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Modelling and Optimization for Management of Municipal Solid Waste

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Abstract: It is critical to adopt a broad approach in developing a working framework for waste management. This covers various aspects like the economic, environmental and social dimensions. Therefore it is important that the right action be carried out at the right level. The management of solid waste is an important & biggest problem from time to time. It covers collection, transportation, processing, recycling and disposal of solid wastes. The proper management of municipal solid waste solves the dual purpose as it helps to protect the environment from polluting and use the untapped potential of municipal solid waste to make the eco-friendly future fuel. Our purpose is to form some integrated techno-economic programming models, which can determine the optimal cost of solid waste disposal and explains the inter-parametric linkages. The aim is to form models, which provide tool to engineers, planners, and constructor's to determine the best scenario for a solid waste management planning. In this paper, linear programming model is discussed to manage & optimize the solution for problem of municipal solid waste. While developing this mathematical model, various environmental and economic costs associated are considered.

Key words: modeling; optimization; management; municipal solid waste.

1. Introduction

The demand of fossil fuel is continuously rising. In contrast, fossil fuel resources are limited and decreasing due to over exploitation. The need of hour is renewable alternate energy resources like bio-fuels, solar energy, hydro energy etc. The bio-fuels include biomass, bio-diesel and biogas. These bio-fuels can be produced from biodegradable materials like animal solid waste, human excreta, municipal solid waste, crop solid waste etc.

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If this municipal solid waste is properly managed/processed this solid waste has potential to provide us the biogas which can replace approximately 10% of total energy requirement. This municipal solid waste is segregated into biodegradable and non- biodegradable material. The non-biodegradable material consists of mineral water bottles, polythene and other metallic solid wastes, which can be utilized for constructing roads. The biodegradable solid waste along with sewage water can be used in the digester and biogas can be produced, compressed and filled into the cylinders and dispatched to the user. This biogas can be used to run any kind of automobile engine after some minor alternation and it is 100% safe. The solid waste slurry of the digester can be buried in the large pit with a layer of soil which forms very good organic manure. It can replace chemical fertilizers to a large extent. The processing & management of solid municipal waste solve the dual purpose as it helps to protect the environment from polluting and use the untapped potential of the waste to make the eco-friendly future fuel.

The management of solid waste is concerned; the human safety in terms of health and environmental burdens of solid waste like energy consumption, pollution of air, oil, water and loss of amenity must be taken under consideration.

Countries like India have a wide range of solid waste problems, including inadequate solid waste collection system, open illegal dumping, improper disposal, environmental pollution and waste pickers scavenging at landfills. These problems are being aggravated by growing solid waste generation rates associated with economic growth, which increase the consumption levels, and the transition to mass consumption life style in developing countries. There is concern that these problems, if left unattended, will become a serious challenge for generations to overcome.

Solid waste management is a fundamental problem faced by municipal corporations. It is therefore, the responsibility of municipal corporations to provide solution. To manage solid wastes at municipal level, an effective strategy should be planned with consideration to various conflicting objectives (e.g. health, normative, economic and technical). The environmental impacts should also be considered along with all expenditure. This usually can't be dealt with by economical quantification only.

A large number of mathematical models are available in the literature for planning and management of wastes. The literature reveals the complexity of the available models. It has been observed by technical professionals that most of the available models are complicated and cannot be used practically.

In some cases the model is used for resource management and the mathematical program is designed to prescribe decisions for operation and planning to minimize cost subject to quality standard constraints.

Our MC's are failed to keep the city properly clean and thus giving rise to health and environmental problems. So our purpose was to form some integrated techno-economic models, which can be utilized to determine the optimal cost of solid waste disposal and also explain the inter-parametric linkages. Hence our purpose is to formulate such programming models for solid waste management planning.

In this paper, linear programming model has been developed to integrate the following different options involved in MW management. Various environmental and economic costs associated with MW management were taken into consideration while developing the model. The following components were considered:

1. **Community compost plant (CCP): C**omposting pits in local area were used by community for converting biodegradable solid waste into compost.
2. **Mechanical aerobic compost plant (MACP):** Industries were used to convert the organic components of MW into manure through aerobic composting**.**
3. **Sanitary landfill (SL):** The collected solid waste was used to dispose in sanitary landfills.

2. Mathematical model

Considering both environmental and economic factors, a mathematical model has been discussed in this section.

Now cost and benefit depends on various factors as transportation, processing etc. So let us assume

$X_{\alpha\beta}$ = Amount of solid waste transported from generation node 'α' to destination node 'β'

α, β = Aerobic compost plant '*m*', compost plant '*p*' and sanitary landfill '*l*'.

C_m = Cost of solid waste processing at aerobic composting plant '*m*'

B_m = Total benefits of solid waste processing at aerobic composting plant '*m*'

C_p = Cost of solid waste processing at CCP compost plant '*p*'

B_p = Total benefits of solid waste processing at CCP compost plant '*p*'

C_l = Cost of solid waste disposal at SL landfill '*l*'

B_l = Total benefits of solid waste under sanitary landfill '*l*'

t = Per km transportation cost of solid waste per ton

S_{jm} = Distance from generation node 'j' to aerobic composting plant 'm'

S_{pl} = Distance from compost plant '*p*' to sanitary landfill '*l*'

S_{jl} = Distance from generation node '*j*' to sanitary landfill '*l*'

F_b = Fraction of biodegradable material in total solid waste

O_m = Operating cost for MACP aerobic compost plant (per ton solid waste)

O_p = Operating cost for CCP community compost plant (per ton solid waste)

O_l = Operating cost for SL sanitary landfill (per ton solid waste)

L_p = Cost of land associated with CCP community composting

L_m = Cost of land associated with MACP aerobic composting

L_l = Cost of land associated with SL sanitary landfill

E_m = Environmental cost for aerobic composting (per ton solid waste)

E_p = Environmental cost for CCP community compost plant (per ton solid waste)

E_l = Environmental cost for SL sanitary landfill (per ton solid waste)

F_k = Fraction of recyclable material '*k*' in total solid waste

P_{ac} = Price of aerobic compost

P_{cc} = Price of community compost

P_k = Price of recyclable waste '*k*'

A. CONSTRAINTS

1) Mass balance constraints

Solid waste produced at source *j*, should be transported to SL sanitary landfill *l*, or to CCP community compost plant *p*, or to MACP aerobic compost plant *m*. So if G_j is the amount of solid waste produced at node '*j*' then

$$G_j = \sum_m X_{jm} + \sum_l X_{jl} + \sum_p X_{jp}$$

2) Capacity limitation constraints

Let V_m and V_p denotes the maximum capacity of aerobic compost plant '*m*' and community compost plant '*p*' respectively. Then capacity at each plant should be equal to or less than the maximum capacity of the plant.

Hence $\sum_j X_{jm} \le V_m$ and $\sum_j X_{jp} \le V_p$.

Then the total cost is given by,

$$TC = \sum_m C_m + \sum_l C_l + \sum_p C_p$$

Where,

$$\sum_m C_m = \sum_m \sum_j t * S_{jm} * X_{jm} + \sum_m \sum_j O_m * X_{jm} + \sum_m \sum_j L_m * X_{jm} + \sum_m \sum_j E_m * X_{jm} * F_b + \sum_m \sum_l O_l * X_{ml} + \sum_m \sum_l L_l * X_{ml} + \sum_m \sum_l E_l * X_{ml}$$

$$\sum_l C_l = \sum_l \sum_j t * S_{jl} * X_{jl} + \sum_l \sum_j O_l * X_{jl} + \sum_l \sum_j L_l * X_{jl} + \sum_l \sum_j E_l * X_{jl}$$

$$\sum_p C_p = \sum_p \sum_j F_b * O_p * X_{jp} + \sum_p \sum_j L_p * X_{jp} + \sum_p \sum_j E_p * F_b * X_{jp} + \sum_p \sum_l t * X_{pl} * S_{pl} + \sum_p \sum_l O_l * X_{pl} + \sum_p \sum_l L_l * X_{pl} + \sum_p \sum_l E_l * X_{pl}$$

And total benefits are given by,

$$TB = \sum_m B_m + \sum_l B_l + \sum_p B_p$$

Where,

$$\sum_m B_m = \sum_m \sum_j P_{ac} * F_b * X_{jm} + \sum_m \sum_j \sum_k F_k * P_k * X_{jm}$$

$$\sum_l B_l = \sum_l \sum_j \sum_k F_k * P_k * X_{jl}$$

$$\sum_p B_p = \sum_p \sum_j P_{cc} * F_b * X_{jp} + \sum_p \sum_j \sum_k F_k * P_k * X_{jp}$$

B. OBJECTIVE FUNCTION

If *TC* is total cost and *TB* is total benefit associated with solid waste management stream then the objective function will be to

Minimize (TC – TB) or Maximize (TB-TC)

Hence we have transformed the problem of management of solid waste into above linear programming problem.

Conclusions

An optimization model for management of solid waste system is developed. To get optimal result, it is better to process all solid waste at compost plants and inert material should only be transported to dump. Hence, the dominant role is played by community compost plant. The compost thus produced and recyclable materials can be sold to reduce the effective cost of waste management system.

Thus the model proposed here minimizes the economic cost and the quantity of solid waste sent to landfill. It will also control the environmental pollution as the incinerator emissions are reduced. Moreover, it takes care of loss of amenity along with the health parameter.

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