GUIDELINE PROPOSAL FOR AN INTEGRATED AND SUSTAINABLE SOLID WASTE MANAGEMENT AT SMALL COMMUNITIES

CYNTHIA FANTONI ALVES FERREIRA - Civil Engineering. Environmental Management Specialist. Master in Environmental Science. Doctor student and Research Assistant at Federal University of Minas Gerias, Sanitation and Environmental Engineering Department – DESA/UFMG

LISÉTE CELINA LANGE - DESA/UFMG - Ph.D. Environmental Technology, London University/UK. Lecturer, Sanitation and Environmental Engineering Department – DESA/UFMG

CONTACT
Cynthia Fantoni Alves Ferreira
DESA/UFMG, Department of Sanitation and Environmental Engineering, Federal University of Minas Gerais, School of Engineering, Contorno Avenue, 842 – 7th Floor, 30.110-060, Belo Horizonte, Minas Gerais, Brazil
Phone: +55 31 3238-1039 - E-mail: cynthia@desa.ufmg.br

TECHNICAL SUMMARY

In Brazil, around 73% of the municipalities have populations of less than 20,000 inhabitants (IBGE, 2005). In many of these towns, shortage of skilled labor, and the lack of technical, economic, environmental, and social criteria to deal with solid waste are enormous administrative and environmental problems.

Usually, these small communities receive small resources and few lines of credit, which results in the inexistence of public sanitation programs. Therefore, the development of directives to guide the adequate waste management and to implement efficient projects in accordance to environmental standards and sanitation sustainability is vital.

This article is based on a Reference Protocol for the implementation of Integrated and Sustainable Solid Waste Management system at small communities (FERREIRA, 2004).

Alternative, simple, and feasible techniques for small communities have been researched. Effective guideline for a final disposal facility (sustainable landfill) and technologies for minimization and treatment of solid waste (selective collection, storage of recyclable elements, organic fraction composting, among other actions) aiming environmental licensing have been prepared.

This guideline is based on technical, administrative, legal, social, and economic aspects of integrated and sustainable solid waste management at small communities (ISSWM) found to be relevant and which are described step by step.

The guideline elaborated in this research might help small community decision makers to
determine the practical actions to be undertaken to solve their solid waste management problems and avoid significant loss of public resources.

The best alternatives shall be dictated by local and particular conditioning factors pertaining small municipalities, among which are the preliminary conditions: environmental, socio-cultural, political, economic, financial, and simultaneously the integration and sustainability to the other management stages.

INTRODUCTION

The rising quantity of municipal solid wastes (MSW), associated with the growing concern about environmental quality, health of the population and the lack of a suitable management model at the municipal governments, has led to the search for technologies that can meet a standard of economic, environmental, technical and social sustainability.

Management of solid urban waste must be integrated, i.e., it must encompass articulated stages, from waste reduction to its final disposal and its activities must be compatible with other environmental sanitation systems. The active and cooperative participation of the first, second, and third sectors, namely, governmental offices, private initiative, and the organized civil society is essential.

In most municipalities, including small size municipalities whose population is under 10,000 inhabitants and that correspond to 48 % of the Brazilian municipalities, the commonest final destination of municipal solid waste (MSW) is its disposal at open-air landfills. Census data from the Pesquisa Nacional de Saneamento Básico – PNSB (2000) indicate that 63.6 % of these municipalities dispose of MSW in dumps, 13.8 % in sanitary landfills, and another 18.4 % send their waste to controlled landfills. Thus, it is observed the great need of most small municipalities concerning technical, economic, and political conditions to solve the waste problem.

In this context, this work constitutes a proposal to develop a guideline to meet small community requirements. It allows municipal officers and their assistants to understand the Integrated and Sustainable Solid Waste Management (ISSWM) better by offering elements and guidelines for decision-making and in this way contributes to reduce planning and work execution costs, implementing effective actions with the optimization of use of financial and human resource available.

METHODOLOGY

This phase presents how a small municipality manager should proceed to elaborate a ISSWM system step by step so that technicians and city hall managers have some material in hand to guide them about planning, project, implementation, operation of systems which are at the same time efficient and economical and suitable to the typical characteristics of each region, and evaluating their systems. (Figure 1)

This protocol seeks to identify simple technical alternatives for the municipalities. It takes into account from the final disposal unity (sustainable landfill) to minimization and treatment technologies (selective collection, separation warehouse, and composting unity) to environmental licensing.
RESULTS

1. PLANNING

The planning stage is fundamental for the Protocol framework. All necessary information for choosing the system to be adopted is presented.

General data survey
Data collection must be made at regional scale. Data not available at the city hall can be easily obtained at IBGEs site (www.ibge.gov.br) and from related institution. The information surveyed must include a general description of the municipality, characterization of the current urban cleaning system and wastes generated, and the current situation of the final waste disposal.

Municipality Characterization
In terms of municipality characteristics and the ISSWM system for small communities, it is necessary to search specific information on physical (area occupied, number of districts, location), environmental (existence of parks, environmental protection areas), social-economic (economic activity of the municipality, commerce, industry), infrastructure aspects (water, sewage, health services). Equally important are data on the population, population growth forecast, community buying power, and habits which define the type of inhabitants living in the city and that generates the waste which will be disposed of in the environment.
**Characterization of the current urban cleaning system**
The identification of the current operational structure of the cleaning system and the information on all stages, from generation to final disposal, are fundamental for the preliminary diagnose of the USW situation of the municipality.

It consists in the survey of data such as “per capita” waste production, waste handling, collection and transportation, system scope, types of equipment used, existence of drop-off areas, collection frequency, occasional treatments, and recycling and disposal of final residues.

**Area chosen for the disposal of final residues**
The selection of an appropriate area for the implementation of a landfill reduces the costs and prevents unnecessary expenses. The area selection criteria will vary according to the municipality, depending on the physical environment, urban infrastructure, and others. Many times, the city hall has areas available that it wants to be evaluated, or even some plots which have been used as landfill. Thus, land expropriation costs and delays in landfill implementation can be reduced.

Other data to be surveyed for the preliminary characterization of the area location restrictions are soil type and local geology, type of vegetal covering, hydric resources (including water bed level in the disposal area), prevailing winds, use of neighboring areas (urban, rural, agricultural, livestock farming , and industrial), and topography. In the case of hydric resources, as they are the most important natural resources and are finite, description of their use for municipal water must be included, if such is the case.

**Environmental education**
Environmental education is a fundamental part for the success of any selective collection program. Sensibilizing the community and getting its participation are fundamental for the guideline.

The environmental education program have envolved a elaboration educational materials, lectures, events with organized associations, schools, workshops, theaters, stimulating the community perception as to the problems caused by wastes.

**2. PROJECT**

After planning and with these data in hand, it is possible to choose the type of system to be adopted. The elaboration of projects aimed at small size communities must follow engineering criteria with an economic evaluation suited to their reality. The choice of the system to be adopted shall take into account the area available for the final disposal of USW, the area topography, type and characteristics of the soil, residue characterization, weather data, and others.

**Sustainable Landfill**
In the case of small size municipalities, the alternative suggested is the implementation of a sustainable landfill. It consists in trenches where residue is disposed and covered with intermediate layers of the excavated soil in the end of each daily journey. Leachate and gas draining and insulation shall be used accordingly.

A sustainable landfill for the final disposal of solid waste(SW) must be designed according to engineering criteria in which a data set must be collected and incorporated to the project
for the landfill to meet its function along its lifetime and after its closure. (LANGE et al., 2002). A sustainable landfill requires:

The planialtimetric plan, location planning, plan of the location for investigation, plan and details of the draining systems (surface, leachate, gases, etc.) and of the trenches.

Insulation system, if necessary depending on the type of soil.
Due to the reduced volume of residues of small size municipalities, it is possible to adopt simplified systems with the reduction of costs and suitable safety. A significant cost reduction can be obtained with the choice of materials used in the insulation of the bottom and the sides of the landfill and if the soil characteristics are favorable for the use of mineral materials. This means that after the characterization of the soil, compacted soil can be used in insulation as long as it has suitable permeability characteristics. If alternative insulation with local soil is not feasible, the project must provide for geomembranes.

It must be evaluated: layer thickness, soil granulometry, low permeability, low void index, hydraulic conductivity (< 10⁻⁷ cm/s) and the existence/ if the water bed is over 2 m away from the trench bottom. The most common types of soils used are clayey soil with low and high plasticity, and sandy-clayey soil with significant clay content.

Trench Dimensioning
For small communities, it is recommended the used of trenches due to the reduced amount of residues generated by these municipalities and because earth moving machines to open trenches are little availability.

Trenches are excavated into the soil for later filling with residue. The soil removed from the local must be reserved for the intermediate layers in the end of each day work and the final layer. The first stage of the dimensioning of the trenches is sizing itself. The trenches are prism-shaped and have depth ranging from 2 to 3 meters. They can also be parallelepiped-type with sides little inclined in relation to the bottom (inclination 1:2 to 1:3), depending on the type of soil. (Figure 2)
Surface water draining and outflow system

Observed the topography and determined the location of the trenches, the surface draining system for the area must be designed. For conditions such as those of small municipalities, the proposal must be simple, with hand-made culverts in the preferential direction of surface water outflow. (Figure 2)

Residue covering system

The objective of covering (daily, intermediate, and final) is to minimize visual impact and the proliferation of vectors and stenches generated by the presence of open-air residues in the trenches. However, the main function of this insulation is to make water leakage into the anaerobic system difficult. Normally, covering is executed with local soil from the trench excavation.

In the case of the final covering, it is important that there is a compacted impermeable soil layer (clay) along with a surface vegetal protection layer.

Draining and leachate treatment system

In small communities, it is also suggested the adoption of an efficient and simple-operation system compatible with the municipality structure that does not area waste such as occurs in the alternative treatment by basins for example, as the quantity of leachate generated by these municipalities is small enough. It is proposed the excavation of a central culvert at the bottom of the trench (suggested dimension of 50 x 50 cm) filled with 50 cm of crushed stones number 3 and bottom inclination of 2% (Figure 2). The system ends in a well. It is suggested the use of PVC, 150mm.

Gas draining system

For this solid residue landfill system for small communities, although gas generation is reduced, a gas draining system must be provided. The estimation of the gas volume produced by a landfill is not a simple task given the number of factors that influence its generation.

The gas drains must be disposed on the leachate drain system preferably cross the landfill and vertically up to its surface (Figure 2), similar to exhaust chimneys. Traditionally, these “chimneys are made with reinforced concrete draining shackles, preferably with holes. Alternatively, other materials may be used such as tires, oil drums, PVC tubes, and PET bottles, which must be perforated and filled with crushed stone size 2. Additionally, due to the low gas generation, gas burners placed at the top ends of the chimneys can provide controlled gas burning.

Selective collection

As to garbage can design, it is necessary to consult the community and present a number of options as to the type of recipient, frequency of collection, itinerary, collection vehicle to use, etc. The choice of the best containers for selective collection will depend on the economic resources of the municipality. For example, it can be used drums painted with standard colors, polyethylene drums, etc.

The location of the garbage cans must be planned for each town district and they must be placed strategically and not too far apart. The type of residue collected must also be properly identified with colors and signs.

The community must always be informed about the course and the results of the project as a means of stimulating actions and showing the results.
Separation warehouse and composting unit
The project of the separation warehouse must include workbenches for careful separation of recyclable materials by hand, storage booths, stockroom, and toilets. Its size must be calculated according to the quantity of residues generated at the municipality. The choice of recyclable material to be separated depends above all on the market demand. Nevertheless, in general in small communities the following materials are separated: paper and cardboard, rigid/film plastic, PET, glass, and ferrous metals.

The composting yard size must be based on the following data: population considered, generation of composting residues per capita, generation of residues derived from pruning and weeding, collection days, and others. The yard must be properly paved for processing composting and must be slanted enough for draining rain water and leachate produced during composting. It is recommended that the municipality carry out a previous analysis of the selective collection process (if existing) and the real quantity of composting residues produced by the collection for the proper construction of the composting yard and thus avoid financial losses for the municipality.

Legal aspects
Resolution CONAMA number 308 dated March 21st, 2002, which provides for the Environmental Licensing of the final disposal of urban solid residues generated by small municipalities, takes into consideration their difficulties to implement and operate solid residue final disposal systems such as required by the environmental licensing process.

It is considered that the implementation of urban solid residue final disposal systems must be preceded by Environmental Licensing, which is granted by environmental control agencies in the terms of the legislation in force and of this Resolution under the following conditions: (MMA, 2004)

- Urban population of up to 30,000 inhabitants as reported by the last IBGE census.
- Daily production of urban solid residues by the urban population of up to 30 tons.
- For the effects of this Resolution, the measures for the final destiny of the solid residues must observe at least the aspects defined in this Resolution concerning the selection of locations and the technological conception.
- The measures of the final disposal of solid residues considered in this Resolution must be submitted for Environmental Licensing with the appropriate environmental agency belonging to the National Environment System (Sistema Nacional de Meio Ambiente - SISNAMA) and observing the criteria established in this Resolution.
- The appropriate environmental agency may dismiss the Environmental Impact Study and the respective Environmental Impact Report upon confirmation that implanting the landfill shall not cause significant environment degradation.
- The environment control agencies are responsible for enforcing, this Resolution, inspecting, and taking appropriate measures according the legislation in force.

3. IMPLEMENTATION AND OPERATION

After dimensioning the system, the next stage is implementation and operation of the technological model selected as a whole: sustainable landfill, selective collection, separation warehouse, and composting unit.
Sustainable landfill
Followed the stages and defined the dimensions in the project, it is necessary to take measures for implementation and operation: cleaning and isolation of the area, construction of support structures, improvement and/or implementation of access roads, land preparation, overall surface draining around the landfill and in the trenches, and construction of leachate and gas draining systems.

Choosing and dimensioning the equipment to be used in the landfill depend on their size and other variables such as the quantity, types and volume of residues, distance from cover material sources, the degree of compaction indicated in the project, etc. In small community landfills, normally a backhoe and a dump truck are used for the transport of the cover material taken from the trenches. Alternative hand-operated equipment may be use to compact and spread the residue due to the shortage of financial resources and lack of skilled labor.

Selective collection
The implementation of the municipality selective collection program must first and foremost be inserted within an ISSWM system as seen in a previous case study. It was observed that selective collection must be well planned and the results must always be shown to the community and further information must be provided so it is not forsaken. The citizens must be instructed about how to participate in the separation activities correctly and about the importance of their participation.

Door-to-door and voluntary delivery are some of the methods from which to choose. A good strategy to adopt for the sustainability of the program is creating and guiding a voluntary team formed by members of the community who identify themselves with the environmental question and who have interest in following the process, from project design to implementation and operation. This team can be made up of City Hall, NGO, and the general society representatives.

Construction of the separation warehouse and the composting yard
After collection, the recyclable material must be transported to a separation unit equipped with workbenches for the careful separation of materials for commercialization.

The composting yard must be duly paved for this purpose. It is seen as a strategy to integrate solid urban residue management since it will be a recycling process of the organic a fraction of the urban solid residues.

Environmental education program
Environmental education is a fundamental part for the success of any selective collection program. Sensibilizing the community and getting its participation are crucial for ISSWM success.

The environmental education process must reach the entire municipality, initially the districts with existing organized associations, schools, workshops, theaters. The educational materials used must be produced in accordance to the reality of each municipality. The process activities must be combined with advertisement events to extend the result of the actions. Educational materials must also be appropriate for each specific situation. The educational approach must combine information about the problems with enjoyable and artistic sensibilizing activities.
4. EVALUATION

In this stage, one must evaluate the ISSWM in all its aspects so that the small municipality may analyze the efficiency of the proposal relative to its particular conditions. The solutions for the guideline proposal must always consider the local characteristics concerning the community, its economy, culture, and physical environment.

The ISSWM involves from behavior change aspects to the impact on the physical environment. It creates new jobs and has an effect on the economy of natural resources. Due to this broad influence, there is a large number of variables involved in making a decision for a technological solution.

Evaluation Criteria

Table 1 – Criteria for evaluation of the guideline proposal stages

<table>
<thead>
<tr>
<th>Stages</th>
<th>Characterization</th>
<th>Evaluation</th>
</tr>
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<tbody>
<tr>
<td>Planning</td>
<td>Survey of general data (characterization of the municipality, characterization of the urban cleaning system, selection of the final disposal area)</td>
<td>Favorable: reliable data. Unfavorable: not enough information to characterize the municipality.</td>
</tr>
<tr>
<td>Project</td>
<td>Sustainable landfill, selective collection, separation warehouse, and composting unit.</td>
<td>Favorable: Project adequately dimensioned for the reality of the municipality. Unfavorable: Inadequate project dimensioning.</td>
</tr>
<tr>
<td>Implementation</td>
<td>Sustainable landfill, selective collection, separation warehouse, and composting unit.</td>
<td>Favorable: Take actions appropriate for the specifications and the descriptions of the projects and operation. Unfavorable: not taking the specific project and operation method actions.</td>
</tr>
</tbody>
</table>

Source: FERREIRA, 2004

CONCLUSIONS

The integrated sustainable urban solid residue management system is a means by which it is sought to equate and solve the problems related to urban residue that directly or indirectly affect the quality of life of a community and that harm the environment. The evaluation of the social, environmental, and cultural conditions of the population and the community participation are vital for the successful implementation, operation and monitoring of the urban solid residue management in a community.

The ISSWM stages are crucial for the municipality; however, they must be simplified, mainly for small communities, giving priority to the implementation of viable procedures and technologies according to the community conditions to overcome their great difficulties of financial and human resources concerning the residue issue.

The guideline proposal is thoroughly viable and can assist city halls to both implement and operate ISSWM in small communities as long as all stages are considered and the
technical, economic, administrative, legal, and social aspects inherent to the specificity of
the municipality are born in mind.

ACKNOWLEDGEMENTS

The authors would like to thank PROSAB (Programa de Pesquisa em Saneamento
Básiço) and FINEP, CNPq, and Caixa Econômica Federal for the financial support and the
City of Catas Altas-MG, Brazil for its efforts, promptness, financial support and will for
changes in the name of ex-mayor Mr. José Hosken and mayor Mr. José Alves Parreira,
Mr. Geraldo Queiroz and Engineering Carlos Magno de Melo. The authors extend their
gratitude to Civil Engineering student Ramille Araújo Soares.

REFERENCES

CASTILHOS JUNIOR, A. B; LANGE, L. C, GOMES, L. P; PESSIN, N. (Org.). Resíduos
sólidos urbanos: aterro sustentável para municípios de pequeno porte. Rio de Janeiro:
CONSELHO NACIONAL DO MEIO AMBIENTE. Resolução n. 308, de 2002. It provides for
the Environmental Licensing of final disposal of urban solid residues generated by small
size communities. Available at: <http://www.mma.gov.br/port/conama> Acessed on
FERREIRA. C.F.A. Proposta de um Protocolo de Referência para Sistemas de
Gerenciamento Integrado e Sustentável de Resíduos Sólidos Urbanos em Pequenas
Comunidades. Dissertação (Mestrado em Saneamento, Meio Ambiente e Recursos
Hídricos) – Escola de Engenharia, Universidade Federal de Minas Gerais, Belo Horizonte,
2004.
INSTITUTO BRASILEIRO DE ADMINISTRAÇÃO MUNICIPAL. Manual de gerenciamento
INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Pesquisa Nacional de
LANGE, L. C.; SIMÕES, G. F.; FERREIRA, C. F. A. Implantação e Operação de um Aterro
Alternativas de disposição de resíduos sólidos urbanos para pequenas comunidades. Rio
MINISTÉRIO DO MEIO AMBIENTE. Edital nº12, de 2001. Projects of waste managment
system. FNMA. Brasília. Avaiable at: <http://www.mma.gov.br/fnma/editais> Acessed on