate of increase of municipal solid waste is about 7% to 9% [1], and most of waste is mixed collected. In Europe (namely EU25), the total amount of MSW generated increased from 515 kg per person in 1999 to 524 kg per person in 2008. In different countries, however, the MSW generation rate varied significantly, e.g. in 2008 this amounted to 306 kg/person in the Czech Republic and to 802 kg/person in Denmark [2]. The rapid rise in the quantity of MSW has made a great impact on the environment of cities, so various processes have been developed in order to select both environmentally friendly and economically viable methods for waste management. The alternative methods of treating waste range from the old-fashioned landfill, to more modern methods such as incineration, materials recovery, energy from waste, mechanical biological treatment, anaerobic digestion and more specialised methods, such as pyrolysis and gasification [3]. In this paper, an evaluation model is developed to assist the economic assessment of different methods of MSW management, which uses incremental Net Present Value (NPV) to compare alternatives and select the best solution [4].

In this field, many researchers [4, 5] have done a great deal of work generating a lot of outcomes. But at present, few of the outcomes concerning evaluation have been developed using computer technology to assess and compare the different methods of treatment applied to municipal solid waste. This may seem odd, as various applications using computer databases or computer-aided systems for MSW management have been established over many years; and, indeed, in recent years, DSS have been developed and also successfully implemented in many other subjects. At the same time, the rapid increase of internet application and advances of new technologies have opened up new opportunities for enhancing traditional decision support systems. It is therefore possible to develop financial management techniques, correctly supported by scientific tools, which help to find cost-effective solutions in MSW management systems. But this has not yet been achieved.

The waste management industry needs a reliable tool to compare the impact of different waste management methods and make decisions based on more subtle and sensitive analysis, which will reveal the true consequences of one decision as opposed to another. In this paper, the Decision Support System is primarily providing economic evaluation of different landfill alternatives, but can be easily adapted to the needs of the EWM project, which concentrated on Landfill, Incineration, and MRFs. The model was tested and can be also applied for comparing alternative waste treatment methods, i.e. recycling, incineration, landfilling with or without gas recovery, composting, etc.
System Data

This Decision Support System is mostly based on the process of waste disposal, which is divided into three stages: (1) operating (2) closure (3) post-closure. Every stage involves different types of cost, which are stored in the database. General information about the project (qualitative and quantitative) is also involved. The time horizon for financial analysis will be limited to 30 years, and any further cost foreseen after this period will be cumulated in the last year as a residual value. Cost should be calculated according to article 10 of the Landfill Directive.

Evaluation Model

Calculations

For some items in this life cycle model, such as elements of cost by process or cost by type, values change over time for two reasons:
- changes in projected cost levels in each annual period (change in nominal value) - changes over time (change in real value);

Modelling

An evaluation model, based on economics, was developed to find a cost effective model solution for municipal solid waste management systems, in which net present values (NPV) are presented. In economics, the purpose of the financial analysis is to use the project’s cash flow forecasts in order to calculate net present value (NPV), the financial internal rate of return (IRR) as well as annual rate of return RoR both for individual proposed solutions as well as possible alternatives (incremental NPV, IRR and ROR). Incremental NPV (NPV_A – NPV_B) was used to compare mutually exclusive options (i.e. project A or B).

System Flow and System Interface

System Flow

The data flow between the user interface and decision-maker is presented in Fig. 1, which illustrates the sequence of steps in the decision process that the decision maker can utilize for effective design and operation for urban waste treatment.

User Interface

The DSS is divided into several interfaces where all the user’s inputs are completed to make the model operational. This includes details on technology, capacities, timing, etc., but also decisions on Variability Ratio. Depending on the VR inputs and percentage distribution the model calculates the annual cost, both “by process” and “by type”. Execution of the model is initiated via the “submit” buttons in an HTML format, launching the DSS’ model management agent. After execution of the model, many results, such as NPV, annual cash-flow, IRR (Internal Rate of Return), RoR (annual rate of return) and so on, are derived from the calculation of the model built into the computer program (Fig.2).
Main Interface

Press the button “please press the button and enter the main evaluation interface”

Input required information

Submit

Input percentage distribution

Submit

Costs by Processes

Submit

Costs by Type

NPV IRR RoR

the Result of Comparison between Technology 1 and Technology 2

Figure 1. The system flow chart

Figure 2. Comparing alternative solutions
Conclusions

This DSS is a simple, but flexible and easy-to-operate tool. Usually, to compare alternative solutions, a great deal of input data is required. This model enables quick comparisons, as it works with more aggregated data, mostly those that can be obtained from an accounting system (for historic data) or the planning department (for projections). At this stage it is possible to add a sub-interface that allows work with more detailed information, also those not expressed in monetary value (e.g. environmental impacts, which are not yet considered in the model). To create a tool for a complex evaluation of MSW management there is still much more work needed – a good DSS requires continuous development and permanent collaboration between users, field experts and system developers.

References

INTEGRATED WASTE MANAGEMENT IN URBAN AREAS USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

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ABSTRACT Urban Solid Waste Management is considered as one of the most immediate and serious environmental problems confronting municipal authorities in many of the developing countries. There has been a significant increase in the generation of MSW (Municipal Solid Wastes) in India over the last few decades. Tiruchirappalli is the fourth largest Municipal Corporation in Tamil Nadu state covering a geographical area of 146.70 sq.kms comprising of 60 wards and 4 administrative zones. According to the 2011 census, the population of Tiruchirappalli is 27,13,858. Due to urbanization and increase in population, the generation of Solid Wastes also increases day by day and the total quantity of Solid Waste generated in Tiruchirappalli is 408 tonnes /day. Geographic Information System (GIS) is used as a decision support tool for planning Waste Management in Tiruchirappalli. The Solid wastes disposal sites are located at Ariyamangalam (19.31 acres) and Panchapur (25 acres). Other than these locations Tiruchirappalli has more than 25 unauthorized disposal sites existing in the city. All these areas are very closer to the densely populated residential/ commercial/ institutional areas. This kind of improper Solid waste disposal leads to serious health hazards such as development of vector habitats, transmission of diseases like Dengue, chickungunya and malaria have been found to occur. For the management of hazardous and solid wastes in an environment friendly safe manner, effective steps have to be taken. ArcGIS10 spatial analyst was applied for integrating various thematic layers, primary and secondary attribute data such as land use land cover, ground water quality, population density, distribution respectively. All these factors have been integrated in GIS platform to provide a scientifically/ technically validated management planning strategies.

Keywords: Geographic Information System, Global Positioning System, ArcGIS, Solid waste management, Vector habitat

Introduction

As a developed country that has harvested the successes of economic growth, the consumption and production behavior of its millions of residents greatly threatens the quality of the environment. Municipal Solid Waste (MSW) is a term often used for the solid heterogeneous by-product of different human activities (Ming-Lang Tseng, 2011). The waste generally contains discarded material like papers, plastic, glass, metal fine earth particles, ash, sewage sludge, dead animals, etc. However, waste generation increases continuously in proportion with population and challenging more land disposal (Indris et al. 2004). It is reported that the chemicals from solid waste disposal site pollutes underground water, rendering it unfit for consumption (Samsudin et al. 2006; Singh et al.1999). Similarly, dumping of solid waste results in explosion of gases (Lamar et al. 1978). The solid waste contains a high proportion of organic matter, and this attracts the flies and rodents. The high temperature and humidity favour rapid bacterial growth and decomposition of waste that causes bad smell and odour which invite different diseases as well as disturb the aesthetic beauty of the area (Sharma 2005). GIS is an effective integrated method by which Solid Waste Management is handled efficiently in several ways. One of the most important issues related to waste management is the appropriate location of treatment facilities and disposal sites. These tasks require processing significant amounts of spatial information, including environmental, social, economic and engineering data. Collecting and analyzing these data is time consuming and tedious. Thus, a computerized geographic information system (GIS) has been used in recent years in order to facilitate sitting-related tasks (Sauri-Riancho M. R., et al, 2010). The objective of the present study is to identify the proper disposal site for maintaining good urban environment for long time.
Materials and Methods

Study Area

Tiruchirappalli, situated on the banks of the river Cauvery is the fourth largest city in Tamil Nadu. Tiruchirappalli city is located 10.00'-10.30' N Longitude and 75.45'-78.50' E Latitude. The total area of the study area is 4403.83 Sq.Km. Tiruchirappalli city corporation consists of 60 wards and 4 zones, 15 wards to each zone including, Srirangam, Ariyamangalam, Ponmalai and K.Abishekapuram (www.trichycitycorporation.com). The Study was conducted to understand the current problem of waste disposal in Tiruchirappalli and to suggest best possible sites for waste disposal. The total length of the underground Drainage system present in the study area is 147.30 kms. The garbage dump is spread over an area of about 45 acres has turned a veritable swamp of putrid and reeking mounds of garbage, accumulated down the years. About 350 to 400 tonnes of garbage collected from the city is dumped at site every day. Local residents in recent years have been demanding shifting of the dump maintaining that it has turned into a health hazard (The Hindu, March 12, 2010).

Spatial and Non Spatial Datasets

Spatial data: Lansat ETM satellite imagery 15th May 2001 and SOI Topsheets (58J/9,58J/10 and 58J/13) were used.

Non Spatial data: Field data, Topography, Amount of waste generated, Ground water quality

Attribute data: Land use/land cover, other thematic layer, climatology data

Socioeconomic data, Population data

Tiruchirappalli, has a population of 27, 13,858. Males constitute 49.67% of the population and females 50.33%. Trichy has an average literacy rate of 91.45%. Male literacy is 94.17% and female literacy is 88.73% (Census 2011). The urban population of the city is around 10, 26,931 in 2010, making it the 50th largest urban agglomeration in India. As per the reports available in Indian Meteorological Department -IMD, 2010 the average rainfall is 906.1 mm/annum. Summer during March to May have a maximum temperature of 41°C and a minimum of 36°C. Winter during December to February is warm but pleasant with temperature ranges by 19°C to 22°C. Monsoons during June to September have moderate rainfalls and the atmosphere becomes humid during this season. (www.imd.gov.in/section/nhac/dynamic.htm).

Criteria for Selecting Solid Waste Dumping Site

Following parameters were used for the selection of proper solid waste disposal sites, It includes Depth of bedrock, Slope, Rock type, Structural features, Water table depth and fluctuation, Surface drainage, Soil type and Permeability, Population, Land use, Type of waste generated etc (Upasana Shrivastava, 2010). Maps are generated for each parameters and finally overlay analysis done at GIS platform to identify the suitable site for waste disposal.

Present status of disposal Sites in the Study Area

The composting yard is situated in Ariyamangalam which is 6 km away from the Trichy Central Bus Stand. The composting yard occupies 47.7 acres with compound wall and two water tanks with one lakh litre capacity to avoid fire accidents. Degradable and non-degradable wastages generated from the city have been collected 51 appropriate vehicles, which includes small container lorries, big container lorries, compactor lorries, JCB, and Chain dozer. In average the amount of solid waste collection per day from all over the city varies from 410-420 tonnes. Gandhi market, Central and Chatram bus stands are the places which generate large amount of solid waste in the city among other areas. Approximately 70 tonnes of degradable solid wastes are collected from Gandhi market area and 20 tonnes of degradable and non-degradable wastes are collected from the Central and Chatram bus stand area and all Ulavazar santhai occasions. According to the survey carried out by Tiruchirappalli Corporation, 4-5 grams of wastages are dropped by each person in the Tirucirappalli city. Industrial and hospital wastages are not allowed into the compost yard because of the risk for fire accidents and disease causing organisms. The annual averages for the amount of solid waste
generated in each zone are given in the Table 1. The amount of waste from Gandhi market, Central and Chatram bus stand are given separately.

Table 1. Solid Waste Generated in Tiruchirappalli City Corporation - March 2011

<table>
<thead>
<tr>
<th>S.No</th>
<th>Zone</th>
<th>No. of trip vehicles</th>
<th>Amount of Solid waste (Ton./Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Srirangam</td>
<td>53</td>
<td>79.180</td>
</tr>
<tr>
<td>2</td>
<td>Ariyamangalam</td>
<td>49</td>
<td>54.440</td>
</tr>
<tr>
<td>3</td>
<td>Ponmalai</td>
<td>46</td>
<td>61.390</td>
</tr>
<tr>
<td>4</td>
<td>K. Abishekapuram</td>
<td>59</td>
<td>91.240</td>
</tr>
<tr>
<td>5</td>
<td>Gandhi market (Ariyamangalam zone)</td>
<td>12</td>
<td>55.680</td>
</tr>
<tr>
<td>6</td>
<td>Chatram bus stand (Srirangam zone)</td>
<td>01</td>
<td>02.200</td>
</tr>
<tr>
<td>7</td>
<td>Central bus stand (Ponmalai zone)</td>
<td>01</td>
<td>02.800</td>
</tr>
<tr>
<td>8</td>
<td>Compactor lorry (All over the city)</td>
<td>12</td>
<td>72.080</td>
</tr>
<tr>
<td>9</td>
<td>Night shift (All over the city)</td>
<td>01</td>
<td>05.620</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>424.63</td>
</tr>
</tbody>
</table>

Figure 1. Land Use/Land Cover Map of the Study Area

Land use / Land cover

Orthorectified Landsat ETM images covering Tiruchirappalli for the year 2001 were downloaded from the site www.landsat.org. This data were projected on Universal Transverse Mercator (UTM) projection system with datum WGS- 84 and zone 44. The Land use/ Land cover classification was done for the satellite imagery of the study area. For this the signatures were collected from the signature editor and supervised
classification was performed. It was classified into various classes such as river, vegetation, Settlement, Wetland, Tanks, Crop land and Waste land respectively. The Land use/Land cover map for Trichy city (May 2001) is as shown in figure 1. This resultant Land use/Land cover map can be useful in locating the solid waste dumping sites.

Data Integration
The land use/land cover is the basic data source to select the suitable site waste disposal. Different types of data have been integrated by Arc GIS using criterion analysis for proper solid waste disposal in the study area. The concept is where the land having hard rock terrain for less seepage of polluted water, poor population density, the location should be a waste land away from the commercial/industrial areas are the suitable site for disposal.

Results and Discussion
In respect with Trichy City Corporation they have not been integrate available data. Also the existing disposal site Ariyamangalam, Panjapur and other locations there is no proper planning. Corporation never made any attempt to select a suitable site for this purpose. In this situation peoples are living near by this locations are suffering by odder, health hazards such as increasing mosquito population relatively vector borne diseases in different seasons in the local areas. Quality of ground water also declined.

Conclusion
The study reveals that lack of urban planning and management strategies in and around Tiruchirappalli City Corporation is the main reason for this situation. Further we suggested authorities to consider the factors which are influencing major issues may give high significance on solid waste management practices.

References
A DECENTRALIZATION-BASED APPROACH FOR URBAN WASTE MANAGEMENT: MOVING TOWARDS SUSTAINABLE RESOURCE MANAGEMENT

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ABSTRACT Waste is not waste - much of our disposed waste should not be considered waste, but misplaced resource. Currently, these resources are incinerated or buried in landfills. Such waste management concepts need to be revised as natural resources are fast depleted. Waste can be potential sources for resource recovery. This is especially relevant to land-scarce and resource-limited Singapore and many other cities in the Asia and Pacific region. In this article, a decentralization-based solution that will revolutionise current urban waste management concepts is introduced.

Keywords: Decentralization, Resource recovery, Co-digestion, Co-composting, Material recovery, Energy recovery

Introduction

Waste is not waste. Much of our disposed waste should not be considered as waste; they are simply misplaced resources. Based on current waste management concepts, these resources are incinerated or buried in landfills. Such waste treatment/disposal approaches need to be revised as natural resources are fast depleted. Waste can be potential sources for resource recovery. In economically developing countries, resource recovery is a common and widespread occurrence at the community level and reusable materials are often used as feedstock for remanufacturing. However, this is not the case in developed countries. Fortunately, there is a move towards that direction through increased awareness in recycling to improve land use efficiency. Resource recovery would be especially relevant to land-scarce and resource-limited Singapore and many other cities in the Asia and Pacific region.

Issues of Current Waste Management

Natural resources are not efficiently used by human beings. The majority of natural resources are considered unusable waste in our industrial systems. If natural resources can be efficiently used, the rapid depletion of resources can be mitigated, while waste management problems can be solved. The long used centralized waste treatment/disposal approach is a critical issue that needs to be addressed in future waste management. Also, due to concerns about the potential environmental impact that may be caused, especially in urban areas, both solid and liquid wastes have long been transported to remote areas for treatment or disposal. The need to collect and transport waste to centralized waste treatment/disposal facilities causes a significant amount of energy to be consumed. The energy consumption in such waste management practices was not seriously considered in the past as energy prices were not a concern. However, due to the increasing price of fossil fuel, the cost of energy consumption needs to be taken into account in future waste management practices.

The Proposed Solution: Communities as Renewable Resource Recovery Centres

To develop a sustainable urban waste management approach for the next decade and beyond, the idea of “Communities as renewable resource recovery centres” was proposed by the Residues and Resource Reclamation Centre (R3C) of the Nanyang Technological University (NTU) in Singapore. It will provide an alternate approach to sustainable urban waste management not only for Singapore but also numerous cities around the world. An $10 million research program was recently awarded to R3C by Singapore’s National Research Foundation. The five-year program is currently being conducted by the R3C/NTU research team together with government agencies, including the National Environment Agency (NEA), the Jurong Town Corporation (JTC), and the Housing Development Board (HDB), industrial partners include Lionapex, SembCorp and Keppel, and international partners include the Technical University of Hamburg and Harburg (TUHH) of Germany and the National Cheng-Kung University (NCKU) of Taiwan. Various technologies, both lab-scale and pilot-scale, will be developed, tested, and demonstrated.
This solution proposes separation of brown water, yellow water and grey water to facilitate the recovery of nutrients and energy at the source and eventually convert a community into a renewable resource recovery centre that can benefit not only from resource recovery, but also from minimising the cost spent on transporting waste for off-site treatment and disposal (Figure 1). This idea challenges the century old domestic wastewater treatment concept (i.e., the activated sludge process) of a centralised system by separating and converting the waste resource into energy and useful materials using proven (e.g., anaerobic digestion) [1] and emerging (e.g., microbial fuel cell) technologies [2]. To our knowledge, no such waste to energy and materials project has been attempted in an urban context, although there are some source separation/anaerobic digestion systems that exist in less populated rural areas. We strongly believe the benefits in terms of water and energy savings of implementing the proposed idea can be significant in urban areas like Singapore that have an established centralised system where more water and energy are required. To achieve the goal, the following research projects are being conducted by our research teams.

Figure 1: Schematic Diagram of “Communities as renewable resource recovery centres”

Source Separation and Nutrient Recovery

An innovative separating toilet model suitable for Singapore is being designed. The proposed separating toilet based system provides different options: less than 0.3 L of water per urine-flushing (yellow water) and 2.5 L of water per fecal-matters-flushing (brown water). In this case, daily flushing water consumption will be dramatically reduced by 24-24.5 L per capita (from 30 L per capita currently to 5.5-6.0 L per capita [3]). When flushing water decreases, less wastewater is produced and less water needs to be transported and treated. This would significantly benefit Singapore’s water authority, the Public Utilities Board (PUB), in water supply and wastewater treatment. At the same time, yellow water and brown water are separated to facilitate further treatment and utilisation. The collected yellow water, containing mainly nitrogen and phosphorus, can be properly treated for nutrients recovery in order to produce fertilizer. This is another source of revenue.
Energy Recovery from Household Brown Water and Food Waste

With rapid increase in population density in Singapore and the fact that more than 80% of the population live in the high-rise Housing Development Board (HDB) buildings, the proposed decentralised anaerobic digestion (AD) system is expected to provide a practical solution for managing large quantities of brown water and food waste on-site. The well established infrastructure for sewer, waste collection and transportation are readily available for simple modifications to transfer the concentrated waste directly to decentralised AD systems. This, together with the high potential for producing a substantial amount of energy in the form of biogas, makes the proposed decentralised AD concept economically realistic. Building AD systems in HDB flats for on-site waste treatment and methane production will become an eco-friendly model for other countries, especially those experiencing rapid urbanisation and water shortage. The challenge is in designing a space-friendly, odour- and pathogen-controlled AD system that can be incorporated into new and existing residential clusters. Based on our characteristics analysis of brown water and food waste (data not shown), it is estimated that about 21 kg volatile solids (VS), equivalent to about 43 kg chemical oxygen demand (COD), are generated through these waste streams per HDB block with 300 residents on average, which can yield about 10 m³ methane when 65% VS removal is achieved. This waste-originated energy can be utilised, for example, for cooking or lighting purposes within the HDB block. Other advantages may include: (1) the digestate can be used as a bio-fertilizer within the parks present around the unit, (2) since 100% of the wastes produced from HDB is managed within the site of production, additional costs for transporting such wastes to the centralised treatment systems are saved, and (3) the life span of landfills can be significantly extended by minimizing the needs for disposal.

Energy and Material Recovery from Commercial and Institutional Wastes

Another core of the distributed resource recovery centres is an integrated thermophilic co-digestion (CoD) and co-composting (CoC) process for energy and compost/fertilizer production from community organic wastes. Some pre-treatment facilities and a combined heat and power (CHP) unit are used to facilitate sorting, shredding and screening of waste to generate heat and electricity from methane, respectively. The classification of organic wastes for this part is based on biodegradability under anaerobic and aerobic conditions and C/N ratios. Waste rich in lignocelluloses are considered “non-biodegradable” or “less-biodegradable” in anaerobic conditions in the treatment time considered (5-10 days). Thus, the incoming waste streams are divided into two types from the beginning: anaerobically biodegradable and only-aerobically-biodegradable. A mixture of anaerobically biodegradable waste is co-digested at thermophilic temperatures maintained by the CHP heat. The digested residue (N rich) is then co-composted with a mixture of only-aerobically-biodegradable waste (C-rich) in a temperature-controlled in-vessel composting system to produce quality compost. The composting temperature is also in the thermophilic range, but is maintained by self-generated heat during aerobic degradation. The AD biogas is turned into heat and electricity in the CHP. Part of the heat is internally consumed to provide necessary heating for thermophilic AD, while part of the electricity is used to operate machines. Also, the proposed resource recovery centres will be equipped with simple facilities for inorganic waste, e.g. ferrous and non-ferrous metals and glass, separation and recycling.

Electricity Generation Using Fuel Cells and Microbial Electrolysis Cells

This part aims to utilize both the liquid and gas phase products from AD process to generate electricity. Part of the electricity can be supplied to other energy-requiring processes, therefore making the whole resource recovery process distributed and self-sustaining. Specifically, biogas will be directly fed to the solid oxide fuel cell (SOFC) system for electricity generation, while AD effluent will be fed to the microbial electrolysis cells (MECs) for the generation of hydrogen, the MEC is then connected to a proton exchange membrane fuel cell (PEMFC) for electricity production. Working in parallel, the proposed research will include three main parts. The first part is to develop an efficient and effective SOFC cell system that can harvest the energy from the biogas which comprises of around 60% of methane, plus CO₂ and other impurities such as hydrogen sulphide (H₂S) and nitrogen (N₂). To achieve this goal, the following tasks should be carried out: the development of (i) a catalyst that can improve impurity tolerance and avoid carbon deposition, and (ii) a catalyst with high performance, stability for long time operation under a wide range of biogas composition. The second part is an MEC combined with a PEMFC to capture energy from AD effluent (~10³ mg COD/L).
Although an MEC requires external voltage, this energy input is far less than the chemical energy carried by the produced hydrogen. The third part investigates the MEC to enhance the hydrogen production rate and efficiency. To achieve this aim, the following tasks are proposed: (i) the development of a composite membrane with gas barrier, high proton conductivity, and low internal resistance, (ii) the preparation of new catalysts with high activation and stability for hydrogen revolution at neutral pH, and (iii) the investigation and selection of appropriate buffers and electrolytes to enhance MEC performance.

Benefits, Economic Potential and Other Contributions of this Study

The economic potential of this study is obvious and could bring Singapore both tangible and intangible benefits including:

- Reduction of water consumption
- Reduction of wastewater treatment cost
- Recovery of energy (biogas) from brown water and food waste
- Recovery of energy (electricity) from brown water, food waste and community organic waste
- Recovery of nutrients/fertilizers from yellow water and digestion residue
- Recovery of energy (biogas) from sludge co-digestion in wastewater treatment plants

The benefits listed above are substantial and most importantly, a decentralised “waste to resource” solution can help make future urban waste management more sustainable as opposed to the current centralised treatment/disposal method that has been implemented for more than fifty years. It is especially important now that natural resources are diminishing quickly.

Conclusion

Waste is not waste. Successful implementation of the ideas proposed in this study would reap another success story like NEWater, e.g., NEWPower and NEWMaterial. We hope this program can eventually be introduced to other cities around the world. It would be especially important for mega cities that are beginning to emerge in the next few years.

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Reference

SUPPORTING INNOVATION IN WASTE MANAGEMENT - THE SITA BLUE ORANGE APPROACH

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ABSTRACT With rapid world-wide urbanization and growing population, waste management is becoming one of the top priorities of city governments. This new social and economic environment requires novel approaches.

One of the difficulties is how to nurture promising new technologies to maturity. SITA, one of the leading waste management companies in the world, as part of its corporate responsibility program supports promising developments through its Blue Orange investment fund.

A recent example of this is the agreement SITA has signed with Cynar Plc, a firm focused on new conversion technology, to build Britain’s first fully operational plants to convert end of life plastic into diesel fuel. The objective is to build 10 UK plants dealing with 60,000 tonnes of mixed plastic waste per year and to commission the first plant in London by end 2011.

Keywords: Waste management, New technologies, SITA, Blue Orange investment fund, Mixed plastic waste
AN APPROACH TOWARDS THE INTEGRATED ELECTRONIC WASTE (E-WASTE) MANAGEMENT TECHNIQUE IN MALAYSIA

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ABSTRACT
In Malaysia, the electronic solid waste management is placed together with the solid waste management based on hierarchy concept. Basically, the conventional method of disposing of electronic waste is mostly by landfill. However, there are several disadvantages of using landfill such that the pollutant of electronic waste are not biodegradable, while its hazardous nature will increase the pollution concentration in the leachate, landfill gas emission and possible reaction may occur between electronic waste and other waste at the landfill sites. Therefore, there is a need for environmental friendly strategies to manage electronic waste. The strategy should be based on the economic and technical capability of the country, competitive and realistic. In order to implement the strategy, the concept of integrated electronic solid waste management is considered in this study. However, there is a need to develop infrastructure facilities such as waste collection, central sorting (Material Recovery Facilities (MRF) & Refuse Derived Fuel (RDF) recovery facilities), recycling, thermal treatment (RDF or Catalytic De-polymerization Process (CDP) technology) and landfill system to support the integrated concept. The advantages of implementing integrated electronic waste management are the system able to contribute to the economic increase of a country and reduce the impacts of pollutants to the environment. For such purpose, this study discusses an approach towards the integrated electronic waste management in Malaysia.

Keywords: Electronic waste, Management, Integrated concept, Approach

Introduction
The accumulation of solid wastes is closely associated with the rapid emergence of populations, industries, urbanizations and the standard level of occupants of an area. The accumulated wastes have to be managed with the best technology that emphasizes the environment. In order to achieve the environmental-friendly management objectives, the management technology has to forecast more than on safe disposals and on regaining resources from the accumulated wastes. The management objectives have to scrutinize the roots of the problems and the adapted technology has to be at par with the objective to achieve an environmental-friendly management pattern. In Malaysia, the past waste management strategies were focusing more on the hierarchical waste management system. In brief, the hierarchy system proposes management technology options according to priority that is to start with the waste reduction technology, re-using, recycling, composting, incineration with energy production, incineration without energy production, and the final is landfill technology. However, the management based on hierarchical concept has some drawbacks because none of the management technologies are able to produce optimum management effects [1]. With regards to this, the strategies including the basis of waste management practices in our country must be amended promptly. In order to achieve the environmental-friendly waste management pattern, an integrated solid waste management system has to be executed. The necessary integrated system concepts include collecting system and sorting wastes followed by one or more management options such as recycling, thermal treatment or landfill technology [1]. For that reason, this paper is to introduce the integrated electronic waste management (IEWM) concept as a sustainable system to be implemented in the next future. Fundamentally, the sources of electronic wastes come from residential areas, commercial buildings and industrial sectors. In Malaysia, there are two major electronic waste flows that are through the Municipal Solid Waste (MSW) flow and also the Industrial Waste (IW) flow. Usually, the bulk electronic wastes will go through the MSW flow while the electronic wastes from industrial disposals will go through the IW flow[2]. An electronic waste management will undergo processes of gathering, collecting, re-using, recycling and finally the process of disposal. Basically, the practiced methods in managing electronic wastes are re-using, recycling and disposing. The re-using method encompasses the concept of
contribution or donation such as for users to give such electronic products to others, for manufacturers to re-claim the electronic apparatus for further processing and for users to mend the electronic waste components. As for the recycling method, materials from the electronic wastes like plastics, metal and other valuable components will be assembled at recycling centers. These materials will be processed into secondary raw materials and then to be sold to local or international manufacturers for the production of certain products. The disposal method that practices landfill technology will dispose the electronic wastes that have lost their values in an absolute manner [2].

An Approach Towards the Integrated Electronic Waste Management Technique in Malaysia

Figure 1. illustrates the flowchart of an approach towards the integrated management concept for electronic wastes as practiced in our country. With reference to the figure, the integrated waste management for electronic wastes from the point of accumulation to the point of disposal will undergo four stages namely collection system as the first, waste reduction system as the second, raw materials recovery system as the third and finally, the disposal and recovery of energy resources system. To refer to Figure 1, electronic wastes accumulated by users will go through the first stage i.e. the collection system. The solid waste collection system needs a very high financial allocation as compared to other management components in the integrated system. Therefore, in order to practice the integrated electronic solid waste management, the first suggested method is for users to bring their broken electronic apparatus to the electronic shops when they want to purchase new ones. Indirectly, these electronic shops will become the recycling collection centers. This method has been successfully practiced in other countries (Japan) in which as an example, users have to bring their fluorescent lamps to the electronic shops whenever they want to change them [3].

The second method that can be practiced is the method of reclamation of electronic materials by the suppliers. For example, companies like IBM, Dell, HP and other computer products manufacturers should take back their own products from users when these products are no longer in use for the purpose of re-processing [4]. The third method is for users to bring electronic wastes to the re-purchasing centers for recycling. In our country, the second and the third methods have already been practiced in managing valuable electronic wastes such as computers, televisions and printers while the components that have no value such as small domestic appliances like fluorescent lamps, food blenders, ovens and others, they will be directly disposed at disposal sites [2]. Although there are some disposal sites that have their own small scale recycling centers (in which there are workers to sort MSW electronic wastes to be sold), in general, most of the electronic wastes are directly disposed at the disposal sites. Therefore, it is suggested that the government should enact a policy for the first method to be practiced in order to upgrade the present electronic waste collection system.

The successfully gathered electronic wastes will undergo the second stage that is to re-use those electronic apparatus. The components in electronic apparatus which are still in good condition will be used again by the manufacturers to produce secondary products [4]. The non-functional components will undergo the third stage i.e. the process of sorting and recycling in order to regain secondary raw materials from wastes. The by-products of the electronic waste process at the third stage will undergo the process of disposal by using thermal treatment technologies such as Catalytic De-polymerization Process (CDP) and Refuse Derived Fuel (RDF) burning (stage four). Materials such as plastics that possess high heating value have the potentials to become fuel for the production of synthetic diesel and electrical energy while other wastes will be disposed at the ordinary disposal sites for those non-hazardous and for those hazardous wastes, they will be sent to the secured landfill at Kualiti Alam Sdn. Bhd. toxic waste treatment plant in Bukit Nanas, Negeri Sembilan. The integrated solid waste management method is able to contribute to the economic increase of a country and reduce the impacts of pollutants to the environment if it is properly implemented. An economic increase is achievable based on the reduction of the amount of energy usage (electricity, gas, diesel or petrol), the re-using of wastes as secondary raw materials, the reproduction of energy from wastes, the reduction of the waste total volumes at the disposal sites and the reduction of the pollutants emissions to the environment.
Conclusions
The present practice of solid waste management has given negative impacts on the valuable resources, the country’s economy, the environment and the health of the country’s population. The management that only emphasizes on collecting and disposing wastes has affected the environment by reducing its aesthetic values due to solid waste pollution such as air, water, smell and noise pollutions. To improve and upgrade the present management practice, the integrated solid waste management is the solution to the country’s solid waste management problems. The 9th Malaysian Plan (from the year 2005-2010) has outlined an emphasis on the solid waste policy and management in which it has to be carried out in its totality and in an organized manner. In answering to the government’s call, integrated electronic waste management is a best management solution in order to achieve the government’s inspirations.

Acknowledgements
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References
ENVIRONMENTAL RISK RELATED TO SPECIFIC PROCESSES OF SCRAP COMPUTERS RECYCLING AND DISPOSAL

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ABSTRACT The purpose of this work is to make a better understanding of the generation of toxic chemicals related to specific processes of scrap computers recycling and disposal, such as thermal recycling of printed circuit boards (PCBs) and land-filling or dumping of cathode ray tube (CRT). Tube furnace pyrolysis was carried out to simulate different thermal treatment conditions for the identification of the by-products and potential environmental risk from thermal recycling PCBs. Toxicity Characteristic Leaching Procedure (TCLP) and a column test were used to study the leaching characteristics of lead from waste CRT glass, which is one of the most important environmental concerns deriving from e-waste. The results obtained indicate that the environmental risk related to specific processes of scrap computers recycling and disposal varies with the characteristic of waste and disposing scenario, which is useful when take specific measures to reduce environmental risk under different situations.

Keywords: E-waste, Cathode ray tube, Printed circuit board, Environmental risk

Introduction

E-waste is becoming a major environmental concern globally. In China, most e-waste was processed in small sectors that lack of pollution control facilities, resulting in serious local environment pollution[1]. Some scattered studies reported the contamination situation in e-waste recycling areas/clusters in China, however, mainly focused on surrounding environment [2-5]. Scrap computer contributes one of the most significant kinds of e-waste. The purpose of this work is to make a better understanding of environmental risk related to specific processes of scrap computer recycling and disposal. According to the existed research, thermal treatment printed circuit boards (PCBs) and the disposal of cathode ray tube (CRT) glass, including land-filling and dumping, are the two significant processes resulting in environmental risk, which are selected as the focal point of this work.

Pyrolysis is a chemical recycling technique that has been widely researched as a method of recycling synthetic polymers. The pyrolysis oils contained high concentrations of phenol, 4-(1-methylethyl) phenol, and p-hydroxyphenol, as well as bisphenol A, tetrabromobisphenol A, methyl phenols, and bromophenols [6]. A study using the US Environmental Protection Agency (USEPA) Toxicity Characteristic Leaching Procedure (TCLP) has shown that lead leaches from the CRTs produces an average concentration of 18.5 mg/L in TCLP extracts [7]. This exceeds the TCLP regulatory limit of 5.0 mg/L which will result in the waste being classified as hazardous by the toxicity characteristic. Existed research on thermal treatment of PCBs mainly focused on inert atmosphere, such as nitrogen and helium. However, this process is more often carried out in oxidizing atmosphere in reality. Also, long term risk of CRT leaded glass when treated with municipal solid waste is not clearly clarified. The purpose of this study is to make a better understanding of the pyrolysis characteristics of PCBs in oxidizing atmosphere and long term risk of CRT when land-filled and dumped, both of which from scrap computers.

Materials and Methods

Materials

The PCB and CRT leaded glass used in this study was obtained from scrap computer collected from resident. The base plates of PCB consisted of a woven fiberglass mat impregnated with thermo set resins with copper coating on the base plates. The content of PbO in CRT leaded glass in 22%.

Experiment Procedures

A laboratory-scale fixed bed tubular batch reactor (BR) was used to carry out PCBs thermal decomposition runs. The experiments were mainly aimed at the recovery and characterization of the different fractions of
decomposition products. Typical sample weights in the experimental runs were 80g. Experimental runs were performed using a purge gas flow of pure nitrogen and air to control the reaction environment and to limit the extension of secondary gas-phase reactions. Volatile products evolved during thermal degradation were transferred by the gas flow in a series of cold traps, maintained at -20 °C by a sodium chloride brine/ice bath. Condensable products were recovered at the end of the run from the cold traps for chromatographic analysis. The traps were followed by a gas sampling bag for gas analysis.

A multistep sequential leaching procedure was used to determine the long term leach ability of CRT leaded glass. Not the same as leaching procedure described in existing research, the leaching reagents used in every step are unaltered, in other words, repeating the TCLP. A column test is another type of leaching test used to study the leaching process from waste material. The test involves a continuous flow of leaching solution through waste material placed in a column. The leaching solution used in simulative acid rain, made of sulfuric acid, nitric acid, and other inorganic minerals. Qualitative and quantitative analysis of decomposition products was carried out by GC/MS methods. Further details are reported elsewhere. Lead concentrations in leached were determined by Inductively Coupled Plasma (ICP).

Results and Discussion

Pyrolysis Yields of PCBs

The solid, liquid and gas yields (wt. %) were obtained in the PCB pyrolysis experiments carried out at 275, 325, 400, 500 and 625°C. Results are presented in Table 1. It could be seen that at 275, 325 °C, pyrolysis was incomplete since solid yield was much higher than the other temperature, while at 400, 500, 625 °C the solid yields were approximately equal. Compare to the PCBs pyrolysis yields in nitrogen and air, pyrolysis were more complete in air than in nitrogen above 400 °C, resulting from the oxidation reaction of PCBs.

<table>
<thead>
<tr>
<th>Temperature (° C)</th>
<th>275</th>
<th>325</th>
<th>400</th>
<th>500</th>
<th>625</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nitrogen</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid yield</td>
<td>95.0</td>
<td>83.6</td>
<td>79.4</td>
<td>78.4</td>
<td></td>
</tr>
<tr>
<td>liquid yield</td>
<td>2.6</td>
<td>7.4</td>
<td>11.0</td>
<td>12.6</td>
<td></td>
</tr>
<tr>
<td>gas yield</td>
<td>2.4</td>
<td>9.0</td>
<td>9.5</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td><strong>Air</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid yield</td>
<td>97.6</td>
<td>90.0</td>
<td>75.9</td>
<td>75.1</td>
<td>73.5</td>
</tr>
<tr>
<td>liquid yield</td>
<td>1.4</td>
<td>5.9</td>
<td>7.8</td>
<td>8.2</td>
<td>7.3</td>
</tr>
<tr>
<td>gas yield</td>
<td>1.0</td>
<td>4.1</td>
<td>16.3</td>
<td>16.7</td>
<td>19.2</td>
</tr>
</tbody>
</table>

Degradation Products Formed in PCBs Pyrolysis

The products were identified in the fractions recovered from pyrolysis yields of PCBs in this study. HBr, bromphenol and brominated bisphenol a derivatives are the dominated compounds, which was comparable with the existing research. There is one exception for benzene series, including benzene, methylbenzene, dimethylbenzene, ethyl benzene and styrene, which was detected in this study but not mentioned in aforementioned studies. The yields of benzene series in liquid and gas products are presented in Table 2. Benzene series yields are much higher than the other temperature above 400 °C and much higher in air than in nitrogen, which may also resulting from the oxidation reaction of PCBs. Benzene series are known as carcinogenic substance and volatile, which should also be paid special attention to when recycling of PCBs under thermal conditions, especially for the baking of PCBs without any protection.

Leaching of Lead from CRT Glass

The multistep sequential leaching procedure was used to determine the maximum leaching ability of lead when land filled with MSW. The column test was to simulate the leaching characteristics of leaded glass when open dumped without any treatment. The results are presented in Fig.1 and Fig.2. Fig.1 shows that after ten step sequential leaching procedure, the concentration of lead still exceeds the TCLP regulatory limit of 5.0 mg/L which will result in the waste being classified as hazardous by the toxicity characteristic. However, the total amount of lead leaching from CRT only contributes less than 1% of the total in leaded
glass, which indicated that lead would still release for quite a long time at a high concentration, resulting a high environmental risk. Fig. 2 shows that the leach ability is really small when leaching solution flow and without any glass immersed in. The concentration of lead is lower than the limit of 0.05 mg/L that is the standard of surface water III in China, posing little environmental risk.

<table>
<thead>
<tr>
<th>Table 2. Benzene series yields under different atmosphere (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Nitrogen</strong></td>
</tr>
<tr>
<td>Benzene</td>
</tr>
<tr>
<td>Methylbenzene</td>
</tr>
<tr>
<td>Dimethylbenzene</td>
</tr>
<tr>
<td>Ethylbenzene</td>
</tr>
<tr>
<td>Styrene</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
<tr>
<td><strong>Air</strong></td>
</tr>
<tr>
<td>Benzene</td>
</tr>
<tr>
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</tr>
<tr>
<td>Dimethylbenzene</td>
</tr>
<tr>
<td>Ethylbenzene</td>
</tr>
<tr>
<td>Styrene</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

Figure 1. Concentrations of lead leaching from multistep TCLP procedure (two parallel samples)

**Conclusions**

The environmental risk related to scrap computers recycling and disposal varies with the characteristic of waste and disposing scenario. It poses risk to environment and labours when dissembling PCBs by baking or air cooking. Benzene series should be paid more attention to when recycling of PCBs under thermal conditions, especially for the workman without any protection. The risks aroused by cathode ray tube land filling are different between when disposal with municipal solid waste or separated from other waste, the former process posing a really high risk to environment, especially the groundwater.

**Acknowledgements**

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Figure 2. Concentrations of lead leaching from dynamic column test procedure

References


ENERGY AND MATERIAL RECOVERY TO PHASE OUT MSW LANDFILLS IN MAINLAND CHINA

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ABSTRACT In 2004 China has taken the worldwide lead in solid waste production. The rapid growth of megacities, till 2050 another 300 mn people will migrate and the urbanization rate will reach 70%, is besides of an increasing living standard the main reason for a continuous annual 10m/m% MSW growth rate. Solid waste management (SWM) will play more than before an important role; within the 11th-Five Year Plan (FYP) period the target to increase the treatment ratio of collected waste to 60% could not be achieved and treatment capacities are today lacking behind by 22 mn t/yr [1]. Therefore during the upcoming 12th-FYP period, the investment in this sector will be doubled, reaching CNY80bn and new concepts will be adopted. New integrated SWM solutions, appropriate to the local conditions, have to be approached.

Keywords: Integrated solid waste management, China, Biogas, RDF, Climate change, Bement industry

Introduction

During the last decade the amount of collected municipal solid waste (MSW) was raised continuously in Mainland China, but the waste treatment capacities could hardly satisfy the demand and the ‘mix’ of waste treatment and disposal methods could not be changed significantly. Valuable materials, suitable for material recycling, were mostly recovered in a traditional way by means of house to house and street collection, and are estimated to account for about 20m/m% of the total waste stream [2]. By 2009, due to a better diversification of treatment and waste classification, Beijing was able to reduce the waste amount for final land filling by 4.8m/m% [3].

MSW Landfills

Land filling disposal is still the most wide spread practice, accounting for 89% of 157 mn t/yr. In 2009, 654 cities have operated 447 ‘Chinese standard’ engineered landfills to ‘manage’ 57m/m% of the total MSW [4]. The remaining 28m/m% of the collected MSW is dumped at uncontrolled landfills. If this land filling practice is continued, from whatever reason - on purpose or lacking other solutions - China will need another 1600 landfill sites by 2030 [5, 6].

But compared to western countries, a significantly different composition of MSW leads to different landfill behavior and in the typical Chinese MSW more than 80m/m% of the organic matter is fast and easy biodegradable with a low lingo-cellulose content [5, 7]. This and the practice of landfill operation are the reasons why the expected landfill gas (LFG) collection of 56 landfill CDM projects in March 2011 and their certified emission reduction (CER) of potentially 6.9 million t CO2eq under UNFCCC CDM [7, 8, 9] could not be realized.

MSW Incineration

Since 1988 MSW 93 incineration plants were built in China and the treatment capacity should cover about 10m/m% of the waste or 25 mn t/yr in 2010 [9]. But, due to various reasons, such as the low caloric value of the MSW, the insufficient flew gas emissions standard [5] and due to the lack of public acceptance, this capacity goal could not be reached. To overcome this problem in 2011 a new flue gas emission standard (draft EY2000/76/EEC) requesting a Dioxin limit value of 0.1 ng TEQ/m³ should come in force. Till 2020 the number of waste incineration plants should be 400 in cities and 200 in rural areas with a total capacity of 103 mn t/yr, which would mean about two third of the collected waste should undergo thermal treatment by be incineration [9].
Bioorganic Waste Treatment

The MSW composting has decreased during the last ten years significantly. The disregard of biotechnological process principles, a poor hardware and mixed MSW as input material led to a low quality end product, which was in turn not accepted by the users; even though clean organic fertilizers achieve good prices in cash crop eco-farming and horticulture.

The biogas generation potential of bioorganic municipal waste (BMW) from source separation pilot tests in Shenyang in Liaoning from 2006 till 2009 [10], was found high and the BMW suitable as feedstock or co-feedstock for biogas plants. The biogas can be used locally, but also for grid connected electric power generation, space heating, or as biogas respectively bio-methane for natural gas grid injection or vehicle use.

Until now, the agricultural sector has started to utilize organic wastes from animal farms and the agro industry for energy production. By 2009, 3,700 large scale biogas plants with a digester volume of >300m³ were built, with the target to set up 10,000 middle and large scale biogas plants till 2020. Together with the biogas from industrial wastewater 14 bill m³ shall be produced till 2020 and a grid connected power generation capacity of 3 GW should be available [11, 12]. The potential contamination of farmland by using municipal waste (MSW or BMW) as a feedstock or co-feedstock is still seen and used as an argument to not introduce co-fermentation, even though the level of pollution of BMW from households (kitchen waste from food preparation and leftovers) was found low [13]. Therefore MSW biogas plants are further under discussion and standards for emissions and effluents are required, which may affect the operation costs. During the 12th 5-Year Plan period until 2015 50 projects for anaerobic treatment of kitchen waste from restaurants with a capacity of 8,000 to 10,000 t/d shall be built in 33 cities [9].

Greenhouse Gas Emission Mitigation Through SWM of Municipal Waste

The new driver for waste management development in China is the reduction of greenhouse gas (GHG) emissions for a low carbon economy [15]. SWM has contributed to GHG emission reduction in Europe. Compared to the baseline with uncontrolled dumping the potential net savings per t of MSW are 1.7 t CO2eqv with landfilling and gas flaring, and 3.6 t CO2eqv if aerobic digestion is employed [14]. The EU-27 GHG reduction trends 1990 – 2006 and the projection 2010 shows [16] that SWM contributes the most to reduce emissions. The EU net GHG emission from SWM are declining from a peak of 55 mn t CO2eqv in the 1980s to an estimated 10 mn t CO2eqv by 2020 [17], as seen in Figure 1. Between 1990 and 2006, EU-15 greenhouse gas emissions from waste decreased by 39% and they are projected to decrease further to 45% by 2010.

Integrated Solutions to Approach a ‘Landfill Free’ SWM System in China

To meet the anticipated SWM targets, new concepts have to be applied. This includes the consideration of the bioorganic fraction of Waste (BMW) by anaerobic fermentation and biogas use.

Figure 1. Changes in EU-15 greenhouse gas emissions by sector 1990 - 2006 - 2020 [17]
BMW deriving from source separation leads to a clean compost or fertilizer suitable for soil application. The digester effluent from BMW processed in the way of mixed feedstock (with or without sewage sludge) can, after dewatering and biological drying, be landfilled or used as refuse derived fuel (RDF) [18]. To realize this concept the Chinese cement industry got the target to establish a MSW treatment capacity of 42 mn t/a in the 12th-FYP till 2015. Figure 2 shows a flow chart of such an integrated waste treatment model. The investment to build the capacity for 100,000 t/a in accordance with the international state-of-the-art will be about CNY200mn. Revenues from biogas [2], RDF, CDM and the waste fees from the cities, so far used to run the landfills, help to make these projects economically feasible.

![Figure 2. Integrated waste treatment model with RDF for the cement industry [2, modified]](image)

Conclusions

For the above mentioned reasons, disposing MSW by (i) engineered landfilling (incl. LFG collection and leachate treatment), by (ii) composting, (iii) incineration, (iv) gasification, and even (v) biogas production with upright fermenter systems, was not successful during the 11th-FYP period [1, 3]. Therefore the existing landfill capacities are running out and the set-up of new landfills, in particular in the eastern coastal provinces, are due to the available space limited. ‘Landfill-free’ solutions have to be approached.

The new SWM system may follow the following material streams: (i) 20-25m/m% as secondary row material recycled prior waste collection will remain [2]; (ii) the bioorganic matter in the residual MSW in China will stay high for the next decades [5] and 70% of the collected waste shall therefore be used to generate biogas (most likely in dry-fermentation or in combined systems); (iii) the biogas will, in line with the target of the Renewable Energy Law [1, 3] supply power to the grid; (iv) the fermenter residues from clean feedstock will be a valuable resource of organic matter and nutrients for soils in line with China’s soil protection efforts, and (v) not clean residues from MSW will, after biological drying and stabilization either be still disposed or used as construction material additive; (vi) the high calorific RDF fraction of about 20m/m%, but with 85% of the energy content [2,18] will be used as fuel for the industry, such as in cement kiln.

References

CO-DIGESTION OF TANNERY SOLID WASTE- CARBON TRADING OPPORTUNITIES IN LEATHER SECTOR

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ABSTRACT The leather industry has gained high socio-economic relevance in India and has contributed significantly to economic growth and it also provides job opportunities to millions of people. Nearly 2000 tanneries are located throughout India with a total processing capacity of 700,000 tonnes of hides/skins per annum. Around 500 kg of solid wastes will be generated per tonne of raw hides/skins processed. The process wastewater generated from tanneries are treated in common effluent treatment plants (CETPs) resulting in the generation of primary and secondary sludge with the volatile solids (VS) content of about 50 to 60%. Sludge disposal is a major concern in terms of protecting the environment. European Commission has introduced a landfill directive in 1999. According to the directive the total organic carbon (TOC) content in the waste to be dumped into landfill should be less than 5% from the year 2004. Similar or more stringent regulation may also arise in India in future. At present the primary sludge is being dumped into secured landfill facilities (SLF) after reducing the VS content. In order to utilize the sludge generated from CETPs and to reduce the cost of treatment towards sludge disposal, co-digestion studies were carried out. Primary and secondary sludge along with the fleshings - one of the biodegradable solid wastes generated during the leather process with VS content of 70-90%, was considered as one of the substrates for the co-digestion of tannery solid wastes. It was observed from the co-digestion studies that 24 kwh of bio-energy will be generated for processing one tonne of raw hides/skins processed per day. As part of recent developments in the implementation of Kyoto Protocol for reduction of Green House Gas (GHG) emissions into atmosphere, majority of waste to energy, biomass based bio-energy projects are nourished for implementation of Clean Development Mechanism (CDM) in many parts of the world. The present paper delineates the bio-energy generation during co-digestion of tannery solid waste, advantages of co-digestion studies and carbon trading opportunities during bio-methanation of tannery solid waste with reference to Indian scenario.

Keywords: Co-digestion, fleshings, Sludge, Bio-energy, Clean development mechanism (CDM), Carbon trading

Introduction

The leather industry has gained high socio-economic relevance in India and has contributed significantly to the economic growth and it also provides job opportunities to millions of people. Nearly 2000 tanneries are located throughout India with a total processing capacity of 700,000 tonnes of hides or skins per annum. Fleshings are one of the major solid wastes generated from tanning processes and 70 to 230 kg of fleshings are generated per tonne of raw hides and skins processed [1]. During early industry practices, fleshings were used in glue manufacturing processes whereas today many synthetic types of glues are commercially available. Hence, usage of fleshings in glue manufacturing process is seldom practiced. Since the demand is low, disposal of fleshings has become a major environmental concern.

For processing one tonne of raw hides or skins into finished leather, 30 to 50 m³ of wastewater and 175 to 225 kg of primary and secondary sludge will be generated. Sludge disposal is also a major concern in terms of protecting the environment. The cost of the sludge management comprises approximately 30-40 percent of the capital cost and about 50-55 percent of operation and maintenance cost of the tannery wastewater treatment. It has been observed that 60–65 percent of the solid waste generated from tanneries is predominantly biodegradable in nature Disposal into landfills is restricted to non-biodegradable, inert wastes and other wastes that are not suitable either for recycling or for biological processing.
In recent years, anaerobic co-digestion studies are gaining momentum due to the dilution of potential toxic compounds if any, improved balance of nutrients, synergistic effects of microorganisms and better biogas yield. Not only that, but also anaerobic co-digestion of the organic waste has the potential to contribute significantly to the reduction of the landfill disposal route as well as contribute significantly to the renewable energy budget [2]. Many researchers have carried out co-digestion studies using organic fraction of municipal solid waste (MSW) along with waste activated sludge (WAS) to enhance biogas generation [3-5]. In the present study, co-digestion was carried out for bio-energy generation using fleshing, primary and secondary sludge.

**Materials and Methods**

**Characterization of Fleshings and Sludge Samples**

The fleshings are the process solid waste generated during processing of raw hides/skins into finished leather. Fleshings samples were collected from a commercial tannery, situated in Chennai, India. Primary and secondary sludge samples were collected from common effluent treatment plant (CETP) exclusively operating for treatment of tannery wastewater situated in Chennai, India. Fleshings, primary and secondary sludge samples were characterized for pH, total solids, volatile solids, as per procedures given in Standard Methods 20th edition - APHA, 1998 [6]. Also moisture and fat content were analyzed in fleshings samples [6]. Elemental analysis was carried out using Elemental Analyzer, (CHNS-O, Model- Euro EA 3000, Euro Vector Spa, Via Tortona, Milan, Italy).

**Experimental Set-up for Anaerobic Digestion**

Co-digestion experiments were conducted in batch reactors in 650 mL glass bottles. Inoculum was obtained from an anaerobic digester operating for the digestion of waste activated sludge (WAS). Substrates selected for co-digestion studies were (i) fleshings, a process solid waste and (ii) primary and secondary sludge (PS and SS) generated during the treatment of tannery wastewater. After adding the substrates and inoculum, the reactors were closed with a rubber cap and an aluminum seal to make them air tight. Nitrogen gas was purged at the rate of 15 mL per second for 25 minutes into the reactors to remove oxygen and to maintain anaerobic conditions. The co-digestion studies were carried out with an inoculum to substrate ratio of 1:1 with a total volatile solids input of 5 g with varying proportions of fleshings (F), primary sludge (PS) and secondary sludge (SS). Details of substrate input for co-digestion studies are presented in Table 1.

<table>
<thead>
<tr>
<th>Reactor</th>
<th>Mix proportions of Substrates (based on VS)</th>
<th>Total input of Volatile Solids (grams)</th>
<th>Residence Time (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fleshings (F) (grams)</td>
<td>Primary Sludge (PS) (grams)</td>
<td>Secondary Sludge (SS) (grams)</td>
</tr>
<tr>
<td>R1</td>
<td>2.5</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>R2</td>
<td>2.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>R3</td>
<td>3.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Biogas generation from the reactors were monitored by means of a water displacement method based on Mariotte principle (i.e., the volume of water displaced is equivalent to volume of biogas generated) [7]. To measure biogas, 650 mL glass bottle was filled with water and closed with a rubber cap and aluminum seal to make it air tight. Schematic diagram for typical experimental set-up for co-digestion studies is depicted in Figure 1.
The methane content present in the biogas was analyzed using a Thermo Scientific Cerus 800 model gas chromatography (GC) fitted with thermal conductivity detector (TCD) and a 1.83 m x 3.18 mm ID stainless steel packed column with molecular sieve of 5A. The oven, injector and detector temperatures were kept at 50° C, 70° C and 200° C respectively. Helium was used as carrier gas at a flow rate of 2 mL/ minute.

At the end of residence time of 6 weeks i.e. biogas generation ceased and digestate was characterized for undigested volatile solids (expressed in percent) and also volatile fatty acids (VFA). VFA was measured with the help of GC fitted with flame ionization detector (FID) and a capillary column of 0.32 mm ID and 60 m length. The oven, injector and detector temperatures were kept at 110° C, 180° C and 220° C respectively. Helium was used as carrier gas at a flow rate of 2 mL/ minute with split ratio of 1:10.

Results and Discussion

Characterization of Fleshing and Sludge Samples

Typical characteristics of substrates i.e., fleshings, primary and secondary sludge samples are given in Table 2.

From the elemental analysis of C, H, N S and O of the fleshings, the chemical formula for the fleshings was obtained as: C_{66}H_{9}N_{19}SO_{66} and C/N ratio of 3.53, primary sludge C_{8}H_{N_{2}}S_{4}O_{20} and C/N ratio of 6.77 and for secondary sludge C_{8}H_{N_{2}}S_{4}O_{20} and C/N ratio 4.99.

Anaerobic Digestion

In batch reactors, anaerobic co-digestion studies were carried out to assess biogas generation. Biogas generation was monitored on daily basis. Biogas generation at the end of every week is presented in Table 3.

It was observed from the studies that, for the volatile solids input of 5 g, variations in biogas generation were observed based on characteristics of substrates added. It was observed from the Table 3 that, in reactor R1, where equal proportions of fleshings and mixture of sludge was co-digested, biogas generation of 230 mL per gram of VS added was observed whereas in reactors R2 and R3, biogas generation was 308 and 408 mL per gram of VS added was observed. The reason for more biogas generation in R3 reactor for the same volatile solids input of 5 g is due to addition of fleshings i.e. lipid rich waste. Secondary sludge primarily consists of biomass and extra cellular polymeric substances (EPS) which is difficult to degrade and also requires more residence time in reactors for degradation. Hence the co-digestion of tannery solid waste reveals that to enhance biogas generation, optimization of mix proportions of substrates is necessary. From co-digestion studies, 230 to 408 mL of biogas was generated per gram of VS added with methane content of...
65 to 70 percent was observed from gas analysis. From digestate analysis 32, 45 and 54 percent of volatile solids digested in R1, R2 and R3 reactors and at the end of digestion period volatile fatty acids were 32.5, 11.4 and 8.4 meq/L respectively.

Table 2. Characteristics of Substrates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Fleshings</th>
<th>Substrates</th>
<th>Substrates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Primary Sludge</td>
<td>Secondary Sludge</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>11.0</td>
<td>8.4</td>
<td>7.62</td>
</tr>
<tr>
<td>Moisture content</td>
<td>Percent</td>
<td>84.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total solids</td>
<td>mg/g on wet weight basis</td>
<td>15.88</td>
<td>91.66</td>
<td>15.44</td>
</tr>
<tr>
<td>Volatile solids</td>
<td>mg/g on wet weight basis</td>
<td>14.19</td>
<td>41.62</td>
<td>6.75</td>
</tr>
<tr>
<td>Fat content</td>
<td>Percent on wet weight basis</td>
<td>2.93</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C, H, N, S, O analysis data on dry solids basis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>(%)</th>
<th>Fleshings</th>
<th>Substrates</th>
<th>Substrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Content</td>
<td>40.97</td>
<td>28.21</td>
<td>22.23</td>
<td></td>
</tr>
<tr>
<td>Nitrogen Content</td>
<td>11.63</td>
<td>4.17</td>
<td>4.62</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Content</td>
<td>5.79</td>
<td>3.51</td>
<td>2.94</td>
<td></td>
</tr>
<tr>
<td>Sulphur Content</td>
<td>0.62</td>
<td>13.29</td>
<td>12.23</td>
<td></td>
</tr>
<tr>
<td>Oxygen Content</td>
<td>40.98</td>
<td>50.82</td>
<td>57.99</td>
<td></td>
</tr>
<tr>
<td>C/N ratio</td>
<td>3.53</td>
<td>6.77</td>
<td>4.99</td>
<td></td>
</tr>
<tr>
<td>Chemical formula</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>C_{66}H_{99}N_{19}SO_{66}</td>
<td>C_{8}H_{NS_{4}}O_{14}</td>
<td>C_{8}H_{N_{2}}S_{4}O_{20}</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Monitoring of biogas generation

<table>
<thead>
<tr>
<th>Reactor</th>
<th>VS added (grams)</th>
<th>1st week</th>
<th>2nd week</th>
<th>3rd week</th>
<th>4th week</th>
<th>5th week</th>
<th>6th week</th>
<th>Total biogas generated (mL)</th>
<th>Biogas generated (mL/gram of VS added)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>5.0</td>
<td>354</td>
<td>359</td>
<td>140</td>
<td>114</td>
<td>95</td>
<td>92</td>
<td>1154</td>
<td>230</td>
</tr>
<tr>
<td>R2</td>
<td>5.0</td>
<td>673</td>
<td>547</td>
<td>159</td>
<td>74</td>
<td>64</td>
<td>25</td>
<td>1542</td>
<td>308</td>
</tr>
<tr>
<td>R3</td>
<td>5.0</td>
<td>624</td>
<td>657</td>
<td>382</td>
<td>205</td>
<td>110</td>
<td>60</td>
<td>2038</td>
<td>408</td>
</tr>
</tbody>
</table>

Studies on Potential Carbon Trading Opportunities from Tanning Industry

As a result of Kyoto Protocol signed in the Year 1997, carbon has become a tradable commodity with an associated value under Clean Development Mechanism (CDM) that has emerged as a business mechanism under the Kyoto Protocol. Based on co-digestion studies it was found that, total biogas generation was estimated 7.98 x 10^6 m^3 per annum, which is equivalent to 5.6 x 10^6 m^3 per annum of methane. The calorific value of methane per m^3 is equivalent to 8580 kcal and will generate nearly 16800000 kwh energy per annum. This energy can be utilized for operation of the CETP.
Secondly Global warming potential (GWP) is a measure of the relative effect of Green House Gas emissions compared to Carbon-di-oxide emissions. As discussed in UNFCC document one tonne of methane emissions are equivalent to 21 tonnes of Carbon-di-oxide emissions [8]. Expected methane gas generation from the co-digestion of tannery solid waste was arrived as 7.98 x 10^6 m^3 per annum, which is equivalent to 118 million tonnes of Carbon-di-oxide emissions per annum. Hence Co-digestion of tannery solid waste is a Clean Technology initiative for promotion of energy recovery from wastes and reduction of methane gas emissions into the atmosphere.

Conclusions

At present primary sludge is being dumped into secured landfill facilities (SLFs) after reducing the VS content whereas secondary sludge and fleshings are not allowed for disposal into SLFs. During co-digestion of tannery solid wastes, the maximum biogas generation of 408 mL was observed with F: PS: SS in the ratio of 3.0:1.0:1.0. Optimization of mix proportions of primary and secondary sludge also plays a major role in generation of biogas wherein addition of more proportion of secondary sludge resulted in generation of less biogas. Secondary sludge primarily consists of extra cellular polymeric substances (EPS) which is difficult to degrade and also requires more residence time in reactors for degradation.

The potential of bio-energy generation and green house gas emission reductions from tanning industry for total processing capacity of 700000 tonnes per annum was estimated as 16.8 x 10^6 kwh and 0.3 million tonnes of Carbon-di-oxide equivalents per annum respectively. However in India, for demonstration purpose, pilot scale plants have been installed for bio-energy generation from tannery solid waste and the momentum has gained. Apart from bio-energy generation, co-digestion of tannery solid waste has potential in carbon trading opportunities. Ministry of Environment and Forests (MoEF), Govt. of India has taken initiatives to fund projects which are falling under the category of implementing Clean Development Mechanism (CDM). To reduce green house gas emissions into the atmosphere, the Indian Tanning industry can also get benefits from tapping bio-energy and carbon credits under CDM.

Acknowledgements

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References

CO-COMPOSTING OF PALM OIL MILL WASTE AND WASTE WATER – A POWERFUL PROCESS TO REDUCE GREEN HOUSE GAS EMISSIONS

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ABSTRACT In palm oil mills the residues from the production process, dumped Empty Fruit Bunches (EFB) and stored Palm Oil Mill Effluent (POME) in anaerobic ponds, are responsible for emissions of green house gases (methane and laughing gas). Co-composting of EFB and POME in open windrows is the only alternative to treat both in a sustainable way. In a life cycle assessment (LCA) the Global Warming Potential (GWP) of conventional EFB and POME treatment and of co-composting, with and without biogas production from POME, was determined. The GWP of palm oil mill waste treatment can be reduced from 245 kg CO2eq per t FFB (worst case: POME in anaerobic ponds, dumping of EFB) up to 6 kg CO2eq per t FFB (co-composting of EFB and POME, biogas from POME at CH4 losses <2%) due to reduced methane emissions and nutrient recycling. Co-composting of EFB and POME is a profitable way to use the nutrients from both POME and EFB.

Keywords: Palm oil, Waste; Waste water, POME, EFB, Co-composting, LCA

Introduction

With an annual production of about 42 million t palm oil is the most important vegetable oil in the world. It can be used as edible oil, in chemical, pharmaceutical and cosmetic industry, for energy production and as biofuel. The oil palm plantation area in the main production countries Indonesia, Malaysia, Thailand, Columbia and Papua New Guinea is about 11 million hectare. A duplication of that area is expected until 2050, because of growing world publication and growing per capita consumption. At the production of 1 t of palm oil 1.2 t of waste (Empty Fruit Bunches, EFB) and up to 3.25 m³ of waste water (Palm Oil Mill Effluent, POME) accumulate. Whereas the fruit wastes, mesocarp fibres and kernel shells, are used as energy source in the oil mill, POME is treated in open anaerobic ponds and EFB is dumped or used as mulch in plantation. These residues cause considerable environmental burdens, particularly greenhouse gas (GHG) emissions (methane and laughing gas).

Materials and Methods

To calculate the environmental impacts of POME and EFB treatment a detailed life cycle model has been used. The options under investigation are:

(1) Dumping EFB and storing POME in ponds,
(2) Returning EFB to the plantation and POME as before,
(3) Using EFB and POME for co-composting and returning the produced compost to the plantation,
(4) Generating biogas from POME and thereafter as in (3).

The CML 2001 method included in the GABI 4.3 software package has been used for the impact calculations (PE Europe 2003). The scale basis for the calculations is 1 t of Fresh Fruit Bunches (FFB).

Results and Discussion

A new process for co-composting of EFB and POME in open windrows (EcoEFB™) is an alternative to treat the waste and the waste water and to produce an organic fertilizer with the nutrients from both, figure 1 [1, 2, 3, 4]. The process leads to a considerable nutrients recovery, additionally to GWP reduction. Thus the composting process reduces not only environmental burdens; it leads to net environmental benefit regarding most environmental impact categories, e.g. acidification potential, eutrophication potential, ozone layer depletion potential, etc. due to the avoided emissions from inorganic fertilizer production.
Due to the low bulk density of the chopped EFB (0.3 t/m³) and high air and windrow temperature for several weeks a huge amount of water, which is added step by step, can be evaporated, figures 2 and 3. In practice the relation between EFB and POME is 1 to 2.7. The open windrows are turned frequently 2 to 3 times a week. After 6 to 10 weeks a mulch or compost is ready for application in the oil palm plantation or for other crops. With pay back times of one to three years the process is profitable.

The main sources of GWP are from the composting process itself are the methane and laughing gas emissions from the biological activity in the windrows, figure 4. The emissions from the diesel fuel consumption of the windrow turner and the transport by a wheel loader in the composting plant are negligible. The electricity for the chopping machine is produced by the oil mill itself.

Under “good practice” conditions, regularly turning of the windrows and no overloading with waste water, the total GWP from the composting plant is 16.6 kg CO2eq/t FFB minus the credits for saved fertilizers and, for alternative 4, for biogas. Finally the GWP is 7.4 and 6.2 kg CO2eq/t FFB resp., for the alternatives 3 and 4, figure 5.
Figure 5. Global warming potential of EFB- POME co-composting with and without previous biogas generation from POME

Compared to conventional practice in palm oil mills to treat the waste water and waste, the GWP reduction by co-composting is about 97%, figure 6.

Figure 6. Global warming potential of EFB- POME co-composting for conventional practice in palm oil mills and for co-composting of EFB and POME

Even at poor managed composting plant the GWP is lower than in conventional mills, as shown in figure 7.

Figure 7. Global warming potential of EFB- POME co-composting (good practice: CH₄ losses 1% of C_{tot}, N₂O losses 0.5% of N_{tot}; poor practice: CH₄ losses 5% of C_{tot}, N₂O losses 5.0% of N_{tot})
Conclusions

A life cycle based comparison of conventional and advanced treatment systems for EFB and POME can support decision makers regarding waste treatment options and provide information on technology risks involved. The results of this study may be used as basic calculation data for CDM (Clean Development Mechanism) for palm oil mills. LCA is shown to be a powerful tool to estimate and compare environmental impacts of different options. Unfortunately it is rarely used in the palm oil industry in order to improve or optimise palm oil production systems. It can be shown that nutrient recovery from POME and EFB offers considerable environmental and economic benefits to palm oil production systems. However, using EFB for energy production, as it is discussed and realized by some palm oil mills prohibits environmental beneficial POME utilisation.

The co-composting of EFB and POME is

- profitable
  - by saving mineral fertilizer
  - by higher yields of oil
  - by CO₂ credits (CDM)
- environmental friendly
  - by reduction of green house gases and smell and other environmental impact categories
- socially acceptable
  - by new jobs in the composting plant

References


ESTABLISHMENT OF AN ECO-WASTE CENTER AT BARANGAY VALLEY, ORMOC CITY, LEYTE, PHILIPPINES

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ABSTRACT

With the enactment of Republic Act 9003, the Philippines provided the needed legal framework to address environmental problems caused by improper waste management. However, due to lack of funds and expertise, so far only some municipalities were able to comply with the legal requirements. Ormoc City is one of the few Local Governments that developed and implemented an Integrated Solid Waste Management system (ISWM). A main component of the new system is a Sanitary Landfill (SLF) to provide safe waste disposal. This paper summarizes challenges and experiences made during planning and construction of a clay lined SLF.

Keywords: Integrated solid waste management, Sanitary landfill, Clay liner construction

Introduction

To tackle the numerous environmental issues related to Municipal Solid Waste Management, the Philippines issued the Republic Act 9003 (RA 9003), also called Ecological Solid Waste Management Act of 2000. This Act and its related administrative orders and regulations define specific minimum standards and recommend appropriate measures for the safe management of waste. One main component of the Act is to implement safe waste disposal systems. RA 9003 demanded the closure of open dumpsites and established new SLFs by 2006. However, only a few municipalities have complied with the legal requirements so far. According to the National Solid Waste Management Commission, only 30 SLFs were constructed as of 2009, whereas 1,234 open and controlled dumpsites still operate in the country at present (http://emb.gov.ph/nswmc/eswmfacilities.aspx). As a result, various environmental problems related to uncontrolled waste disposal such as surface water and ground water contamination, gas and odour emissions, as well as health hazards remain as major issues and may only disappear by consequently implementing the law.

Development of an Eco-Waste Center (CEC) in Ormoc City

Ormoc is located in the Province of Leyte, in the Eastern Visayas. This region is characterized by comparable high amounts of rainfall, in average 2,500 mm/a, more or less evenly distributed throughout the year (type IV climate zone of the Philippines). A not pronounced dry season1 is denoted from March to June. Ormoc City is a 1st class, independent component city (income ≥ 90 Mio US-$), with a population of about 177,000 (2010) and a land area of 464 km². The City is divided in 39 urban and 71 rural Barangays (smallest administrative unit in the Philippines). The main economic activities related to agriculture (rice, sugarcane, pineapple and coconut) but also Geothermal Power Plants, supplying energy to many parts of the country, thus contributing significantly to the economic growth of the city.

The waste collection organized by the city takes place in 63 Barangays. However, in the rural barangays only households that are close to the highway receive a collection service. Hence, some residents have no access to it. Considering an average waste generation rate of 0.4 kg per person/day and the estimated served/not served population numbers of respectively 84,800 or 91,470 persons the waste amounts can be calculated. The total waste generation for Ormoc is estimated with approx. 71 t of waste/day from which 34 tons are collected by the City. Although not all waste is collected at the moment, the collection rate of 48% is quite high compared to other cities in the Philippines.

1 dry month ≤50mm/month including ≥100mm/month after 3 or more dry months
With support of German International Cooperation (GIZ) Ormoc City developed an Integrated Solid Waste Management system (ISWM) to handle its waste in a proper way and to comply with legal requirements.

Considering the waste composition of the City (Fig. 1) the proposed ISWM system includes the segregated collection of waste and the separate treatment of different waste fractions at the City Eco-Waste Center at Barangay Green Valley. While biodegradable wastes are to be composted in a Material Recovery Facility (MRF), residual wastes are processed in a sorting facility to take out the 9% remaining recyclables. Furthermore, a biological stabilization process (BS) is proposed prior to waste disposal at the new SLF, which will be the first to be operated in Region 8, the Eastern Visayas.

Discussion of Sanitary Landfill Planning and Construction

Initial Planning of the Sanitary Landfill

The planning and construction of the SLF in the CEC was a major challenge for the City. Like in many comparable cases in the Philippines, the site selection was based more on availability rather than suitability, resulting in an area with suitable geology (bentonitic to calcareous shale, K-Value =10x10^{-7} cm/sec as stated in the geological study conducted by the Mines and Geoscience Bureau) but with complex hilly topography and changes in elevation to up to 20 m. Hence, accurate planning and construction management was of uppermost importance in order to minimize excavation works and related construction costs. Likewise, the development of a first landfill cell with 1.8 hectare was a challenging task considering the local weather conditions with regular occurring, heavy rainfalls. As required by law, it was decided to establish a clay lined landfill using the locally available host clay, as its permeability meets the prescribed legal standard. The thickness of the clay liner was planned with 0.75m overlain by a 0.15m sand protection layer and a 0.20m gravel drainage layer. The lateral slope of the V-shaped cell is 2.5%. Due to the topography of the area the longitudinal slope of the cell is quite steep with 10%. The comparable high annual rainfall in the region also demanded detailed planning of the leachate treatment facility with sufficient buffer capacity, especially within the receiving water storage lagoons.

Adjustments Due to Pseudo-gley Horizon

As in most infrastructure projects, adjustments had to be made during construction works to cope with changing field conditions. During excavations works the soil horizon in the area was identified as pseudo-gley. Typical for this type of soil formation is the poor drainage of rain water, leading to periodic or permanent waterlogging. This phenomenon was observed several times at site during the rainy season. Consequently, storm water canalization had to be revised and improved to minimize the infiltration of water.
and to avoid water accumulations below the SLF. Besides, to further reduce water infiltration, as well as for erosion control, open areas needed to be closed. Cococoir was used for this purpose, as it offers a feasible (unit costs of approx 0.8 US$/m²), locally produced and natural protection for soils, already known from disaster management projects in the area. An enhancement of such erosion protection can be achieved with suited vegetation: vetiver grass (http://www.vetiver.org) and perennial peanut (arachis glabrata). A further consequence related to the pseudo-gley horizon is that those soils, due to longer waterlogging, showed a higher permeability than the upper soil samples and could therefore not be used for the clay liner as planned.

Rain as a Limiting Factor for Landfill Construction

Since LGU Ormoc City decided to establish a clay lined landfill of a significant size, the rainy season had to be considered as an important limiting factor for construction works. The construction time for application of all layers of the liner (subsoil preparation, clay, sand and gravel) was estimated with more than 6 months. According to the results of the soil analysis, the moisture content of the host clay in Ormoc should be 30% to achieve the permeability required by the law. This implies that the clay needs to be dried after rainfalls until this moisture content is reached. To be able to finalize the construction in only one dry season period (four months), several possibilities were considered. One option was the development of half of the cell (0.9 ha) with an extra drainage for rain water from the undeveloped part of the cell. Furthermore, the application of HDPE liner as clay substitute was taken into consideration. Costs for the purchase and installation of the HDPE liner were calculated at 14.8 US$/m², while the costs for the clay liner (0.75m @ 1.8ha) were estimated with 12 US$/². For an area of 1.8ha this difference of almost 3US$/m² means significant higher costs of almost 49,000 US$ but also offers considerable savings in terms of time and space. The project implementation with clay liner alone (0.75m @ 1.8ha) would have taken more than 4 months, whereas for the HDPE liner 30-40days are needed.

Conclusions

Despite major challenges during planning and construction, especially due to a prolonged rainy season, LGU Ormoc City is on its way to finalize an engineered landfill. Our experience may serve as example for other landfill planners and for settings with comparable weather/soil conditions and especially applicable to most areas in the Eastern Visayas, Philippines. The presented paper underlines not to underestimate the construction efforts and time needed for the implementation of a clay liner and to consider limitations and constraints when working for liner construction. It is recommended to clarify such aspects during the site selection process in order to reduce risks, time and costs for the grading and levelling works at an early stage of project development.

References


22 Costs/m² were calculated dividing the total costs by the 1.8ha area and using an av. exchange rate of 43PHP : 1 US$
EVALUATION OF E-WASTE GENERATION POTENTIALS IN METRO CEBU, PHILIPPINES

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ABSTRACT In January 2001, the Congress of the Philippines released Republic Act 900, with the main target to enhance municipal Solid Waste Management (SWM) systems. Although RA 9003 contains various prescriptions to improve material recovery and waste disposal, the management of electronic waste (EWM) was not foreseen. Nevertheless, electronic goods import and application steadily increase also in the Philippines, whereas industrial, commercial and municipal sectors are hardly prepared for EWM yet. Hence, a large portion of E-waste either ends up at local dumpsites or is recovered by the informal sector without needed knowledge and tools to dismantle electronic equipment in a proper manner. The presented study aims to clarify E-waste generation potentials for Metro Cebu, an urban conglomerate with around 1.6 Mio inhabitants located in the central Philippines, the Visayas region. The assessment of E-waste generation focused on households, whereas this research distinguished between low-, middle- and high income households, but also considered E-waste generation from industrial, institutional and commercial sectors.

Keywords: E-waste, Generation assessment, Resources recovery, Informal sector involvement

Introduction

Imports and utilization of electronic goods steadily increase in the Philippines as well as in many other countries. The increase is exacerbated by the liberalized import of various surplus and used electronics goods for household use. Presently, there are two legislations applicable in the Philippines that selectively define wastes from electronic goods. The Republic Act 6969, also called Toxic Substances and Hazardous and Nuclear Wastes Control Act of 1990 that specifies solid wastes containing hazardous components as part of the hazardous waste stream. This law also controls the importation of recyclable materials containing hazardous substances but yet with economic value for recovery, recycling and reprocessing purposes. Republic Act 9003 classifies electronic waste as Special Waste that needs to be handled and disposed separately from other municipal wastes. This law also mandates the implementation of enhanced municipal SWM systems for all municipalities. Although these two legislations provide various useful prescriptions and tools to improve material recovery and waste disposal, a separate E-Waste Management (EWM) was not foreseen. Metro Cebu is the largest urban area in the Visayas and considered as an important technology hub to serve the southern part of the Philippines. This is underlined by the presence of export processing zones, numerous call centers and booming IT sectors. Metro Cebu includes the component cities Mandaue, Lapu-Lapu, Cebu and Talisay with a total population of around 1.6 Mio inhabitants in 2005. Up to date, no state of the art recycling facility for EWM is established in Metro Cebu.

Materials and Methods

Methodology

The E-waste survey was conducted from January to December 2010 using official information from various governmental agencies that regulate imports and exports, such as the Bureau of Customs (BOC) and the Environmental Management Bureau (EMB) as well as from the National Statistics Office (NSO). For the households, it was assumed that the various equipments are ubiquitous such as small and large household appliances, television sets and computers, telecommunication equipment, electronic tools, lighting equipment, electronic goods for entertainment, toys and leisure, medical devices, monitoring and control instruments and automatic dispensers. The evaluation of E-waste generation was based on field interviews and surveys conducted for representative sample households, which distinguished between low-, middle- and high income households [1]. Information on the survey questionnaire included: a) type and number of electronic products in households; b) acquisition and purchase manner; c) practices and management of discarded equipment, and d) disposal options.
According to the *Comparative Income Profile and Percentage Distribution* published by the National Statistics Office (NSO) 76.6 % of all households in the Philippines are classified as Low Income Group (LIG) with income < 190 US-$/month, 23 % fall in the Middle Income Group (MIG) with monthly incomes in the magnitude of > 190 to < 1,200 US-$/month whereas only 0.4 % are classified within the High Income Group with monthly incomes > 1,200 US-$ [2]. Calculations for the annual E-waste generation are based on the *E-Waste Assessment Methodology* used by Swiss Institute for Material Science and Technology [3,4]. This method determines the empirical volume of waste generated from sources taking into account the results of the survey, the average weight of equipments, medium life span and average saturation rate.

**Limitations of the Survey**

It was found that official data and statistics from governmental agencies regarding the E-waste sector are not completed yet and hence could not be used for this study. Inventories on imports and trading of used electronic products may be available from few scrap buyers, consolidators and importers that are accredited by EMB since they are required to submit regular reports. However, provided data do not represent a whole picture of the E-waste sector. Besides, in most municipalities a significant number of scrap buyers and importers operate, but they are not accredited. Furthermore, Waste Characterization Studies (WACS) conducted by Local Government Units (LGU) do not specify electronic waste individually but rather integrate them into the categories Hazardous or Special Wastes, which also includes other types of special wastes.

**Results and Discussion**

Households generally tend to dump materials if reuse or recycling options are not available as a common mode of solid waste management. So far, E-waste is considered as Special Waste in most LGUs and hence considered as a minor waste fraction of far less then <1 % of the municipal solid waste stream [5]. This perception may be the reason for low awareness of law makers and local decision makers that E-waste issues may drastically increase within the near future. The NSO conducted a survey for electronic equipments in households in 2004 [6]. Based on their findings around 14.6 Mio households or 87.6% of the 16.6 Mio households in the Philippines rely heavily on electricity for lighting and for running household appliances such as refrigerators, entertainment equipment, gas range and air conditioning units. Data from the National Telecommunication Commission (NTC) for 2007 showed that the total cellular mobile phones subscribers are around 53.7 Mio in the country, which is 15 times higher than subscribers from fixed phone connections [7]. The following table summarizes the findings of the conducted household survey for E-waste generation potentials in Metro Cebu for the year 2010.

<table>
<thead>
<tr>
<th>Table 1. Results of the E-Waste assessment of various household groups in Metro Cebu</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Potential E-waste generation Metro Cebu</td>
</tr>
<tr>
<td>E-waste/person/year, kg/year</td>
</tr>
<tr>
<td>E-waste/person/day, kg/day</td>
</tr>
<tr>
<td>Percentage population/category, %</td>
</tr>
<tr>
<td>Population per category (Total in 4 cities = 1,589,273)</td>
</tr>
<tr>
<td>B. Total E-waste generation (baseline 2010)</td>
</tr>
<tr>
<td>Large equipment (TV, ref, aircon)</td>
</tr>
<tr>
<td>Entertainment &amp; leisure</td>
</tr>
<tr>
<td>Tools</td>
</tr>
<tr>
<td>Office</td>
</tr>
<tr>
<td>Medical devices</td>
</tr>
<tr>
<td>Communication</td>
</tr>
<tr>
<td>Cooking &amp; laundry</td>
</tr>
<tr>
<td>TOTAL E-waste, MT/year</td>
</tr>
</tbody>
</table>

*L-low, M-mid, H-high; IG-income group; average household size for all household categories is 5.1
Based on this research a significant high E-waste generation potential of 34,600 tons/year is estimated for Metro Cebu alone from households, which translates to 95 tons/day respectively 21.6 kg/cap/year.

Conclusions

As in many other countries, E-Waste generation emerges as a new SWM issue in the Philippines. Presently, most of E-Waste either ends up at local dumpsites or is treated by the informal sector, whereas the latter lacks expertise to perform EWM in a proper manner. The conducted research reveals a significantly high potential for future E-Waste generation in Metro Cebu, whereby the households itself have to be considered as main E-Waste generators. It is estimated that the 1.6 Mio residents of Metro Cebu alone generate 34,600 tons E-Waste/year, which translates to up to 21.6 kg/cap/year. Additional E-Waste has to be expected from industrial and commercial sectors. The huge E-Waste potential offers various options for the local recycling sector, but also to integrate the informal sector into new, lucrative business opportunities. However, to clarify roles and tasks of involved stakeholders and to provide standard procedures it is recommended to develop a local ordinance for EWM first.

Acknowledgements

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References

AIR POLLUTION FROM MUNICIPAL SOLID WASTE TRANSPORT: A CASE STUDY OF TRICHY, TAMIL NADU, INDIA

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ABSTRACT Municipal solid waste includes commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes. Transport of municipal solid waste is one of the essential functional elements of solid waste management. This element involves two steps: i) the transfer of wastes from the smaller collection vehicle to the larger transport equipment; ii) the subsequent transport of the wastes, usually over long distances, to a processing or disposal site. In this connection a study has been made to estimate air pollution from municipal solid waste transport haulage sector for Trichy city of South India. Trichy is Tamil Nada’s fourth largest city after Chennai, Madurai and Coimbatore with an estimated population of 1,067,915 (as of 2008). More population results in the increased usage of the resources, which ultimately leads to the generation of more solid waste. Ariyamangalam dumping yard is the only dumping yard in the city, with a capacity of 12 lakh tonnes of solid waste. At least 350 tonnes is added every day with the help of transportation sector, which intern results in release of considerable amount of air pollutants in to the environment. This study was carried out to know the concentration of air pollutants released by transportation of solid waste from different parts of city to the dumping yard. Three parameters, Suspended particulate matter, Sulphur dioxide and Oxides of nitrogen were considered in our present study. High volume sampler has been used to know the concentrations of above said three parameters.

Keywords: Municipal solid waste, Transport, Trichy

Introduction

Tiruchirappalli is a home to several historic temples, monuments, churches and mosques. The present Uraiyyur, which was old Tiruchirappalli, is a town of heritage value with over 2500 years of known history, and was the capital of the early Cholas. The oldest dam Kallani (Grand Anaicut) was built by King Karaikala Chola across the Cauvery about 10 miles from Uraiyur. It was an important town in the days of early Cholas, Nayaks and as well as during the early days of the British East India Company. The conquest of Tiruchirappalli by the British east India Company marked a major step in the British conquest of India. Mr. John Wallace, District Collector in 1801, formed Tiruchirappalli district. The district was then under the rule of British for about 150 years till the independence of India. The fort was one of the main centers around which the Carnatic wars were fought in the 18th century (Tiruchirappalli City Corporation, 2007). Tiruchirappalli is Tamil Nadu’s fourth largest City after Chennai, Coimbatore and Madurai with an estimated population of 1,067,915 (as of 2008). It is situated in the centre of the state; on the banks of the Cauvery River. Tiruchirappalli is a Municipal Corporation and the administrative headquarters of Tiruchirappalli district. Ariyamangalam dumping yard has a capacity for 12 lakh tonnes of solid waste. On average 350 tonnes per day of municipal solid waste transported from the Tiruchirappalli city to the Ariyamangalam dumping yard situated at the outskirts of the city. Therefore municipal solid waste transportation in addition to waste disposal is major contributor to urban air pollution in Tiruchirappalli city. In this context air samples of three air quality parameters Suspended Particulate Matter (SPM), Sulphur dioxide (SO2) and Oxides of Nitrogen (NOx) were considered for the studies. High volume air sampler Envirotech APM430 was used to measure these three air quality parameters.

Municipal Solid Waste Transportation System in Tiruchirappalli City

Transportation of wastes collected forms crucial part of the waste management programme. In India, no single mode of transportation has proved effective and economical due to various constraints encountered like narrow streets, dense population, unorganized dumping, poor quality of waste generated, etc.
Hence it is quite essential that various types of vehicles be used for effective waste transportation. The type of vehicles used in TCC range from primitive hand carts to most modern mechanized Dumper Placer and Compactors. Table 1 shows types of vehicles used in TCC for secondary transportation of MSW.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Type of the Vehicle</th>
<th>Nos.</th>
<th>Waste Carrying Capacity (Tons)</th>
<th>No of Trips / Day</th>
<th>Total Vehicle Capacity (Mt)</th>
<th>Actual carrying capacity (mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lorry</td>
<td>6</td>
<td>5.0</td>
<td>3</td>
<td>90</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>Tractor(2)</td>
<td>2</td>
<td>2.0</td>
<td>3</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Trailer (4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Mini-Lorry</td>
<td>8</td>
<td>2.5</td>
<td>3</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>Dumper</td>
<td>10</td>
<td>2.0</td>
<td>10</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Tipper</td>
<td>22</td>
<td>4.0</td>
<td>3</td>
<td>264</td>
<td>132</td>
</tr>
<tr>
<td>6</td>
<td>Auto</td>
<td>16</td>
<td>0.5</td>
<td>5</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>Compactor</td>
<td>1</td>
<td>7.0</td>
<td>3</td>
<td>21</td>
<td>10.5</td>
</tr>
<tr>
<td>8</td>
<td>Tractor</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Dozer Cum Backhoe Loader</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Bulldozer</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>Excavator Cum Loader</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>68</td>
<td>-</td>
<td>-</td>
<td>547</td>
<td>273.5</td>
</tr>
</tbody>
</table>

Source: Tiruchirappalli City Corporation, 2008

Smaller capacity vehicles are utilized for waste transportation from collection points to Sub centers. Bigger vehicles (Tractor, Tipper Lorry, etc.) transport the wastes from Sub-centers to Ariyamangalam Dumping Yard.

**Private Initiatives**

Pay and use toilets and bathrooms have been privatized in Central Bus stand, Chatiram Bus stand and Gandhi Market and have been leased to a NGO called “AWAKES”. The same NGO is engaged in the task of sweeping and collection of garbage in the above locations and surrounding roads. “KALAI EXNORA” the NGO (otherwise called kalki charitable trust) is also involved in the sweeping and collection of refuse in the ward no. 17, 18 and 31. This NGO is collecting Rs.10 from each households and shop. Trichy District “EXNORA” promotes Door to door collection of garbage in residential areas through various Civic EXNORAs functioning in the City/Municipalities/Panchayats. The main aim of the EXNORA is spreading awareness of rainwater harvesting, source segregation of garbage, garbage to manure, minimization of use of plastics and conservation of water as well as all other resources like electricity, etc., motivating college/school students to maintain their environment clean and green and implementing Solid Waste Management and Waste Water Management in their college/school premises.

**Waste Processing and Disposal**

Tiruchirappalli City Corporation owns 47.70 acres of land in Ariyamangalam village situated along Trichy – Thanjavur Main road at a distance of 10 km away from the city centre and these lands are used for dumping the solid wastes. This site is provided with a compound wall all around. To prevent fire accidents during the summer season TCC constructed a water tank inside the Compost Yard. The water in the tank is refilled by Lorries and pipe line. Details of the existing disposal sites are furnished in Table 2.
Table 2. Existing Solid Waste Disposal Sites-Tiruchirappalli City Corporation

<table>
<thead>
<tr>
<th>Disposal Site</th>
<th>Area in acres</th>
<th>Distance from town</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ariyamangalam</td>
<td>47.7</td>
<td>10 km.</td>
</tr>
<tr>
<td>Panjappur for future disposal</td>
<td>(570 ac including STP Site)</td>
<td>8 km.</td>
</tr>
</tbody>
</table>

Source: Tiruchirappalli City Corporation, 2007

Vegetable waste from the Gandhi market are dumped in the left corner of the compost yard, this vegetable waste is used for the purpose of manufacturing the Bio-manure with the permission of TCC Commissioner. The project is undertaken by a private management, it is called “Kalki Charitable Trust”.

The whole system of working pattern, refuse collection is correctly monitored with the help of wire-less connection. The amount of garbage received and vehicle number are also informed to TCC Office through wireless. Tiruchirappalli City Corporation also owns another site with an existence of 570 acres at Panjapur village (including STP), and this site is proposed to be used as a Compost Yard and landfill site in the future.

Table 3. Estimation Borough wise Emission Status from Waste transport vehicles

<table>
<thead>
<tr>
<th>Type of Vehicles</th>
<th>SPM (g/day)</th>
<th>SO2 (g/day)</th>
<th>NOX (g/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dumper Placer (big)</td>
<td>148.8</td>
<td>58.9</td>
<td>1451.26</td>
</tr>
<tr>
<td>Dumper Placer (Small)</td>
<td>37.06</td>
<td>95.37</td>
<td>221.04</td>
</tr>
<tr>
<td>Hand Load</td>
<td>134.14</td>
<td>41.06</td>
<td>186.08</td>
</tr>
<tr>
<td>Pay Load</td>
<td>44.97</td>
<td>18.45</td>
<td>450.99</td>
</tr>
<tr>
<td>Other</td>
<td>270.83</td>
<td>42.22</td>
<td>2107.73</td>
</tr>
</tbody>
</table>

Basis and Steps of Estimating Different Parameters

- Garage wise availability of different types of departmental vehicles and no of trips covered by those daily: around 50% of departmental vehicles are more than 10 years old. In the existing system a considerable number of old hand-loaded vehicles still exist for quick removal of solid waste. Kilometer-reading meters of most of the old departmental vehicles are damaged and fuel is issued on trip basis, which is quite high. Most of the hired vehicles are also very old and their fuel consumption is considered equivalent to that of tipper trucks. Old age vehicles and inadequate man power leads to around 50% operational efficiency.
- Calculation of borough wise total distance covered by the each type of departmental and private vehicles and their fuel requirements
- Calculations of weighted average of pollutants (SPM, SO2, NOX), estimation of emission factor of the vehicles and of pollutants emission from them
- Calculation for CO2 and SO2 emission from the departmental and private vehicles (CPCB 2009)

Computed Total Emission of Pollutants from Waste Transfer Vehicles

Emission Factor of NOx for the above type of vehicles is more than CO and others because the vehicles were operated by diesel engines. The nano-particulates comprise only 1 to 20% of the total particulate mass emitted from a diesel vehicle, but may constitute more than 90% of the total number of the emitted particles (Kittelson, 2001). Apart nano-particulate range and so, number of SPM emitted does not reduce effectively. From April 2010 the maximum sulphur in diesel will be reduced to 50 ppm to control SO2 emission in Indian cities, however sulphur is not in any way a serious problem.

It may be seen from Table 3 that total pollutant generation from MSW transportation sector of Tiruchirappalli city is around 1,992 T/ year. NOX emission is the largest because of high temperature combustion in diesel engines that generates more thermal NOX. SO2 generation is much less compared to NOX due to stringent permissible sulphur percentage in diesel fuel. Though the emission percentage of SPM is less but the effect is significant due to the presence of higher fraction of nano-size particles. The emission of unburnt hydrocarbons form diesel vehicles is usually less than the petrol driven vehicles.
Conclusions

The solid waste management system of Tiruchirappalli City was analyzed. The departmental vehicles carry less amount of solid waste and make more numbers of trips due to the capacity of the containers being much lower than that of open trucks. More number of trips i.e. higher distance covered entails higher fuel consumption which results in more air pollution as has been seen. If the department carries out the obligatory responsibility of better maintenance of vehicles and increase the capacity of the dumpers (i.e. to reduce the number of trips), then total pollutant emission may not only match with the performance of private vehicles but it may even be better than them. Slow road speed affects not only traffic flow but also results in huge fuel waste and aggravates vehicular pollution. Moreover since pollutant emission is more from stationary vehicles with running engine rather than moving vehicles, solid waste transport systems should avoid the peak traffic hours to reduce air pollutant generation and the obnoxious/foul odour problem during that period from this operation. Total pollutant generation from MSW transportation sector of Tiruchirappalli is around 1,992 T/ year. NO\textsubscript{X} emission is the largest because of high temperature combustion in diesel engines that generates more thermal NO\textsubscript{X}. SO\textsubscript{2} generation is much less compared to NO\textsubscript{X} due to stringent permissible sulphur percentage in diesel fuel. Though the emission percentage of SPM is less but the effect is significant due to the presence of higher fraction of nano-size particles. The emission of un-burnt hydrocarbons form diesel vehicles is usually less than the petrol driven vehicles The estimated pollutants generation from MSW transport sector is considerable and cannot be ignored as it is a part of Tiruchirappalli city as well as global air pollution problem. In order to minimize air pollution, we have to minimize the pollution generation from MSW transportation sector. This may be achieved by (i) minimization of overall trips through optimization of route scheduling, (ii) introducing fuel efficient vehicles, (Hi) use of less pollutant fuel, (iv) reduction of 30-40% pollution load generated by vehicles by following proper periodical inspection and maintenance schedule of vehicles, and (v) replacing old vehicles, that have crossed their age limit. More stringent norms for fuels also help in reduction of the pollutants. Reduction of sulphur content limit to 50 ppm in diesel for urban areas from April'2010 will also reduce total emission of S02 by around 86%.

References


VALUATION OF GREEN HOUSE GAS (GHG) EMISSIONS FROM MUNICIPAL SOLID WASTE MANAGEMENT APPLYING A GHG CALCULATOR IN ORMOC CITY, PHILIPPINES

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ABSTRACT

Climate change is becoming an important determinant of waste management approaches. The enhancement of municipal solid waste management systems has a great potential to reduce Greenhouse gas (GHG) emissions. The presented example from Ormoc City, Philippines underlines the importance to revise solid waste management programs by integrating climate mitigation considerations.

Ormoc City is a medium size city located on the western site of Leyte Island in the Eastern Visayas. Presently, the city collects around 35 tons/day, more than 12,000 tons/year of municipal solid waste. So far, the collected waste is disposed at a local controlled dumpsite. However, the Local Government Unit (LGU) of Ormoc City proposed legal requirements to enhance waste disposal by establishing an engineered landfill. Supported by the German International Cooperation, Ormoc City currently implements an Integrated Solid Waste Management system (ISWM), which aims to reduce, reuse and recycle as many materials out of the local waste stream as possible prior to waste disposal.

Although waste segregation and composting is legally mandated, the municipal waste collection in Ormoc City and elsewhere in the Philippines still receives a large fraction of organic residues. Hence, the LGU explored options to provide solutions to exclude organic waste components from waste disposal. Through the development project “Solid Waste Management for Local Government Units in the Philippines”, a Climate Calculator provided by the German International Cooperation was utilized as a new tool to assess and compare GHG emission projections for various scenarios of the Ormoc City SWM system. The Climate Calculator was used to clarify the baseline situation and realistic options for system enhancement. All in all, 3 scenarios were elaborated applying the GIZ Climate Calculator. System enhancements are especially foreseen if waste recovery, composting and biostabilization (BS), a treatment process conducted prior to waste disposal could be realized. As expected, the increase of segregation of organic components and composting as well as the envisioned BS would result in greatest impacts from a climate perspective and would lead to considerable GHG emission reductions.

The presented paper summarizes the local waste management situation, the results of the conducted GHG calculator application, projects GHG emission reductions for the various scenarios and discusses co-benefits for the municipal solid waste management system and the involved stakeholders as well.

Keywords: GHG emission projections, Waste management, Application GHG calculator
IMPLEMENTING A MONITORING SYSTEM FOR THE WASTE MANAGEMENT CENTER BAYAWAN CITY, PHILIPPINES

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ABSTRACT
In April 2010, Bayawan City launched a new municipal Waste Management Center (WMC) with integrated landfill. Among the few existing WMC’s in the Philippines, there is no clear methodology how to manage and monitor waste streams and how to conduct water monitoring on a regular basis. With the newly installed weighbridge at the WMC more data are available to clarify the various waste streams. Together with data from waste characterization studies, the performance of waste collection services can be assessed and enhancement measures proposed. In order to monitor the environmental performance of the facility, an early warning system was developed and tested. The results are evaluated in close partnership with a local university to bring in the needed expertise and to enhance monitoring performance with locally available knowledge and tools. However, in order to measure basic parameters on a more frequent basis, the municipality needs to enhance its capacity on analyzing wastewater samples.

Keywords: Solid waste, Waste characterization, Landfill operation, Leachate and water monitoring

Introduction
Bayawan City in Negros Oriental responded to the challenge of the new Philippine waste management law and developed a 10-year Solid Waste Management (SWM) plan as guiding framework already in the year 2003. To upgrade the local SWM system, a Waste Management Center (WMC) which includes a material recovery facility, a composting plant and a landfill with leachate collection and wetland for leachate treatment were constructed and launched in April 2010. Additionally, a sludge treatment facility with an Anaerobic Baffled Reactor (ABR) was integrated. The latter serves to receive and treat the septage of around 5,000 septic tanks from the urban center of Bayawan City. With the new facility, the municipality not only complies with legal requirements, but offers by far enhanced municipal services which provide the needed environmental protection measures likewise. Hence, Bayawan City demonstrates how SWM services can be implemented efficiently even within the context of a developing country to comply with common standards in water, soil and air protection.

Materials and Methods
Waste Characterization
Waste characterization data are hardly available in the needed detail and quality in the Philippine setting due to lack of knowledge and funding. This makes it more difficult to plan and implement SWM systems. In the year 2003, the municipality of Bayawan City conducted their first waste characterization survey based on a 7 day event. Later on, it was realized that this method is too costly and time consuming. Therefore, a three day waste characterization was introduced in 2009. According to the Philippine Environmental Governance Program (EcoGov) the 7-day WACS and 3-day WACS collections are comparable in terms of precision [1].

Parameter Selection for Water Monitoring
Water monitoring is a new task for Local Government Units (LGU) and a rather challenging undertaking in the Philippine context where expertise, probes for field testing, laboratory facilities and other tools for environmental monitoring are hardly available. Especially more complex parameters, that require expensive and sensitive laboratory equipment, can only be analyzed in larger cities. For this reason, a special parameter set which can be analyzed locally was proposed to provide sufficient and reliable data for monitoring in an efficient and affordable manner. In general, monitoring of surface, ground and wastewater is regulated within administrative orders. Such were put in place in the Philippines already in 1990.
However, over the years, more information became available regarding monitoring of waste disposal sites. Since the law does not prescribe parameters for environmental monitoring for waste disposal sites, a set of basic parameters was proposed and tested for the Bayawan City WMC.

![Figure 1. Water monitoring at the Bayawan City Waste Management Center](image)

For the baseline monitoring five points were strategically located at the site. For the groundwater wells, two were located downstream and one well was located up stream. For the surface water two samples were taken, one upstream and one downstream. The sample points and their location are represented in Figure 1. It was chosen to measure the full set of parameters in order to establish a good baseline. The set up of the monitoring is based on a proposal [2] prepared by the German International Cooperation (GIZ) and will later be discussed within the chapter results and discussion.

**Limitations**

With regard to the waste characterization study (WACS) as conducted in 2003 and 2009, various discrepancies were observed in the data. Although the EcoGov manual for waste characterization states that there is no significant change in data when performing a 3 or 7 days WACS, the end of pipe (EOP) data show significant differences when compared with actual data collected from the newly installed weighbridge. It is assumed that this deviation is caused by the fact that waste is not collected on a daily basis at all households. Furthermore, it seems plausible that people do not use every collection schedule offered to them to throw waste. Additional to this, market waste may change in quantity and quality depending on weekdays, seasons but also special events or activities. For example, the quantity of delivered fish and vegetables is based on daily changes hereby directly influencing the amount of waste collected. For this reasons, the EOP data from 2009 are disregarded and not used in this study. However, the waste generation data from 2009 show no significant difference with the data from 2003. Therefore, it is decided to use these data in calculating the collection rates.

For water monitoring, samples are analyzed by the participating local university which is the only institution in the province that offers laboratory analysis to the public. It is assumed that results produced by the university do not differ significantly compared with a certified laboratory since the analyses performed are not complex. Besides, certified laboratories are located far away which would result in increased costs and logistical challenges.

**Results and Discussion**

_Waste Stream Analysis by Characterization and Weighbridge_

Due to the newly installed weighing bridge, waste streams can now be monitored more accurate than before. This enables to delineate waste characterization data for the received wastes, which significantly assists to increase knowledge of local waste composition but also as base for adjusting and improving site operations and collection schemes. The generated data is not only important for Bayawan City but also for other
municipalities that have a similar setting and could use such data for planning their SWM facilities. Table 1 summarizes regarding data for the Bayawan City SWM context.

Table 1. Overview of the generated waste together with the received waste at the Bayawan City WMC

<table>
<thead>
<tr>
<th>Type of waste</th>
<th>Total generated waste (2010)</th>
<th>Composition of generated waste (%)</th>
<th>Total collected waste (2010)</th>
<th>Composition of collected waste (%)</th>
<th>Collection rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodegradable</td>
<td>16050.4</td>
<td>69%</td>
<td>2,534.8</td>
<td>58%</td>
<td>16</td>
</tr>
<tr>
<td>Recyclable</td>
<td>480.3</td>
<td>2%</td>
<td>37.1</td>
<td>1%</td>
<td>8</td>
</tr>
<tr>
<td>Residual</td>
<td>6835.4</td>
<td>29%</td>
<td>1,773.3</td>
<td>41%</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>23,366.1</td>
<td>100%</td>
<td>4,345.2</td>
<td>100%</td>
<td>19</td>
</tr>
</tbody>
</table>

1. Based on waste characterisation performed in 2009.
2. Based on weighbridge data produced in the period June’10 until Jan’11.
3. Consists of plastic bottles, scrap metal, cardboard, dry paper, cans and glass bottles.
4. Includes special waste

For SWM and landfill planning accurate data about residual waste collection are needed. Currently, 26% of the residual waste is collected. It is assumed that uncollected waste is buried, burned or disposed illegally. With enhanced waste enforcement and information/education campaigns, the LGU tries to bring down the number of illegal practices. Furthermore, 58 percent of the waste collected from the households and establishments is biodegradable. By treating this organic fraction with composting technology, the municipality easily meets the diversion goal set by national law with 25 percent. In order to improve the monitoring system, the municipality developed a simple computer program in which all incoming and outgoing waste streams are constantly monitored. With this program, the LGU can closely monitor waste streams and propose measures to enhance waste collection and efficiency of the center itself.

Early Warning Monitoring at the Waste Management Center

For water monitoring of the Bayawan WMC a special set of parameters was chosen, subdivided into 1st and 2nd levels of monitoring. The chosen parameters can be analyzed locally and are listed in Table 2. Initially, only 1st level parameters are monitored. Depending on the result of the analysis of 1st level parameters, 2nd level parameters can be analyzed in the laboratory. The decision to analyze 2nd level parameters depends on rules as documented in Figure 2. Reference levels are provided by national law. If not available for a certain parameter, international guidelines are followed. As long as concentrations are within the reference level, no action will be undertaken. Once the outcome of the analysis exceeds by 100% the reference level, the so-called trigger level is reached. If a trigger level is reached, it is strongly advised to intensify the monitoring of 1st level parameters. Currently, the 1st level of monitoring is conducted semi-annually. This may be changed to a quarterly routine later on. However, as of now only two monitoring events were conducted in order to establish baseline data. The first round was conducted before start of operation and the second after 8 months of landfill operation. It was chosen to monitor both 1st and 2nd level parameters for future reference. As expected, there are no alarming levels caused by leachate contamination so far. Besides the early warning monitoring of the WMC and local natural water resources, the water treatment facility itself is monitored on its performance. The monitoring is supported by a local university which provides knowledge inputs and conducts water analyses. In a next step, the municipality needs to enhance its own capacity to analyze wastewater samples in order to safeguard environmental performance of the WMC. The following Table 2 and Figure 2 summarize the proposed parameter set and monitoring procedure.
Table 2. Selected parameters and monitoring level

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Level 1st</th>
<th>Level 2nd</th>
<th>Parameter</th>
<th>Level 1st</th>
<th>Level 2nd</th>
<th>Parameter</th>
<th>Level 1st</th>
<th>Level 2nd</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>V</td>
<td></td>
<td>Sulphate</td>
<td>V</td>
<td></td>
<td>Colour</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Total hardness</td>
<td>V</td>
<td></td>
<td>Potassium</td>
<td>V</td>
<td></td>
<td>Alkalinity</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Nitrate</td>
<td>V</td>
<td></td>
<td>Nitrite</td>
<td>V</td>
<td></td>
<td>Lead</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>V</td>
<td></td>
<td>pH</td>
<td>V</td>
<td></td>
<td>Nickel</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>V</td>
<td></td>
<td>Temperature</td>
<td>V</td>
<td></td>
<td>Chromium (VI)</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td>V</td>
<td></td>
<td>Conductivity</td>
<td>V</td>
<td></td>
<td>COD</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Animal/Vegetable Fat</td>
<td>V</td>
<td></td>
<td>Dissolved oxygen</td>
<td>V</td>
<td></td>
<td>Cyanide (Free)</td>
<td>V</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Flow chart of the water monitoring system at the Bayawan WMC

Conclusions

Although monitoring is a new task for most municipalities in the Philippines, this study shows that it is possible to monitor waste streams and water resources with local available means and knowledge. First results from the weighbridge indicate that the municipality needs to improve their residual waste collection since a larger portion of uncollected waste is most likely still buried or disposed in an uncontrolled manner, especially in more distant parts of the city. However, diversion of biodegradable waste and recyclables already comply with the legal prescriptions with a waste diversion rate > 25%.
Acknowledgements

The authors wish to thank Bayawan City and the German International Cooperation (GIZ) which provided the means to conduct and present this research. Special thanks go to Silliman University which supported actual sampling and laboratory analysis performed.

References


MONITORING HEAVY METAL POLLUTION IN SOILS AND CROPS AFFECTED BY SOLID WASTE DISPOSAL IN VEGETABLE PRODUCTION BASES OF HONG KONG AND MACAO

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ABSTRACT Monitoring heavy metal pollution in soils and crops from vegetable production bases of Hong Kong and Macao, as affected by solid waste disposal, was carried out in 2009. Twenty two vegetable samples and 16 soil samples were collected from 9 vegetable bases in Zhuhai, Zhongshan and Shaoguan. Heavy metal contents in soils and vegetables were determined using ICP-OES. The results indicated that cadmium (Cd) and Chromium (Cr) were the two dominant pollutants in the vegetables sampled, and the levels of Cd and Cr were high and medium respectively. The concentrations of copper (Cu), zinc (Zn) and nickel (Ni) were under the safety limits and met the Chinese national heavy metal evaluation criteria. There no evaluation criteria for manganese (Mn) and iron (Fe), but their concentration were lower than the Ultimate Limit State (ULS) values of daily consumption. No cobalt was detected in all vegetable samples. For the soil samples tested, Fe, Cu, Zn, Mn Cd and Cr were the 6 dominant metal pollutants. A few samples were moderately polluted whereas two samples were polluted with Cr. However, no Co was detected in the soil samples in this investigation. Some metals, e.g. Fe, were extremely high, but they were under the state limit, according to the Chinese National Standards.

Keywords: Heavy metals, Pollution, Soil, Vegetable
SOURCE AND DISTRIBUTION OF POLLUTANTS IN WATER AND SEDIMENT RELATING TO WASTE DISCHARGE IN YAK CHONG RIVER, MACAO

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ABSTRACT A study on the source and distribution of pollutants in water and sediment relating to waste discharge in Yak Chong River, Macao, in collaboration with the Macao Association of Environmental Protection Industry, commercial/industrial sectors of Macao and Hong Kong, and supported by the Macao Environmental Protection Bureau, was carried out during 2010. During the investigation, garbage, oil residues and dead fishes were found in the river. Wastewater discharged directly into the river was monitored, and the water and sediment samples were collected for chemical and biological tests. The results indicated that pollution was serious to certain extents in some areas along the river. The degree of pollution in Yak Chong River was then evaluated and the level of toxicity was assessed based on the Chinese National Standard GB3838-2002. Water quality is divided into five (5) categories with Category I the best and Category V the worst. For the water quality parameters tested, dissolved oxygen (DO) was in Category IV; chemical oxygen demand (COD) in between III and IV; phosphorus (P) in IV; nitrogen (N) was 19 times over V; E. coli was more than 60 times over V. Phosphorus and N are the nutrients that promote algal bloom and consequently result in eutrophication and reduction of the DO level in water. This would be one of the factors caused death of fishes in the river. In addition, heavy metal copper (Cu) in the sediment was 6 times higher than the A level of the Dutch Standard for contaminated soils. One of the significant findings was the high concentration of H2S in sediment and this gas is considered to result in the death of fish as H2S greater than 0.04 mg/L can be toxic to fish. Our results showed that the concentration of H2S was about 4-40 mg/L, which was much higher than the critical value (0.04 mg/L) reported. Therefore H2S together with eutrophication caused fish death.

Keywords: Dissolved oxygen (DO), H2S, Pollutant, Sediment, Water
INTERFACING THE SO-CALLED INGREDIENTS IN SWM ENVIRONMENTAL GOVERNANCE VIS-À-VIS LOCAL AUTHORITIES AND COMMUNITIES IN THE PHILIPPINES

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ABSTRACT
The situation in the Philippines in terms of implementing the Republic Act 9003, the national SWM law, is not inspiring nor motivating for most people in the SWM sector. The sector is even demanding more from the authorities to do more than just implement the basic tenets of the law. The law has loopholes yet the simple and elemental provisions are not even touched by the local governments. The ingredients to a successful SWM governance are promoted by some governmental agencies for local governments to follow thereby hasten the implementation. But the questions remain whether these are valid or enough for the local governments to put this into practice even the most basic provisions of the law much more to advanced topics like climate change adaptation in waste management issues. The purpose of this paper is to check whether the so called ingredients on good governance in SWM (transparency, accountability, participatory) can be used to convince people from the public, private and academic and even the informal sector if these are working or not, going in the right direction? The case of selected two cities in central Philippines will be featured based on their experiences and would be interesting to interface it with. Focus group discussions, key informant interviews and surveys are the tools used. Not only local authorities but also people in the communities who have a stake in the process are also important entity to assess the whole gamut of implementation. Through them the perspectives would be exposed whether it is enough for the central or local government and other parties to demand from the local communities to follow the law or the local communities demand from the government what they want to achieve in SWM.

Keywords: Good governance, Solid waste, Local communities, Climate change, Waste law, Transparency, Accountability and participatory

Introduction
Land, air, and water pollution through municipal solid waste come in many forms. But one thing for sure it come from the various sources whether household, commercial, industrial, institutional and public areas. The rate that local governments are responding to such issue continues to be a struggle among public workers, civil societies and even stakeholders in many Asian countries. In the Philippines, the enforcement of the law (Republic Act 9003) is mainly in the hands of local government units (LGUs). No matter how hard the LGUs and national agencies tasked on this law to market the idea that it is not the government alone that has the responsibilities but also the people themselves, good governance on SWM remain a challenge. In here, accountability takes center stage to mean that it is the degree to which officials and its staff of a government or public agency or instrumentality is held responsible for their decisions and actions in the performance of their duties and functions. Thus, participation, as an ingredient of good governance, means that the degree that the general public like the stakeholders and vulnerable and marginalized sectors (women, children, elderly etc) have access and opportunities to influence the decision and actions of a public agency. Transparency means the extent to which the general public has full and reliable knowledge and information about decisions and actions taken by a public agency or office (Environmental Governance, 2004). So far LGUs usually does not have the luxury of having technical expertise and knowledge, advice and consultancy support to implement a number of provisions in the law such as development and preparation of solid waste management plans, operation and maintenance of materials recovery facilities, judicious use of equipment and resources in collection, design, operation and maintenance of proper disposal facilities. While the monitoring and advisory role on technical matters lies in the Environmental Management Bureau (EMB), still it doesn’t reach the LGUs that often for many reasons.

This piece of work mainly tries to check whether the so called ingredients on good governance in SWM can be used to convince people from the public, private and academic including the informal sector to work and invest on SWM. Selected cities in the Visayas region shall serve as the ‘mirror’ so as to validate the claim if
the so called good governance ingredients in SWM work. If the people and stakeholders view and uphold that there has to be transparency, accountability and participation in order for the implementation to succeed, then it can be considered a contribution to the ever growing demand of good governance for solid waste management.

Materials and Methods

The case studies developed through years of observation, monitoring, joint implementation of projects between LGUs and development agencies are documented. Focus group discussions and key informant interviews likewise were utilized to gather as much information as possible in tackling the subject of this paper. Two cities are featured in this paper namely Bayawan City, Negros Oriental and Ormoc City, Leyte all in the Visayas region.

Results and Discussion

The Case of Bayawan City in Negros Oriental

Bayawan City is situated in Oriental Negros Province, Central Visayas region. Planned and designed in 2006 the Bayawan City Waste Management and Ecology Center (BCWMEC), the SWM Program of the LGU started even before that. In 2002, The EcoGov project assisted the city in the SWM planning including ordinance crafting. The city government signed a Memorandum of Agreement with the German Technical Cooperation (GTZ) - AHT Group AG along with the German Development Service (DED) to help them in the establishment of the facility.

By 2003, Bayawan City through its technical working group, finalized and approved its 10-year Solid Waste Management Plan which proposed the establishment of a waste management center. The construction commenced in June 2008 and operated in April 2010. With this achievement, Bayawan city provided a significant aspect of SWM services towards sustainable development. For sustainability, the city implemented mechanisms for waste segregation at source and for cost recovery through an ordinance. All these proceeded with public consultations and feedbacks through the office of the City Environment and Natural Resources (City ENRO). The complex features a clay-lined landfill for residual waste only, a composting plant, a materials recovery facility (MRF) and a sludge treatment to recover materials for treatment and dispose unavoidable residual waste in an environmentally-sound way (Crucio, 2010).

The city is busy in implementing many environmental laws aside from the solid waste management law. But one thing for sure the city government’s leadership formulated its 10-year solid waste plan, designed, operated and maintained its eco-waste management center with the end in view of providing its constituency the best policies, staff and facilities the city has ever offered. And the people responded with care and abiding the rule of law as a way of contributing to the tenets of good governance for without such response, these tenets will remain an abstract thing.

The Case of Ormoc City in Leyte Province

Ormoc City in Leyte, was a hit city in 1991 when it was struck by a catastrophic flood caused by Typhoon Uring. That sad day caused significant mortality and damage (4,922 deaths, 3,000 missing persons and an estimated 620 million pesos (more than US$12 million) worth of property damages (Predo, 2010). Although experts say that event was mainly caused by climate-related phenomenon, it greatly affected the people of Ormoc city.

Ormoc City is located in the northwest part of Leyte, about 110 kilometers from Tacloban City, the regional capital. It has a land are of 464 square kilometre and mainly an agricultural city with sugarcane, rice, and coconut products. It is home to one of the country’s main geothermal energy sources.

When the German Technical Cooperation through its SWM4LGUs Project partnered with Ormoc City and Environmental Management Bureau Region 8, the project did not proceed as smooth as it was expected. Many factors combined were the reasons why it has struggled to finally implement its solid waste management program. The process was lengthy and encountered various changes. But the process more or less was a kind of step by step and people were informed of their responsibilities including the public workers and officials.
How did it start in terms of SWM full blast implementation? The city organized and created technical working group (TWG) with the able assistance of City Councilor Jose Alfaro, an environmentalist councilman. The acts and decisions of the Mayor on SWM got valuable support and influence from this city councillor. The task of the TWG then was to develop the 10-year SWM plan as mandated by the law through the National Solid Waste Management Commission (NSWMC). The plan was carried out with the assistance of German Development Service (DED). The waste study by Ormoc city revealed that around 50% waste not collected, 51% collected and out of the collected, 43% are organics and 49% residuals and only 8% recyclables. The method of ensuring public involvement came into view through the formulation of the 10-year SWM Plan assisted by the Project. Barangay consultations were done. As the law mandates segregation strategy to reduce waste, the city ordered a “no segregation, no collection” policy. In order to address the 43% organics, the central composting facility using vermi (worm) and windrow composting technique were employed to treat and process biodegradable waste. To address the 49% residual wastes, the city proceeded with the construction of the new landfill facility. Although residuals as it may be called, some of these materials like doy packs and juice packages are transformed into sellable bags and items as a way of diverting the materials from getting into the landfill (Galo-Fumar, 2009). The new landfill facility for residual wastes will be completed soon. The challenge of operating and maintaining such a facility will be put to test once the SWM implementation in full blast this time with the proper disposal management component.

Acknowledgements

The author would like to thank the following: Ms. May Ybañez, EMB-7 Director Alan C. Arranguez, Engr. Amancio Dongcuy, Engr. Loreto Sanchez, Engr. Antonio Aguilar, Institutions which have also inspired and supported this paper in some ways are Miriam College, DENR-EMB-7, and the Hong Kong Baptist University through dr. Jonathan Wong for the scholarship grant awarded to the corresponding author.

References


FOOD WASTE SOURCE SEPARATION AND COLLECTION ARRANGEMENT IN HONG KONG

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ABSTRACT For the incredible increase in the municipal solid waste (MSW) with the economic boom in Hong Kong, landfills become saturated far earlier than expected. It is because landfilling is the main waste treatment strategy in Hong Kong. However, land is not available for the expansion or construction of new landfills; hence new waste treatment method has to be explored. “A Policy Framework for the Management of Municipal Solid Waste (2005-2014)” was published in 2005, it has been stipulated that organic waste from commercial and industrial establishments shall be separately collected and treated by biological treatment technologies, because the organic waste represent 38% of the MSW disposed at landfill. Thus the Organic Waste Treatment Facility (OWTF) has been proposed to treat source-separated organic waste as part of long term waste treatment strategy. Since purity of the organic waste is highly demanded for an efficient biological treatment process, source-separated collection from commercial, industrial and institutional premises deem necessary for collecting untainted food waste. In this study, the current practice and effectiveness of the food waste source separation and collection in Hong Kong have been reviewed through questionnaire survey and site visit, as well as recommendations of the feasible food waste source separation arrangement together with the Safety Management System (SMS) are provided in order to develop an effective and safety food waste source separation and collection arrangement.

Keywords: Food waste, Organic waste treatment facility, Hong Kong

Introduction

The continued growth in generation of municipal solid waste (MSW) runs out of the three landfills far earlier than expected in Hong Kong. Around 17,000 tonnes of MSW were generated each day in 2006, which are more than 30% higher than 10 years ago [1]. In 2008, the per capita disposal rate of municipal solid waste was 1.35kg per day. The organic waste constitutes the largest portion (38%) in the MSW disposed at landfills in Hong Kong [1]. Food waste can be described as any edible waste from food production, transportation, distribution and consumption [2]. Food waste from the commercial and industrial sectors has been increasing sharply from 373kg in 2002 to 847kg in 2008 at Hong Kong [1].

In 2007, Hong Kong government planned to build the Organic Waste Treatment Facilities (OWTF) at Siu Ho Wan in mid-2010s for food waste treatment as a part of a long term organic waste treatment strategy. It aims to treat and recycle source-separated food waste generated from the commercial and industrial sectors, through separation, storage, collection and transportation arrangement to useful products, in order to minimize landfill disposal.

The economic strategy is the most common incentive for the source-separation of organic waste in many countries, including the cited examples, Taipei [3] and Singapore [4,5]. However, it seems that economic instrument alone is not sufficient for successfully implementing food waste recycling. Although the food waste recycling rate in Singapore increased from 2.3% in 1999 to 9.0% in 2007, the recycling rate is still lower than Taipei, it may be because Singapore Government does not form any policy or collection system to specifically encourage source separation of food waste, especially for food waste generated from the domestic sector. There was a study conducted for the comparative factors regarding recycling collection system in regions of the USA and Europe in 2000, the results demonstrated that the particular design of the collection system may play a role in the recycling habits in the following aspects [6-8]. So far there is not any legislation and economic strategy for the food waste source separation and collection arrangement in Hong Kong.

A questionnaire survey has been conducted in this study to investigate the effectiveness of food waste source separation and collection arrangements in Hong Kong and provide recommendations for the effective, sustainable and safety food waste source separation and collection arrangement.
Survey Methodology

To collect information on the current practice of food waste source separation and collection arrangement, as well as the information on major and minor organic waste generators in order to develop feasible options for food waste separation and collection arrangement in Hong Kong, a questionnaire survey was conducted from 3 October 2009 to 27 December 2009 via phone, face to face interview and site visits. In line with the targeted food waste generators set out, 100 shopping malls restaurants and eateries owners’ from commercial have to be approached. A total of 60 completed questionnaires were conducted by face interviews. To make the sampling comprehensive enough to represent the whole picture of food waste generation characteristics of commercial premises over Hong Kong, a careful selection of shopping malls as well as street level eateries in different districts in Hong Kong had been done before conducting site visits. The survey has covered all typical urban settings in Hong Kong, such as early new towns - Tsuen Wan, older urban areas - Kowloon City and newly developed/redeveloped areas – Shatin.

Results and Discussions

Food Waste Generation Characteristics

The summary of data on waste generation characteristics obtained from questionnaires survey is showed in Table 1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Generation Rate (kg/m²/Day)</th>
<th>Organic Waste%</th>
<th>Pre-consumer Food Waste%</th>
<th>Separate Bins for Pre-consumer Organic Waste</th>
<th>Daily Waste Collection Frequency</th>
<th>Waste Disposal Cost $/kg/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping Mall Restaurants</td>
<td>0.18</td>
<td>48</td>
<td>46</td>
<td>61</td>
<td>2.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Street-level Eateries</td>
<td>0.21</td>
<td>54</td>
<td>51</td>
<td>48</td>
<td>1.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>

In addition, four respondents claimed that their food wastes were currently being reused/ recycled. Follow-up calls were arranged to find out how food waste was being recycled. Findings are presented in Table 2. The data showed that the street-level eateries in Tsuen Wan are reported to have generation rate of 0.21kg/m²/day, even higher than the restaurants in shopping mall 0.18kg/m²/day. Two factors may be used to explain the higher waste generation rates in street-level eateries. First, it may be due to the comparatively crowded working environment and the second factor was that street-level eateries in general have higher trading volume.

Around 50% of food waste was untouched food waste. The reason for the high food waste generation rate might be partly due to lack of waste charging, so companies had less incentive to reduce waste generation. This finding indicates potential for waste minimization.

In general, only some 50% of all establishments had separate bins for handling pre-consumer food waste. Among them, street-level eateries had the lowest values of 48% respectively. They may have very limited kitchen space for allocating an extra waste bin; and the waste quantity of each establishment was very low so having an extra bin for handling pre-consumer food waste seems unnecessary.

Among all categories, shopping mall restaurants, street-level eateries had a higher waste disposal cost of $1.2 and $0.9 respectively. It was possibly because that their quantity of waste was comparatively low to bargain for a cheaper collection cost. However, these costs were considered relatively high compared to what contractors actually charge for waste collection in Hong Kong.

Shopping mall restaurants had comparatively higher frequency of waste collection than other establishments. It probably due to more stringent hygiene standard in shopping mall areas, the waste collectors collected wastes more frequently so as to minimize potential odour impact from back corridor
waste bins. This result reflected the usual practice of waste collection handled by shopping mall management bodies to some extent.

Only four survey respondents claimed that they were currently undertaking some form of food waste recycling. The waste is generally used as pig feed and donation but the amount was rather insignificant when compared with total organic waste generation. This indicated that recycling of food waste was extremely uncommon in Hong Kong.

<table>
<thead>
<tr>
<th>Generator</th>
<th>Means of Reuse/ Recycling</th>
<th>Revenue Generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saint Honore Cake Shop - Tseun Wan Chung On Street Branch</td>
<td>Pig feed (managed by waste collector)</td>
<td>Unknown</td>
</tr>
<tr>
<td>Saint Honore Cake Shop - Shatin City One Plaza Branch</td>
<td>Pig feed (managed by waste collector)</td>
<td>Unknown</td>
</tr>
<tr>
<td>Saint Honore Cake Shop – Kowloon City Plaza Branch</td>
<td>Pig feed (managed by waste collector)</td>
<td>Unknown</td>
</tr>
<tr>
<td>Tai Pan Bread &amp; Cake – Shatin Branch</td>
<td>Donate to Elderly Centres</td>
<td>No</td>
</tr>
</tbody>
</table>

Participants’ Views on Separation and Collection of Food Waste

Investigated items are described in Table 3. The corresponding results shown in Table 4 and Fig. 1, the restaurants and eateries owners perceived the highest difficulty scores and reckoned that lack of manpower and space are the major constraints for source separation of food waste to be carried out. This issue will be further discussed below.

<table>
<thead>
<tr>
<th>Items</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty Score</td>
<td>Perceived difficulty in separating organic waste at source (using a scoring scale, with 5 being the most difficult)</td>
</tr>
<tr>
<td>Willingness to Separate</td>
<td>Number of generators (in %) willing to separate organic waste from other wastes on voluntary basis</td>
</tr>
<tr>
<td>Difficulties to Separate</td>
<td>Difficulties expressed by generators if separate collection of organic waste is to be carried out</td>
</tr>
<tr>
<td>Conditions to Participate</td>
<td>Under what conditions would the generators be willing to separate organic waste for collection</td>
</tr>
</tbody>
</table>

From Table 4 and Fig. 1, the restaurants and eateries owners perceived the highest difficulty scores and reckoned that lack of manpower and space are the major constraints for source separation of food waste to be carried out. As showed in Fig. 2, most waste generators are unlikely to separate food waste for collection unless they are lured by economic incentives (64% positive) or required to do so by statutory measures (100% positive). This indicates that in order to foster territorial-wide separation of food waste, legislation is the most effective strategy in the long term, with economic incentives as a complimentary measure or an alternative if legislation is not possible.
Table 4. Difficulty scores and generators’ willingness to separate food waste for collection

<table>
<thead>
<tr>
<th>Category</th>
<th>Average Difficulty Score</th>
<th>Denote</th>
<th>Willingness to Separate%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping Mall Restaurants</td>
<td>3.6</td>
<td>Moderate to Difficult</td>
<td>35%</td>
</tr>
<tr>
<td>Street-level Eateries</td>
<td>3.8</td>
<td>Moderate to Difficult</td>
<td>28%</td>
</tr>
</tbody>
</table>

Figure 1. Difficulties anticipated by generators in separating food waste for collection

Figure 2. The circumstances for generators to carry out source-separation of food waste

**Conclusion and Recommendations**

With an imminent threat of no more landfill space for the increasing waste loads, there is an urgent need to divert the waste from landfills through the development of efficient waste source separation and recycling scheme. Legislative and economic instruments are commonly used to facilitate the implementation of a sustainable waste management to reach environmental targets. It could encourage the public or private
sectors practice the organic waste separation in order to ensure sufficient feedstock for the OWTF. However, at present, there is no specific legislation on waste separation and none is planned in the immediate future, although the government has stressed the importance of it. On the other hand, currently there are no economic tools, such as waste disposal charge or tipping fee used to control MSW disposal and to facilitate organic waste separation, only the C&I charging scheme is being considered.

In order to achieve effective source separation and collection system of food waste, the following measures could be taken: (1) start the food waste source separation scheme by the Government bodies; (2) encourage voluntary participation of food waste separation by the “labeling scheme”; (3) modify refuse transfer stations and refuse collection points

References
INLAND WATER POLLUTION IN BANGLADESH: THE NEED FOR REGULATORY REFORM

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ABSTRACT  Water is crucial to socio economic development of a society and an integral part of environment. Inland water resources in particular are a precious natural resource, commonly utilised for agriculture, navigation, fisheries, livestock, forestry, hydropower and domestic purposes. The proper utilisation of inland water is important to safeguard quality of life and the sustainable socio-economic development of a least-developed country like Bangladesh.

The main purpose of the study was to understand legal measures taken in Bangladesh in order to protect inland water from pollution. The paper also examines the source of inland water pollution and its socio economic impact on the society. The research analysed the strengths and weaknesses of the present statutory framework; and identified the obstacles to implementing existing policies and regulations. The paper also explored the reason for inadequacies of current laws and also suggested some legal reforms to address the problem of inland water pollution.

In general, a legal and policy framework to control inland water pollution exists in Bangladesh. The government of Bangladesh has taken some important steps towards meeting the challenges of inland water management. However, in terms of inland water pollution control measures in a sustainable manner, Bangladesh is still lagging behind. The country has significant inland water resources but its people do not get benefits from them to the maximum possible extent. There is a gap between the planned and actual utilisation of inland water in the country. There is also a lack of institutional capability to enforce laws and policies and substantial shortcoming in terms of skill and expertise in undertaking practical action to protect inland water from pollution. In essence, there exists no plan focussing exclusively on inland water pollution control and therefore formation of such plan remains an important need for Bangladesh.

Keywords: Inland water pollution, Regulatory reform, Bangladesh
CARBON EMISSION AND WAYS OF CARBON REDUCTION IN TREATMENT SYSTEM FOR MUNICIPAL SOLID WASTE

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ABSTRACT Low-carbon treatment of municipal solid waste (MSW) is one of the key contents of low-carbon strategy in China mainland. Based on the analysis of carbon emission reduction differences on different collection-transportation ways, and the comparison of treatment technologies of MSW including landfill, incineration and comprehensive treatment. And then main ways of carbon reduction for every system are proposed.

Keywords: Carbon emission reduction, Municipal solid waste treatment, Collection/transportation

Introduction

In 2009, China mainland declared the reduction target of 40~45% of the carbon emission per GDP unit in 2020, and this carbon emission requirement will be evaluated as an obligation factor in the middle/long term layout of the development of social economy. The treatment of MSW (municipal solid waste) is a big carbon emission source and it is also emphasized as an important field for carbon reduction research. So far the carbon reduction in landfill promoted by CDM is the major work in this field in China. Take the treatment of MSW as a whole integrated system; it also includes the collection and transportation process. In order to have a complete view of the low carbon emission in MSW treatment, the carbon emission reduction in different stage of MSW treatment is analysed based on the calculation formulas and the factors which have influence on the carbon emission. With the analysis result some measurements are provided to control the carbon emission in different stage and would be helpful for the construction theory of low carbon emission city/society.

Carbon emission reduction in the collection/transportation of MSW

Calculation of the carbon emission

The carbon emission in the collection/transportation stage is mainly from the vehicles to transport the MSW, which can be reduced by using less fuel and increase the energy efficiency.

\[ E_{\text{CO}_2} = MSW \times D \times F \times NCV_{\text{fuel}} \times EF_{\text{fuel}} / \rho \]

Where:  
- \( MSW \) = Total amount of municipal solid waste as wet weight transported, t;  
- \( D \) = Distance from generation to treatment facilities, km;  
- \( F \) = Fuel consumption rate, L/(km);  
- \( NCV_{\text{fuel}} \) = Net heat value of fuel, GJ/t;  
- \( EF_{\text{fuel}} \) = CO2 emission factor of fuel, t CO2e /TJ;  
- \( \rho \) = Density of fuel, kg/L

Analysis of factors influencing carbon emission and ways to reduce carbon emission

(1) Fuel properties

Normally the fuel is diesel oil or gasoline, the carbon emission is different. In Table 1 below there are the data of the dumpcart of 3t loading, it can be seen that the carbon emission is a bit less when using gasoline. Considering gasoline truck is more appropriate to small load, so when the transportation requirement is not high it is recommended to use small trucks.

(2) Fuel consumption of trucks with different load

Obviously the carbon emission will be different when the load is not the same. To the dumpcart with common load value, the fuel consumption of unit distance and the corresponding carbon emission are listed in Table 2. It is indicated the emission of unit distance of big load is much less than that of small load, i.e. the
efficiency of big load dumpcart is better. So it is recommended to choose proper load of dumpcart to get an economical result.

Table 1 Carbon emission of trucks with diesel oil and gasoline as fuel

<table>
<thead>
<tr>
<th>Item</th>
<th>Net heat value (TJ/ t)</th>
<th>Emission factor (kg CO₂e/TJ)¹</th>
<th>Density (kg/L)²</th>
<th>Emission of unit fuel (kg CO₂e/L)</th>
<th>Fuel consumption of unit distance (L/km)³</th>
<th>Emission of unit transportation (kg CO₂e/ km · t garbage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel oil</td>
<td>43</td>
<td>74100</td>
<td>0.83</td>
<td>2.77</td>
<td>0.13</td>
<td>0.12</td>
</tr>
<tr>
<td>Gasoline</td>
<td>46</td>
<td>69300</td>
<td>0.73</td>
<td>2.36</td>
<td>0.14</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Notes: (1) Quoted from IPCC 2006¹; (2) Data from manufacturer of dumpcart

Table 2. Carbon emission by unit distance of dumpcarts with different load

<table>
<thead>
<tr>
<th>Tonnage</th>
<th>2 t</th>
<th>3 t</th>
<th>5 t</th>
<th>8 t</th>
<th>10 t</th>
<th>10 t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel consumption of unit distance (L/km)¹</td>
<td>0.1</td>
<td>0.13</td>
<td>0.18</td>
<td>0.2</td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td>Emission of unit transportation (kg CO₂e/ km · t garbage)</td>
<td>0.14</td>
<td>0.12</td>
<td>0.10</td>
<td>0.069</td>
<td>0.066</td>
<td></td>
</tr>
</tbody>
</table>

Notes: (1) Data from one manufacturer of dumpcart, fuel is diesel oil.

(3) Transportation distance and collection mode

The distance between garbage origination and the treatment facilities influence the carbon emission of transportation significantly. It is a common problem that the site selection of MSW is very difficult and limited, and mostly far from city center. To build the garbage collection and transfer center is a good way which can reduce the total transportation distance and create the condition to use big load dumpcarts instead of small one, thus reduce the carbon emission in this stage. In summary, the selection of using collection and transfer center, especially with compressing function, will reduce the carbon emission effectively before entering MSW treatment facilities which is far from garbage origination area. Of course, the configuration of collection and transfer centers is also very important to achieve a good transportation cost.

Carbon Emission of MSW by Landfill

Calculation of the Carbon Emission

IPCC stated that landfill is the major carbon emission source in the management of solid waste, but also the most feasible and effective field to realize the carbon emission reduction. The content of landfill gas is mainly CH₄ and CO₂, but the gas content and gas production depend on a series of parameters like local climate, geography conditions, etc. The recommended method is as follows:

\[
E_{CH_4} = MSW_L \times DOC_j \times DOC_j \times r \times \frac{16}{12} \times F
\]

\[
E_{CO_2} = MSW_L \times DOC_j \times DOC_j \times r \times \frac{44}{12} \times (1 - F)
\]

Where : \( E_{CH_4}, E_{CO_2} \) =Methane or carbon dioxide emissions at landfill, t; \( MSW_L \) = Total amount of municipal solid waste landfilled, t; \( DOC_j \) =Fraction of degradable organic carbon (by weight ) in the waste type j, %; \( DOC_j \) =Fraction of degradable organic carbon that can decompose, %; 16/12=Conversion factor from C to CH₄; 44/12=Conversion factor from C to CO₂; \( F \) =Fraction of methane in the landfill gas, %
This module is a quick and convenient way to calculate landfill gas production, when the total MSW amount in the city and the landfill rate are available. But it doesn’t take the landfill gas generation principle of MSW and influence factors into account so the result is gross and appropriate to estimate the gas production in a relatively big range such as a city, a province or a country.

Analysis of Factors Influencing Carbon Emission and Ways to Reduce Carbon Emission

(1) Garbage composition

The degradable organic carbon content depends on the garbage composition, which alters by season, city properties, geography conditions, resident living custom, standard of living and civil fuel structure, etc. To prevent the degradable organics from entering landfill can reduce the carbon emission.

(2) Landfill type

CH₄ content in landfill gas is different with landfill type. By the reaction principle, landfill can be divided into anaerobic, anoxic and aerobic. The typical CH₄ content of them is shown in Table 3.

By the domestic category, the landfill can also be sorted as sanitary landfill with collection and utilization of landfill gas, sanitary landfill without collection and utilization of landfill gas, simple landfill and semi-aerobic landfill. The landfill gas collection rate in landfill with collection and utilization system is about 30~40%. The carbon emission of these landfill types is shown in Table 4.

<table>
<thead>
<tr>
<th>Table 3 Landfill gas composition under different reaction principle (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill type</td>
</tr>
<tr>
<td>CO₂</td>
</tr>
<tr>
<td>CH₄</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4 Carbon emissions by unit MSW treatment in different landfill type (tCO₂e/t MSW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill type</td>
</tr>
<tr>
<td>sanitary landfill (with collection and utilization of landfill gas)</td>
</tr>
<tr>
<td>sanitary landfill (without collection and utilization of landfill gas)</td>
</tr>
<tr>
<td>Simple landfill</td>
</tr>
<tr>
<td>Semi-aerobic</td>
</tr>
</tbody>
</table>

The sanitary landfill and simple landfill are normally anaerobic process, so the CH₄ content is relatively higher, thus have the potential to bring high carbon emission. In the sanitary landfill with collection and utilization system of landfill gas, the CH₄ can be used properly, so the carbon emission can be controlled at almost the same level of aerobic landfill. Semi-aerobic landfill is similar to aerobic landfill and the landfill gas is mostly CO₂, so the carbon emission is less. Semi-aerobic landfill is advantageous on the carbon emission reduction but it is still a newly developed technology with relatively high cost. The sanitary landfill with gas collection and utilization system is currently the most feasible way of carbon emission reduction for landfill treatment. By the construction of big scale sanitary landfill, optimal design of landfill gas collection wells, and the proper management of collection system, gas collection rate can be higher and realize better carbon emission reduction target.

Carbon Emission of MSW Treated by Incineration

Calculation of the Carbon Emission
The carbon emission from incineration of MSW is the CO₂ generated in burning process, and the CO₂ production estimation formula is as follows:

\[
E_{\text{CO}_2} = MSW_t \cdot \sum_j WF_j \cdot dm_j \cdot CF_j \cdot CFC_j \cdot OF_j \cdot \frac{44}{22} + T_j \times CF_j \times OF_j \times \frac{44}{12}
\]

Where: \( E_{\text{CO}_2} = \) Carbon dioxide emission at incinerator \( \cdot \) t; \( MSW_t = \) Total amount of solid waste incinerated \( \cdot \) t; \( WF_j = \) Fraction of waste type/material of component j in the MSW as wet weight \( \cdot \) %; \( dm_j = \) Dry matter content in the component j of the MSW incinerated \( \cdot \) %; \( CF_j = \) Fraction of carbon in the dry matter of component j \( \cdot \) %; \( CFC_j = \) Fraction of fossil carbon in the total carbon of component j \( \cdot \) %; \( OF_j = \) Oxidation factor \( \cdot \) %; \( \frac{44}{12} = \) Conversion factor from C to CO₂; \( T_j = \) Auxiliary fuel consumption for incineration, t; \( CF_j = \) Fraction of fossil carbon in auxiliary fuel, %.

**Analysis of Factors Influencing Carbon Emission and Ways to Reduce Carbon Emission**

(1) Garbage composition

The mineral carbon content in the formula above (\( WF_j \cdot dm_j \cdot CF_j \cdot CFC_j \)) depends on the garbage composition. By the data of domestic garbage shown in Table 3 above, the plastic content is the main factor reflecting the mineral carbon.

(2) Incineration furnace type

The grate furnace and fluid bed are the most popular MSW incineration equipment in China. But in bed fluid some coal (normally less than 20%) is needed to co-burn with MSW, so the carbon emission is much higher. The carbon emission of unit garbage treatment is shown in Table 5.

**Table 5 Carbon emission of unit garbage treatment by incineration (tCO₂/t garbage treated)**

<table>
<thead>
<tr>
<th>Furnace type</th>
<th>CO₂ (t)</th>
<th>Remark (Calculation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grate furnace</td>
<td>0.557</td>
<td>By the garbage content date in reference 1, 2</td>
</tr>
<tr>
<td>Fluid bed</td>
<td>0.994</td>
<td>20% coal co-burnt, carbon emission of standard coal is 2.493t CO₂/t</td>
</tr>
</tbody>
</table>

**Conclusions**

Carbon emission reduction is an important part of MSW treatment, by the carbon emission analysis of the entire process of MSW treatment, the ways below are indicated to control the carbon emission: 1) use big load dumpcart to get high transportation efficiency; 2) build collection and transportation center with compressing facilities when the treatment site is far from garbage origination area with high garbage generation; 3) reduce the organic content in garbage entering landfill; 4) construct the sanitary landfill with landfill gas collection and utilization system of high efficiency; 5) grate furnace is better to control the carbon emission than fluid bed under the same conditions, so recommend to use when feasible.
IS NON-PROBABILITY SAMPLING A FEASIBLE APPROACH FOR STREET INTERCEPT SURVEYS IN HONG KONG?

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ABSTRACT This study examined the feasibility of using the less resource intensive non-probability sampling (NPS) in conducting street intercept surveys in a setting where refusal rates are high. NPS results were compared to probability sampled (PS) data from in-street interviews on household electronic and electrical equipment consumption and disposal patterns in Hong Kong. Respondents were selected at six major transport hubs (339 by NPS and 125 by PS methods). Of the 430 variables tested for differences in distribution between the two sampling methods, less than 3% were considered to have an impact on policy making. Although it was reaffirmed that PS generates more representative estimators for socio-demographic variables, NPS data were of similar quality to PS data and can be used as a more time- and cost-saving approach if researchers are interested in the broad picture (e.g. household-based parameters) and that socio-demographic characteristics are not known to have influence on the data.

Keywords: Probability sampling, Non-probability sampling, Street intercept survey, E-waste, Hong Kong

Introduction

Hong Kong residents are consistently bombarded with various forms of questionnaire surveys both to obtain information and as marketing strategies to sell under the guise of research. The general decline in response rates is a cause for concern for researchers in obtaining reliable data from a large number of individuals using conventional probability sampling (PS) methods. Unless there is a way to prove that no systematic differences exist between the respondents and non-respondents, non-response bias may be present when participants are recruited by PS means thus making the distribution of PS results similar to those obtained from non-probability sampling (NPS). This effect will be more prominent in survey environments where response rates are low. The current study aimed to explore the use of NP sampling as opposed to P sampling with face-to-face interviews to collect consumer consumption and behavioral patterns for the upcoming producer responsibility scheme on waste electrical and electronic equipment in Hong Kong.

Often used in quantitative research to gather statistics for a given set of questions, questionnaire based research is a useful tool for gathering information from a large number of individuals for policy and decision making. Since a full list of all (or even the majority of) households is not publicly available in Hong Kong, a feasible alternative to obtain family-based information is to conduct interviews by intercepting passer-bys on streets. Face-to-face interviews using NPS is usually less costly and more time efficient to implement for long questionnaires because of the higher degree of interviewer control and the ability to achieve higher response rates compared to telephone, postal and online surveys1. Hence, if our hypothesis is true, that NPS generates practically the same results as those from PS in certain contexts, it may then be permissible to use the more cost-saving NPS in future surveys without compromising on data validity.

Materials and Methods

Street Intercept Survey

Six interview locations, all important transport hubs connecting different parts of the city, were selected for carrying out the questionnaire survey. The scope of the questionnaire was limited to household ownership of televisions, washing machines, air-conditioners, refrigerators, and personal computers (TWARC). These five types of electronic and electrical equipment have been prioritized in the proposed producer responsibility scheme. It was expected that the respondents will not be restricted to certain geographic or demographic characteristics.

Intercept interviews at these locations were conducted in two ways. The first way was a NPS of 339 respondents. No instruction on how to select the respondents were given to recruited surveyors and their feedback showed that they tended to intercept pedestrians who have been subjectively judged as easy-to-approach or more likely to answer the questionnaire. The other part of the street survey involves the
completion of another 125 questionnaires using PS at the same locations. The surveyor would first choose a spot with high pedestrian concentration and then the closest passer-by would be intercepted for interview at 30-second intervals no matter what. Should the intercepted pedestrian decline to participate in the survey, the surveyor would intercept the pedestrian passing the surveyor on the next 30th second. To allow for more stringent analyses of the data, response rates (percentage of number of successful cases divided by the number of people approached) were noted down for both PS and NPS approaches.

Data Analyses

Key variables to the study were first tested for normality using the Kolmogorov-Smirnov test with Lilliefors Significance Correction (K-S test). Differences of mean between P and NP groups were then tested using the independent samples t-test and Mann-Whitney U Test on discrete and continuous variables. Categorical and nominal variables on the other hand, will be analyzed using the Chi-square test and Fisher’s Exact Test. In all cases, 2-tailed tests were performed and SPSS, version 14.0 for Windows software (SPSS, Inc., Chicago, Illinois) was used for data analyses.

Results and Discussion

A total of 1851 and 1503 persons were approached for NPS and PS respectively. The numbers of successful interviews were 339 (NPS) and 125 (PS) yielding higher response rates for NPS (18%) compared to that of PS (8%). A low response rate is not uncommon for street interviews in our study given that all six locations are busy commuting hubs (i.e., the passer-bys are usually in a rush) and there is a general decline in the willingness of individuals to participate in surveys owing to widespread use of surveys to obtain information and ‘sugging’ (selling under the guise of research).

Demographical Characteristics

Both P and NP data yielded a median per capita income group of HK$8000 – HK$14999, which contains the citywide median monthly income value of HK$10000. However, both groups of respondents were better educated than the average Hong Kong citizen at the expense of the less and non-educated sector of society. Since they are both voluntary surveys, it is common to find exclusion of less educated individuals due to self-selection bias. All respondents in the NP group were younger and received formal education. The older population, especially the 65+ group, was under-represented. Results confirm that PS is the preferred sampling method as far as demographic and socio-economic variables are concerned and that the low response rate (8%) has not hampered the representativeness of the socio-demographic data.

Variation in the Age and Numbers of TWARC Owned

About one-third of the tested variables were shown to have different mean values (Table 1). The differences in the means of variable with respect to the two sampling methods are non-unidirectional and the actual difference in the mean value is also small. For example, the mean numbers of TV in use were 1.67 and 1.90 respectively for the NP and P groups. Upon rounding, both would mean about two TVs per household with the NP group having less than 0.3 set of TV per household. The situation is similar for variables on other TWARC quantities found at home. Whether the small differences noted is material or not depends much on the way the data will be used. If the household based findings are extrapolated to obtain a city-wide estimate, the differences in the mean values detected can be material. For example, there are currently 2.34 million domestic households in Hong Kong indicating that the territorial wide average for TVs in use and requiring proper treatment (assuming that mean service life remains the same as the one found in the present study) would be 3.90 and 4.44 million units respectively for NP and P groups yielding a difference of 0.54 million units. According to Robinson (2009), the contribution of each item to the annual electronic waste (e-waste) production can be calculated using Equation 1:

\[
E = \frac{WN}{L}
\]
Where: E = E-waste production; N = Number of units in service; M = Mass of the item; L = Average lifespan

Table 1. Key variables with statistically significant differences between PS and NPS data

<table>
<thead>
<tr>
<th>Method</th>
<th>Mean</th>
<th>SD</th>
<th>Levene’s Test Sig</th>
<th>t-test Sig. (2-tailed)</th>
<th>U test Sig.(2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traditional flat panel television</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number in use</td>
<td>NP</td>
<td>0.61</td>
<td>0.79</td>
<td>0.03*</td>
<td>0.01*</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>0.42</td>
<td>0.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average age of previous set(s)</td>
<td>NP</td>
<td>6.43</td>
<td>2.72</td>
<td>0.64</td>
<td>0.03*</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>7.95</td>
<td>3.50</td>
<td></td>
<td>0.02*</td>
</tr>
<tr>
<td><strong>High Resolution LCD/plasma television</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number in use</td>
<td>NP</td>
<td>0.16</td>
<td>0.44</td>
<td>0.00**</td>
<td>0.00**</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>0.52</td>
<td>0.76</td>
<td></td>
<td>0.00**</td>
</tr>
<tr>
<td>Average age of current set(s)</td>
<td>NP</td>
<td>0.18</td>
<td>0.54</td>
<td>0.00**</td>
<td>0.00**</td>
</tr>
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<td></td>
<td>P</td>
<td>0.57</td>
<td>1.00</td>
<td></td>
<td>0.00**</td>
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<td><strong>Television total</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Number in use</td>
<td>NP</td>
<td>1.67</td>
<td>0.79</td>
<td>0.00**</td>
<td>0.03*</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>1.90</td>
<td>1.07</td>
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<td><strong>Window type air conditioner</strong></td>
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<td>Average age of current set(s)</td>
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<td>4.92</td>
<td>3.33</td>
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<td>3.90</td>
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<td></td>
<td>P</td>
<td>8.09</td>
<td>2.55</td>
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<td>0.00**</td>
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<td><strong>Split type air conditioner</strong></td>
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<td>Average age of current set(s)</td>
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<td>1.29</td>
<td>2.41</td>
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<td>0.01*</td>
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<td>P</td>
<td>2.08</td>
<td>3.05</td>
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<td>0.02*</td>
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<td>NP</td>
<td>5.37</td>
<td>3.14</td>
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<td></td>
<td>P</td>
<td>7.48</td>
<td>2.63</td>
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<td>0.00**</td>
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<tr>
<td><strong>Refrigerator</strong></td>
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</tr>
<tr>
<td>Average age of current set(s)</td>
<td>NP</td>
<td>5.84</td>
<td>3.70</td>
<td>0.01*</td>
<td>0.03*</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>6.95</td>
<td>4.95</td>
<td></td>
<td>0.04*</td>
</tr>
<tr>
<td>Average age of previous set(s)</td>
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<td>6.94</td>
<td>2.64</td>
<td>0.17</td>
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</tr>
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<td>P</td>
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<td>2.54</td>
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<td>0.00**</td>
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<td><strong>Desktop Computer</strong></td>
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</tr>
<tr>
<td>Number in use</td>
<td>NP</td>
<td>1.25</td>
<td>0.74</td>
<td>0.64</td>
<td>0.00**</td>
</tr>
<tr>
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<td>0.77</td>
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<tr>
<td>Number stored</td>
<td>NP</td>
<td>0.12</td>
<td>0.38</td>
<td>0.00**</td>
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<tr>
<td></td>
<td>P</td>
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<td>0.55</td>
<td></td>
<td>0.01*</td>
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<tr>
<td><strong>Laptop Computer</strong></td>
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</tr>
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<td>Number in use</td>
<td>NP</td>
<td>0.55</td>
<td>0.80</td>
<td>0.50</td>
<td>0.02*</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>0.76</td>
<td>0.87</td>
<td></td>
<td>0.01*</td>
</tr>
<tr>
<td>Average age of current set(s)</td>
<td>NP</td>
<td>0.86</td>
<td>1.41</td>
<td>0.00**</td>
<td>0.01*</td>
</tr>
<tr>
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<td>P</td>
<td>1.41</td>
<td>2.04</td>
<td></td>
<td>0.00**</td>
</tr>
<tr>
<td>Number stored</td>
<td>NP</td>
<td>0.02</td>
<td>0.13</td>
<td>0.00**</td>
<td>0.00**</td>
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<td></td>
<td>P</td>
<td>0.18</td>
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<td><strong>Computer total</strong></td>
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<tr>
<td>Number stored</td>
<td>NP</td>
<td>0.13</td>
<td>0.42</td>
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<td>0.00**</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>0.42</td>
<td>0.87</td>
<td></td>
<td>0.00**</td>
</tr>
</tbody>
</table>
Substituting the figures into equation one using an average TV weight figure of 0.0308 tons/unit from Chung et al. (2011), the annual difference in tonnage between NP and P groups would be approximately 1077 tons or less than 3 tons per day. If such a figure was used to plan for treatment or recycling facilities for the entire city, then a difference of a thousand tons a year will not make any difference in the larger plant’s designed capacity as it is a standard practice to factor in spare capacity in the order of 10-15% of the actual processing capacity. Similarly, if it is household-based parameters that are in question (such as for estimating the amount of advanced recycling fee that needs to be paid per household), then the differences are also immaterial.

Variation of Categorical Variables

While a larger proportion of P group (64.1% compared to 52.1% of NP group) was selling old TWARC to e-waste collectors as their adopted method of disposal, this remains the prevailing means to get rid of e-waste for both groups both in practice and preference. Therefore, observed differences in terms of how consumers dispose of their TWARC waste should not have much effect on e-waste collection and transportation policy making.

The decision on whether to purchase new televisions as a result of digitalization was also seen to be significantly different between P and NP groups. Almost half of the P group (46.3%) compared to 24.5% of the NP group indicated that they had already bought or would buy new television sets whereas over half of the NP group (52.7%) compared to 43% of the P group indicated that they will not. A larger proportion of the NP group (22.7%) relative to the P group (10.7%) are still undecided whether to procure new television sets because of the digitalization. Such difference in preferences between the two groups may have an effect on predicting the life spans of television sets and on designing treatment capacities. But since the change to digital broadcasting is an one-off event, even if there is an unexpected rise in the obsolescence of televisions, it will not be too difficult to handle them by making incremental changes to existing or planned infrastructure.

Conclusions

The differences observed between the two sampling methods were considered to be moderate and low for most of the key variables. Thus, in terms of policy making, NPS generated similar quality of data compared to PS. Therefore, NP sampling can be a more time and cost-saving approach in obtaining data of similar quality to those from P sampling if researchers are interested in only the broad picture (e.g. household-based parameters) and that socio-demographic characteristics are not known to have influence on the data.

Acknowledgements

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References

A COMPARATIVE REVIEW OF LIFE CYCLE ASSESSMENTS IN MUNICIPAL AND ORGANIC WASTE MANAGEMENT

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ABSTRACT Despite the increasing use of Life Cycle Assessment (LCA) in waste management policies and strategies in the past decade, there is still a lack of qualitative review of the role LCA in waste management sector. This paper is based on a review of over 15 process-based LCAs in municipal solid waste (MSW) and organic waste management systems, which were published between 2000 and 2010 in peer-reviewed journals or consultancy reports. Methodological aspects of the selected LCAs were compared according to the requirements and guidelines stipulated by International Standard Organisation (ISO). The results suggest that LCA is a useful tool to analyse the environmental burdens and economic benefits, and the necessity of a certain type of waste management. It should be used as a decision support tool in waste management. It is particularly useful to identify the most significant environmental burdens for a waste management scenario and evaluate alternative scenarios to see which system can result in better environmental performance. Recommendations on how to make LCA more useful and robust in waste management will be provided in this paper.

Keywords: Life cycle assessment, Municipal solid waste management, Organic waste management

Introduction

Life cycle assessment (LCA) has been commonly used to evaluate the environmental performance of MSW management systems in the past decade. However, there are very few studies being done to review the methodological aspects of the LCA studies in waste management. This review aims to qualitatively compare 16 process-based LCAs focusing on MSW or organic waste management systems which are published between 2000 and 2010 in peer-reviewed journals or university report. Through this review, we will understand the methodology of the LCAs in waste management particularly whether their LCA analysis are consistent with the requirements and guidelines stipulated by ISO [1-2] regarding the four main phases of an LCA (i.e., goal and scope definition, inventory analysis, impact assessment and interpretation). Moreover, this review can also help us understand the degree of usefulness of LCA as a tool to support decision-making in waste management.

LCA in Waste Management

Past decisions on waste management strategy and the structure of waste management systems have relied on the waste management hierarchy originally advocated by the European Union. This has varied in its exact form, but usually gives the following order of preference: waste reduction; re-use; materials recycling; composting; incineration with energy recovery; and landfilling. Although the hierarchy has the advantage of being simple and providing a sound principle regarding the priority of waste management options, the use of such a priority list has its limitations [3]. For example, there is no scientific or technical basis on the selection of waste treatment option (e.g., why materials recycling should always preferred to energy recovery in real life situation). The hierarchy cannot predict what combination of treatment options is more preferable in an integrated waste management system (e.g., whether composting combined with incineration of the residues would be preferable to materials recycling plus landfilling of residues). Moreover, the hierarchy does not consider economic issues.

There is a shift in focus from relying much on the waste hierarchy, i.e., basic guidelines on how to prioritise ways of handling waste in general, to moving more towards specific analyses which are based on broader environmental and economic analysis [4-5]. In other words, rather than a rigid hierarchy of preferred waste management options (e.g., landfills vs. incinerators), many suggest a holistic approach which recognizes that all individual waste management options can have a role to play in sustainable waste management, and the overriding objective is to optimize the whole waste management system to make it environmentally and
economically sustainable and socially acceptable [3, 6]. Therefore, the waste hierarchy is a sound principle regarding how our waste should be handled, however, it should be validated by introducing life-cycle approaches in waste management. In particular, LCA is a useful tool to support decision-making on which combination of waste treatment technologies is the most environmentally preferable.

This paper will present a review of 16 LCAs published between 2000 and 2010, which focus on MSW and organic waste management. It aims to understand how LCAs are being conducted in these studies, whether LCAs can address the original goals and objectives for these studies, and what further improvements can be made for future LCA studies in waste management.

Method
A total of 16 LCA on waste management systems published between 2000 and 2010 are selected in this review. Each selected LCA addresses a wide array of environmental emissions and/or impacts. Most of the selected LCAs are proposed in peer-reviewed scientific journals and one is published by a university. These selected LCAs are believed to represent the majority of those LCAs conducted in waste management sector in the past decade. The issues to be covered in this review of life-cycle analysis on waste management include definition of goal and scope, inventory analysis, impact assessment and data interpretation. These issues are considered important in the ISO14044 Life Cycle Assessment requirements as stipulated in the international standards [2, 7]. They depict the characteristics of the LCA design and are essential to the interpretation of the LCA results.

Results and Discussion

Definition of Goal and Scope
According to ISO [2], the goal and scope of an LCA shall be clearly defined and described with the intended application. The reviewed LCAs address waste management strategy on MSW or organic waste at local, regional and national scales in various countries, as well as at a specified unique scale such as a traditional market or a hypothetical community in various countries. In these LCAs, the geographical specificity is considered less important than the evaluation of the waste treatment processes which are essential to the calculation of the life-cycle inventory. All of the reviewed LCAs make comparative assertions by evaluating the environmental performance of various types of solid waste management systems or technology options. The comparison is usually made between alternative scenario(s) and a defined baseline (the current waste management system) or comparison be made among various systems or options. However, the functional unit is not defined very clearly in the reviewed LCAs. Most of the studies mention the amount of waste generated and composition of waste but only a few studies explicitly include a temporal component (e.g., per year) in the defined functional unit. Without a temporal component in the functional unit, it is impossible to relate the environmental impacts and waste generation to a particular period of time. In the reviewed LCAs, the life cycle stages of MSW management commonly include the following: (1) collection; (2) transportation to a sorting facility; (3) sorting; (4) transportation to a treatment facility; and (5) treatment – including recycling, biological treatment, thermal treatment and landfilling. Nevertheless, there is a lack of clarity to define the system boundaries in the reviewed LCAs and only a few studies do justify with reasons for the choice of the system boundaries and provide the assumptions made behind their choice as required by ISO [2]. This may be of greater concern because the omission of certain processes, inputs or outputs associated with life-cycle stages without clear explanations will affect the validity of the LCA results.

Inventory Analysis
The LCAs reviewed shows that it is common to use data from the literature, government statistical reports and database to determine environmental emissions or burdens. One reviewed LCA also use actual emission measurements for building its inventory data for an incineration process. Although the use of database from computer softwares is a common trend in LCA, it should be borne in mind that some databases may be country-specific and there may be geographical differences in terms of data quality as observed in this review. Efforts should thus be made to collect/use data that are as specific as possible for the processes in question and that the data represent the temporal and spatial boundaries of the study as
stipulated in ISO [1, 6]. It is thus recommended to choose computer models that allow users to put in new data for modeling based on site-specific information.

**Impact Assessment**

The most common impact categories included in the reviewed LCAs of MSW or organic waste management include global warming potential, acidification potential, eutrophication and photochemical oxidation whereas toxicity impacts are much less popular possibly due to its complexity and uncertainties involved [8]. Most of the reviewed LCAs are presented by the individual impact categories which are normalized by a reference value in some cases. Moreover, weighting valuations across impact categories is not widely used in the reviewed LCAs possibly due to the reason that weighting methods are subjective and there are no credible scientific methods to do it. To overcome this problem, more than one weighting method can be applied in a study to increase the credibility of the weighting results. It is especially valid for LCA applied in waste management as the weighted impacts, if done in a credible way, can provide a better basis for public discussion. From the reviewed LCAs, only a few incorporate life cycle costing (LCC) in their analysis. The LCC tend to focus on the waste management financial costs (e.g., waste collection fees, processing costs, landfill costs) and revenues from the systems (e.g., compost and electricity). One LCA include the consideration of greenhouse gas savings in their costs and benefits analysis but not other environmental impacts. In general, the reviewed LCAs do not consider monetized environmental burdens in their LCAs of MSW management.

**Interpretation**

The preferred order of waste management illustrated by the results of the reviewed LCAs is consistent with the waste hierarchy except for the mixed treatment scenario types which use a combination of waste treatment technologies. This observation has two insights. First, this indicates that LCA can be a useful tool to validate the waste management strategy promulgated in the waste hierarchy. Second, the environmental performance of mixed treatment option may vary depending on local factors and system characteristics and thus cannot be predicted by a simple waste hierarchy. In such cases, LCA can be used to estimate the environmental burdens of the mixed treatment options and provide information on the best preferable option in each individual case. Nevertheless, the result interpretation of the reviewed LCAs may be limited because they do not cover all impacts of the waste management systems but only focusing on a few major impact categories. The comparative assertions made be these LCAs can be improved if other impacts are also considered such as noise, odours, land use, degree of public participation. This is also in compliance with the ISO [2] requirements that a sufficiently comprehensive set of impact category indicators should be selected for LCAs intended to be used in comparative assertions for public disclosure. Meanwhile, it is also useful if the results can be weighed by credible methods so as to assess the combined total impact of different environmental impact categories and this can reaffirm the validity of the LCA results on which waste management scenario performs the best in the environmental view. Moreover, to make a more comprehensive analysis on the economic costs, environmental LCC in addition to financial LCC should be included which can help assess the economic costs and monetized environmental burdens from each treatment scenario.

**Conclusions**

Overall, it can be concluded from this review exercise that LCA is a useful tool to analyse the environmental burdens and economic benefits, and the necessity of a certain type of waste management. It should be used as a decision support tool in waste management. It is particularly useful to identify the most significant environmental burdens for a waste management scenario and evaluate alternative scenarios to see which system can result in better environmental performance. To make LCA more useful and robust in waste management, the future LCA practitioners should follow more closely the requirements and guidelines given by ISO [2]. Specifically, the system boundaries should be defined more clearly and with justifications for any omissions of processes or emissions involved. Further efforts can be made to expand the impact categories considered in waste management and to apply more scientific and credible weighting methods to assess the total impact across different environmental impact categories. This would enhance the validity of the LCA results for comparative assertions on waste management. Moreover, to make a
more comprehensive analysis on the economic costs, monetised environmental costs in addition to financial costs should be included in the life cycle costing analysis.

References