THE URBAN SOLID WASTE MANAGEMENT PROBLEM IN INDIA— AN ECONOMIC APPROACH AND FRAMEWORK FOR POLICY

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ABSTRACT

Urban solid waste presents a growing problem to policy-makers in many developing countries. In India, composting of organic waste and recovery/recycling of dry waste has been strongly recommended as the solution to the problem. However, social welfare is maximized only when composting is undertaken with organic waste segregated at-source. Many efforts have been made through awareness-building programs to induce households to segregate organic waste at-source. These have achieved limited success. Through a microeconomic analysis of organic waste management, we are able to understand why an incentive-based approach for source-segregation, which has been functioning efficiently for dry waste like paper, has not evolved sufficiently for organic waste. Market failure calls for government intervention through a tax and incentive approach, which imposes no net cost on stakeholders in the urban solid waste management system. However, many practical issues in its implementation remain unanswered and must be well thought-out.

Keywords: Urban solid waste, municipal solid waste, organic waste, composting, source separation.

INTRODUCTION

India, with a total population of over a billion, has an urban population of almost 275 million, growing at about 3.5% and generating approximately 30 million tons of urban solid waste[i] (USW) annually. There is general agreement amongst stakeholders including researchers, government and non-governmental institutions as well as the general public[ii] that the present USW disposal system in India is far from satisfactory[iii] and cause for serious concern when we take into account the growing quantum of wastes, the resource constraints faced by municipal authorities and environmental effects of the waste disposal methods adopted. "Managing the Monster," the title of a book on the USW problem in African cities (Onibokun 1999), would be equally apt for the Indian situation.

Several policy recommendations have been made to improve USW management in India. These include (Beukering et al 1999):

- Administrative restructuring of municipalities
- More efficient and effective resource mobilization by government agencies
- Application of technological innovations by municipal authorities for waste disposal
- Encouraging involvement of non-governmental organizations (NGOs) in public awareness-building activities
- Ensuring people's participation in the collection, segregation and disposal of garbage by forming eco-clubs or community organizations.

We see two problems in such recommendations. First, implemented all together, they amount to nothing less than a complete overhaul of the present waste management system. We must then beg to question by whom, why, how and when will such a restructuring be brought about? Furthermore, municipal authorities face a credibility problem in claiming better management of new facilities and systems given their track record in governance and management of public services (Beede and Bloom 1995). Second, it is unclear whether each of these policies, if independently implemented, can alleviate the USW problem. Take, for instance, a public awareness campaign for segregation of organic waste. Of what benefit is this when wastes are in any case mixed during transportation and then dumped together at a dumpsite? At the same time, use of an improved composting technique may fail to meet its objective if segregation of organic waste by households cannot be consistently ensured. Organizational restructuring of municipalities does not address the problem of identifying and establishing landfills at optimal distances from cities.

Faced with difficulties in the simultaneous implementation of these recommendations, municipalities and community organizations have resorted to measures like door-to-door collection of garbage and the use of private contractors for garbage clearing and transport. Though these measures may achieve greater efficiency in clearing of wastes from streets, they remain, what Einsiedel (2001) calls, an "out of sight, out of mind" attitude to the USW problem.

At the same time, since the early 1990s, the efforts of stakeholders has led to a better understanding of and a better articulation of the long-term policies needed to alleviate the USW problem in India. But successful and sustained implementation of policies continues to pose a challenge to authorities and concerned non-governmental organizations.

Our objective is to develop a microeconomic characterization and analytical framework of the USW problem in India. The economic model brings out clearly why a sub-optimal situation exists in Indian cities and helps us analyze the economic and environmental implications of various USW management policies. The model also helps us to explore possibilities on the wider use of monetary incentives in waste management. Though theoretically justifiable, the practical difficulties in implementation of recommended policies need to be well thought-out.

A NOTE ON METHOD AND INFORMATION USED FOR ANALYSIS

The aim of our study is to develop an analytical framework to characterize the USW problem in India. It is not an empirical study; rather it is hoped that the analysis will become a basis for more directed empirical research. Personal discussions with stakeholders, published and unpublished literature both academic and popular as well as the experience from living in Indian cities have contributed to this analysis.

USW DISPOSAL OPTIONS FOR INDIA

USW can be "disposed" in several ways, including:

- Dumping
- Sanitary landfills
- Incineration
- Recycling, including composting of organic waste and recovery/recycling of dry wastes

In many developing countries, including India, wastes are most commonly dumped in open lands located on the city periphery (GOI 1995, Beukering 1999, Onibokun 1999, Einsiedel 2001, Executive Summary). The dangers of such a practice are many: health hazards to rag-pickers at the dumpsite, pollution of ground water, highly toxic smoke from continuously smoldering fires, spread of infectious diseases like plague, dengue and malaria, infections to and poisoning of scavenging animals, and foul odors from decomposing garbage (Einsiedel 2001, Prakasam 2001, Executive Summary). Open dumping of USW then cannot be considered as a long-term environmentally safe method of disposal.

Controlled and regulated landfilling of urban solid waste, a method adopted widely in advanced countries, is still uncommon, if not non-existent, in India. Landfilling is also not without limitations: the required capital investment and operating costs are substantial (Waite 1995, Interim Report 1998), often requiring the imposition of a tipping fee. This could induce private and municipal operators to illegally dump collected wastes in open sites so as to avoid high tipping charges (Beede and Bloom 1995). In India, suitable sites are difficult to find (Sreedharan 2001) and there could be strong resistance from local residents. Furthermore, though superior to open dumpsites, landfills too have adverse environmental consequences. It is pertinent to point out that even in the U.S., one study found 90% of landfill sites with groundwater contamination (Miranda et al 1994) and another reports and estimated 40000 landfill sites contaminating groundwater (Powell and Craighill 2000). Moreover, landfill gas containing mainly carbon dioxide and methane, is a major greenhouse gas (Powell and Craighill 2000). For these reasons, sanitary landfilling in India is recommended only for rejects in composting (Interim Report 1998) and residues from incineration of bio-medical waste.

Incineration has not been considered a suitable option for disposal of urban solid waste in India. Incineration requires strict control of toxic fumes and disposal of toxic residue (ash) in sanitary landfills (Waite 1995, CEE South 1995, Henderson 2000). Moreover, the low calorific value and the low combustible component of garbage in India make incineration uneconomical (IHS 1997) and even led to the failure of an incinerator plant in New Delhi (Einsiedel 2001). The Interim Report (1998) states that incineration is not recommended as a method of disposal of USW[iv] and, therefore, is ignored as a policy option in this paper.

In comparison to dumping, landfilling or incineration of mixed-waste, recycling (recovery/recycling of dry waste components and composting of organic waste) may be considered the best option[v].

Recovery/recycling of dry wastes (paper, plastics, metals, etc.) must be based not only on economic viability but also on environmental considerations. There may be dangerous environmental consequences of recycling plastics, lead acid batteries and other toxic waste in poor countries (Lardinos and Klundert 1996a, Lardinos and Klundert 1996b, Eerd 1997, Sunil Kumar 2001[vi]). Strict regulation of recycling technologies is a necessary precondition for any dry waste recycling policy. We will return to recovery/recycling of dry wastes later in the paper.

The environmental benefits from composting of organic (or wet) wastes are many, including the return of nutrients back to the soil, improving soil texture and reducing ground water pollution arising from seepage of toxic mixed waste leachates at dumpsites. The economic benefits of composting include a reduction in area required for dumping or investments in sanitized landfills and creating value from waste. For these reasons, the Interim Report (1998) categorically states, "composting is the process of waste disposal which our predominantly agricultural country must follow." The Gazette of India (2000) has also endorsed the recommendation that biodegradable waste must be composted.

We can summarize the formally recommended USW disposal options in India to be:

- Composting of biodegradable waste
- Recycling of dry waste where economically viable and environmentally safe
- Regulated landfilling of the remaining elements.

Given the above preferred options for safe disposal of USW, its management becomes problematic not so much due to the quantity of waste but due to its nature, in particular, it being unsegregated. As we will see, it is the non-segregation of wastes at-source that makes it difficult, if not impossible, to dispose waste optimally. It is then necessary that any USW management system gives due importance to segregation of waste.

THE ORGANIC WASTE COMPONENT IN USW AND NEED FOR ITS SEGREGATION AT-SOURCE

As mentioned above, urban India generates approximately 30 million tons of USW annually, 50-75% of which is organic waste, 15-35% ash (all of which is not necessarily suitable for composting) and dust. Less than 10% in weight of total USW consists of paper, glass, metals and plastic (GOI 1995, CEE South 1995).

The quantum of organic waste in the total solid waste stream in Indian cities makes it imperative that we give special emphasis to tackling organic waste. Very little of organic waste is recovered by private agents for recycling or composting, and therefore remains to be collected and disposed by municipal authorities. In Mumbai, for instance, Beukering et al (1996) report on the basis of data complied from various sources that, even though almost 70% of garbage in bins is organic matter, only about 2% of it is recovered for recycling[vii]. Waste pickers have very little interest in organic waste both in terms of quantities collected and its share in their earnings. Post-recovery, approximately 85% of waste collected by the Mumbai municipality is organic waste and dust and only 15% consists of paper, plastic and other dry wastes (Beukering 1996).

Although USW collected by municipal authorities may contain a high percentage of organic waste, it, being mixed with non-organic materials, needs segregation. There are two possibilities for the segregation of waste: -

- At the composting plant, by screening during and after the maturation process (Waite 1995)[viii], also referred to as mixed-waste composting, or
- At-source, by waste generators

Ideally, from an environmental point of view, segregation should be done at-source before collection, transport, storage and processing. This is important since delayed segregation during or at the end of the composting process will allow toxic elements from post-consumption wastes like broken fluorescent tubes, batteries, printing inks, etc. to leach into the compost (Lardinos and Klundert 1996a). There is also the problem in many smaller Indian cities where sanitation facilities are poor of human excreta being mixed with USW (GOI 1995). Furthermore, "potentially hazardous wastes especially from small industrial units are dumped along with municipal wastes. These contaminate the municipal waste ...." (GOI 1995).

In Table 1, we present the findings of a non-governmental organization from a chemical analysis of compost from a plant near Bangalore working with waste unsegregated at-source and compost using segregated waste (CEE South 1995). The standards for metals in compost as per Schedule IV (Gazette of India 2000) are also presented.

The high level of toxic elements in unsegregated waste is a cause for concern as they could eventually enter the food chain through the compost used in agriculture, with costly health implications not only for the current, but also for future generations (Beede and Bloom 1995). Recognizing the danger of contaminated compost, the Gazette of India (2000) has notified,

"Compost (final product) exceeding the above stated concentration limits shall not be used for food crops. However, it may be utilized for purposes other than growing food crops."

Monitoring and enforcing such a directive, however, remains problematic. Prakash (2001) therefore opines that,

"It is very essential that the quality of urban compost has to be standardized so as to prevent the hazards due to heavy metals and poisonous substances."

Unsegregated waste composting can also be physically unsafe when contaminated with glass, needles, shreds of plastic and other materials, making it unsuitable for agriculture (Einsiedel 2001) or for use in public places like parks.

TABLE 1
Chemical Standard for Compost and Chemical Analysis of Aerobic and Vermi Compost from Segregated and Unsegregated Waste

Parameters	*C1*	*C2*	*C3*	*C4*	*C5*
Nitrogen	-	1120.80	1081.57	280.2	700.5
Arsenic	10.0	Nil	Nil	Traces	Traces
Zinc	1000.0	8.6	4.8	25.12	20.99
Cadmium	5.0	0.39	0.46	1.52	1.87
Hex.Chromium	-	2.58	1.02	3.68	39.59
Chromium	50.0	11.33	4.89	10.11	72.07
Copper	300.0	203.10	152.32	9.21	65.96
Lead	100.0	1.08	1.01	2.84	3.68
Nickel	50.0	Nil	Nil	1.84	3.96
Cyanide	-	Nil	Nil	Nil	Nil
Mercury	0.15	-	-	-	-

Notes:
C1 Standards for Composting, Schedule IV, Source: Gazette (2000). Concentrations are < mg/kg dry basis.
C2 Aerobic compost, segregated waste (mg/100 gms). Source: CEE South (1995).
C3 Vermi compost, segregated waste (mg/100 gms). Source: CEE South (1995).
C4 Vermi compost, unsegregated waste (mg/100 gms). Source: CEE South (1995).
C5 Aerobic compost, unsegregated waste (mg/100 gms). Source: CEE South (1995).
(-) Indicates concentrations not given.

The official viewpoint on segregation of organic waste at-source reinforces arguments in favor of source-segregation of waste prior to composting:

"A major problem is that there is no system of segregation of recyclable, organic and inorganic waste at the household level and storing them separately until collection" (GOI 1995).

"Priority must be given for the source segregation of recyclable wastes by shops and establishments ... In case of households such an arrangement may be made within one year ... After making arrangements ... it must be made compulsory to do source-segregation from the date that may be notified by the local body" (Interim Report 1998).

Unfortunately, the quantum of organic waste segregated at-source remains limited. To understand why this is so and to look at possible solutions, we must understand the economics of organic waste disposal. This is the objective of the next section.

AN ECONOMIC ANALYSIS OF ORGANIC WASTE DISPOSAL

Figure 1 is a flow diagram of the various options available for the disposal of organic waste. Total waste [W] generated by households [H] and other institutions [U], collectively called waste generators [G], is usually segregated for some high-quality recyclables [R_{HQ}] like paper and glass with the remaining mixed waste [W_X] disposed off by composting firms [F_1, F_2] or by the municipality [M].

In the first stream, waste is collected [E] and transported [T] to a sanitary landfill [L]. Since L is a protected area, rag-pickers would not be allowed to scavenge for recyclable dry waste [W_{Di}]. This system of disposal is "conspicuous by its absence" (GOI 1995) in India.

In the second stream, mixed-waste is dumped in unregulated open lands or dumpsites [D]. Some segregation [S] may take place for W_{Di}, both prior to collection from bins as well as at the dumpsite. This disposal method remains the most prevalent in Indian cities.

Composting with segregation at-source is illustrated in the third stream. Waste is segregated by [G] into compostable

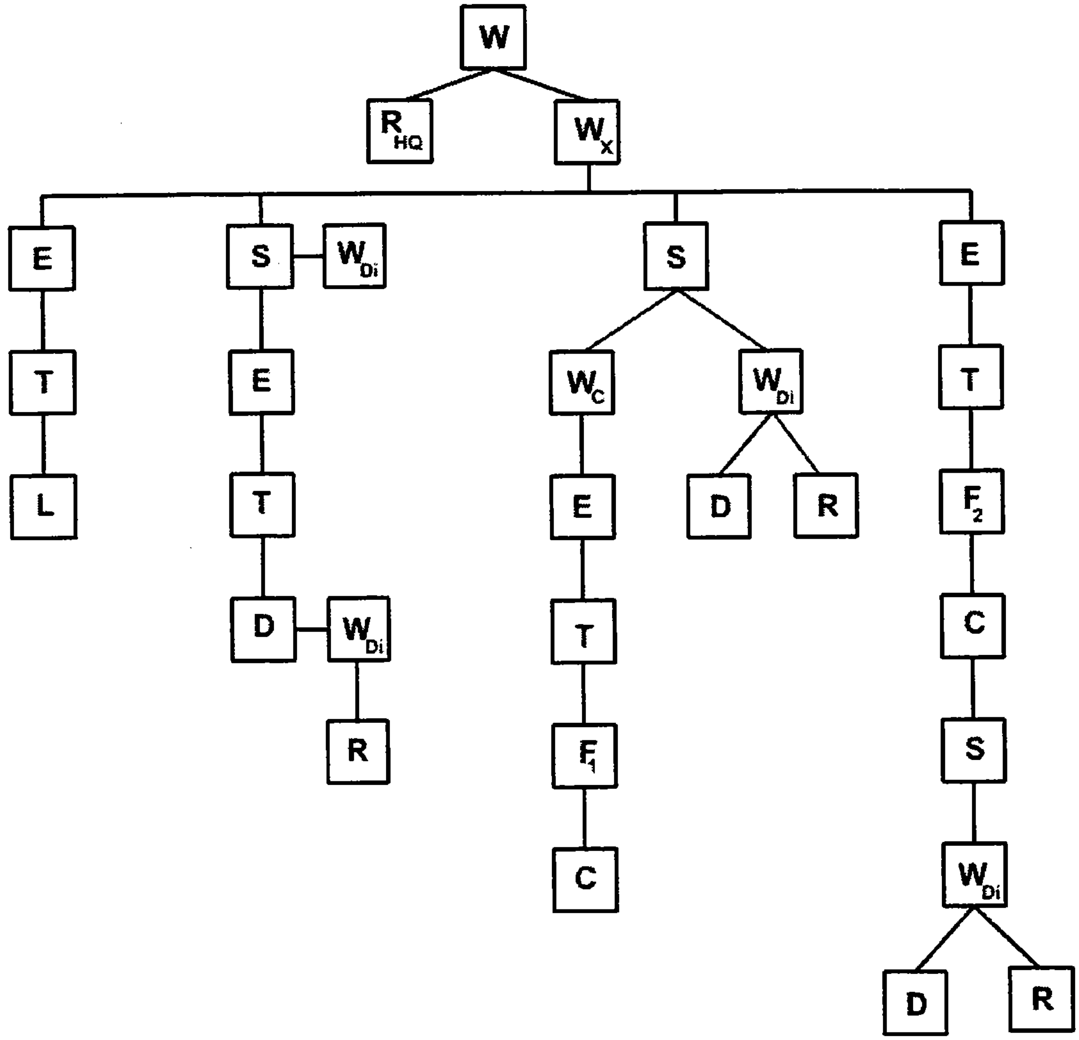

FIGURE 1
Flow Diagram of Options for the Disposal of Organic Waste

waste [W_C] and dry waste [W_D which includes R_{HQ}]. W_C is then collected and transported for composting at plant F_1. W_D may be further segregated for recycling of individual elements [W_{Di}] or for disposal [D].

The fourth stream illustrates composting [C] of mixed-waste with segregation of W_{Di} carried out during and at the end of the composting process. This activity is carried out by plant F_2.

Given that the third stream is environmentally the preferred and officially recommended option for the disposal of organic waste, it is important for G to undertake segregation of W_C. The key problem then is *can* and *how* do we induce G to segregate W_C? We see three possibilities: first, as advocated by civic groups and community organizations, is to make G aware of the environmental benefits of segregation of organic waste at-source. However, the short-term efficacy and long-term sustainability of programs that rely on altruistic motives is doubtful.

A second option is to impose a mandatory requirement on households to segregate W_C through amendment in municipal by-laws (Singh 2001). The easy possibility for illegal dumping and cost of enforcement of such legislation makes this an impractical policy option in Indian cities.

A third possibility is through the use of monetary incentives. Firms in fact commonly use this option when they *buy* organic waste from institutions as raw material for composting or animal feed. Shah and Sambaraju (1997) report a private composting firm in Bangalore *bidding* for organic waste from vegetable markets. This is shown in Figure 2A[ix] where F_1 can buy up to O_U of segregated W_C from U. Note that quantity of composting is represented on the x-axis in the O-O' direction. At O', 100% of W_C is composted so that 0% must be dumped. On the other hand, at point O, 100% of W_C is dumped or uncollected since 0% is composted.

Even if we assume that F_1 pays a constant price for segregated W_C, marginal cost (MC_{F1}) will increase with the difficulty in collection, transport and storage of the segregated waste as well as deterioration in 'quality' of W_C in terms of its suitability for composting. For instance, F_1 may initially procure W_C from vegetable markets and then turn to other insti-

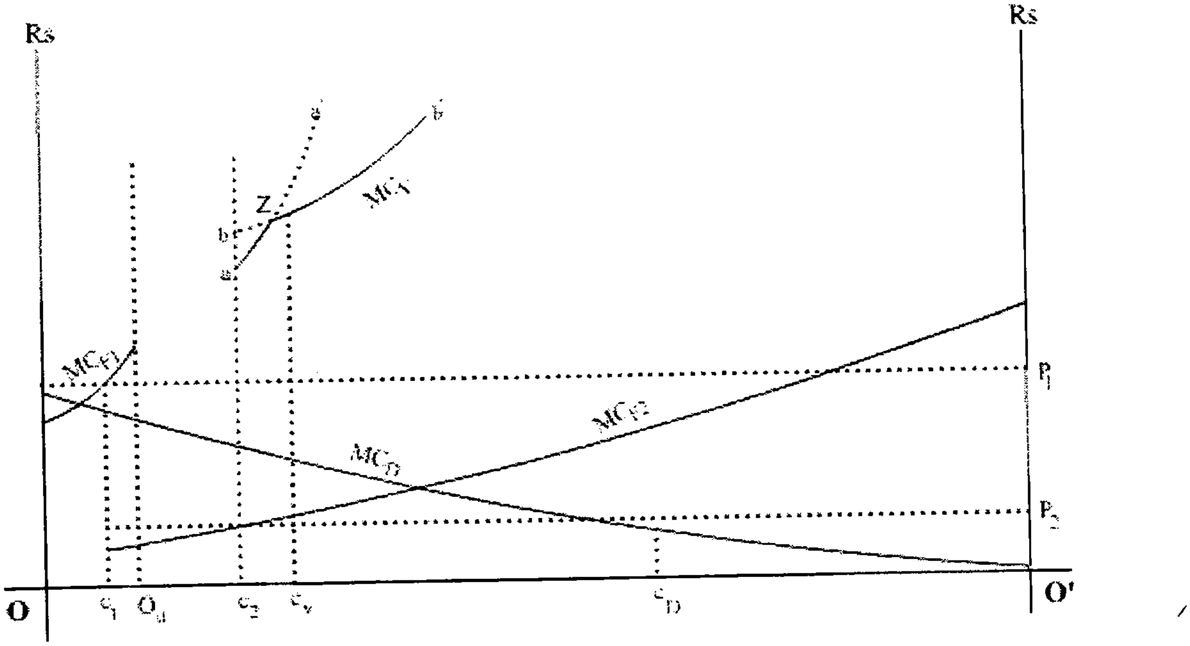

FIGURE 2A
Quantum of organic waste disposed under each option given prices of compost and budget constraints of V and M

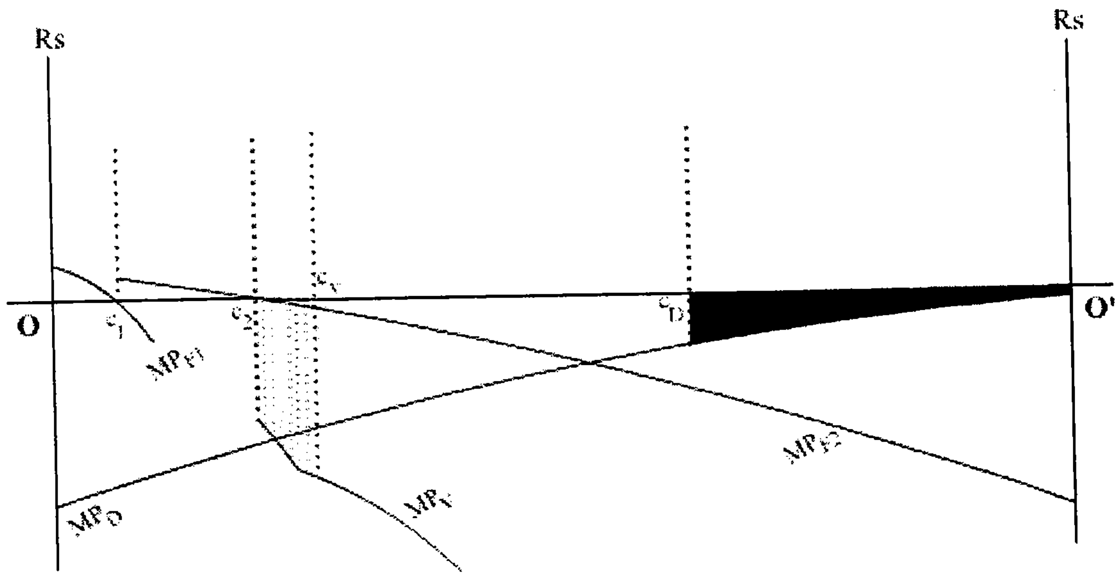

FIGURE 2B
Marginal profits (MP) for each option waste disposal

tutions like food processing industries, hotels, restaurants and canteens. In the latter cases, not only are the sources more dispersed but also the quality of waste declines due to, say, an increase in the content of cooked food in W_C. Marginal cost would then increase with higher transportation costs and additional additives required to maintain the quality of compost.

Beyond O_U, F_1 does not consider procurement of source-segregated W_C from H. The reasons for this will become clear later.

When segregation of waste takes place by F_2 during or after completion of the composting process, the marginal cost curve is shown by line MC_{F2} in Figure 2A. Note that the origin for MC_{F2} is shifted to point c_1 since, as we will see below, O-c_1 of W_C is collected by F_1. Though F_2 may not pay a price for W_X, marginal cost increases due to land requirements, difficulty in collection and higher transport costs. Further, large scale composting of mixed-waste requires mechanized systems that are prone to breakdowns (Shah and Sambaraju 1997, Einsiedel 2001). This may entail increasing cost of equipment repairs and maintenance. Working with large amounts of unsegregated wastes could also lead to a backlog of waste dumped in F_2's yard that would require storage area, fire prevention and maintenance of moisture levels in W_X. For example, the biggest composting plant in Bangalore had a two-year backlog of W_X (Shah and Sambaraju 1997).

To overcome the limited access of firms like F_1 to segregated W_C from households, non-governmental organizations and civic groups [V] have been making efforts to undertake composting of source-segregated W_C *collected from H.* Such organizations induce H to segregate W_C through awareness-building programs. However, as reported by Shah & Sambaraju (1997):

"After two years plastic bins were distributed but by that time the idea of separation had fallen through. In the beginning due to widespread mobilization and awareness raising through various means the level of separation was high, but never more than 30%."

The data from three community projects (Table 2) on the willingness to segregate waste clearly presents the problem faced when objectives are based on altruistic motives.

Increasing the rate of compliance for segregation of waste through awareness programs entails increasing marginal costs given by curve a-a' in Figure 2A. Community organizations must use various means at their disposal including door-to-door interaction with households, public meetings, cable television, posters, pamphlets, etc., (CEE South 1995) all involving significant costs.

Another option used by community organizations for source-segregation of organic waste is to collect W_C from H, which is then "... further separated into organic, dry, soiled and toxic waste" (Shah and Sambaraju 1997). The difficulty in sorting wastes after collection and before composting imposes an enormous cost in terms of labor requirement and the marginal costs are shown by curve b-b' in Figure 2B. For instance, the cost of raw material can be up to 15 times the price of the output (compost)! (Shah and Sambaraju 1997).

The envelope curve MC_V in Figure 2A (a-z-b') illustrates marginal cost of a community organization for composting of W_C. Till point 'z', awareness programs have a lower marginal cost (curve a-a') than post-collection/pre-composting segregation of W_C (curve b-b'). This is reversed beyond 'z' when awareness-building programs become relatively costly. Once again, the origin for MC_V is c_2 since O-c_2 of W_C is collected by F_1 and F_2.

It is sometimes pointed out that for small scale and localized composting units, like those of V, "cost of production per kilogram of compost is much higher compared to centralized production" (Shah and Sambaraju 1997). Such a comparison does not take into account the important fact that F_1 and V obtain organic waste from different sources, U and H respectively. Furthermore, since V typically operates at a low scale, covering about 500 households only, it cannot afford more capital-intensive mixed-waste composting techniques.

For purpose of illustration, we have shown only a single V operating. In reality, Indian cities have seen a number of such initiatives over the last decade. However, the quantum of waste disposal undertaken by such organizations relative to total USW generated remains negligible.

The quantity of dumped (unsegregated and uncomposted) waste is measured on the x-axis in the O'-O direction. The marginal cost curve for dumping is given by line MC_D, which includes cost of land, collection and transport.

Costs associated with sanitary landfilling (L) will be introduced later. Given the above cost structure and competitive market behavior, the choice of method and quantum of organic waste disposed by each method will depend on: -

- The price of compost (P) where compost produced from source-segregated waste usually fetches a much higher price (P_1) than compost produced from mixed waste (P_2) [x]. The study by Shah and Sambaraju (1997) reports a price differential of almost 300%[xi]. The argument by Powell and Craighill (2000) that, "purely organic waste streams can produce a high-quality product, but mixed waste need treatment to remove non-organic waste ... and the result may still be a low-grade product" supports the view of quality and price differentials with respect to segregation.
- Whether some or all disposal activities are operated by the same institution or by independent units.

TABLE 2
Percentage of Households Willing to Segregate Wastes in Community-Based Projects [V] Over Time

Project Site	*At the Start*	*After 2 Months*	*After 1 Year*
Site 1	83%	43%	7.7%
Site 2	90.6%	60.7%	-
Site 3	94%	73.17%	-

Source: CEE South (1998)

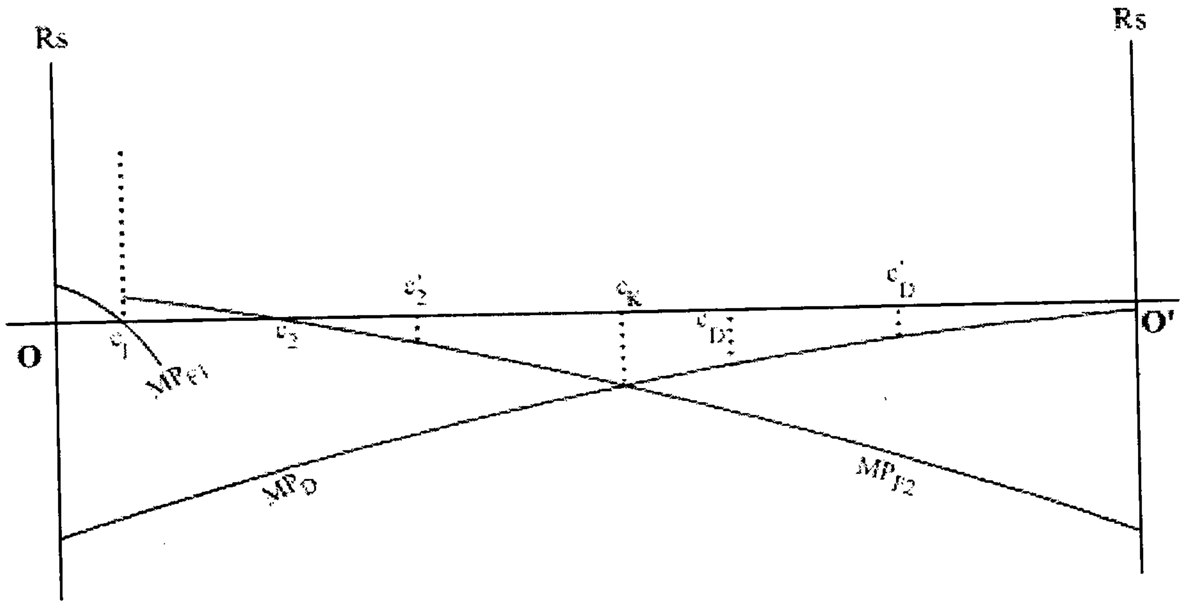

FIGURE 3
Quantum of organic waste composted when F_2 and M maximize joint profit

Figure 2A illustrates the situation where all disposal activities are conducted as independent units maximizing their profit or minimizing loss. F_1 utilizes O-c_1 of W_C, F_2 utilizes c_1-c_2, V collects c_2-c_V, and the remaining quantity O'-c_V is to be dumped by M. The actual quantity of waste collected by V and dumped by M depends on available grants or fees collected and budget constraint respectively.

Figure 2B illustrates the marginal profit or loss (MP) for each method of disposal and the quantity of W_C composted or dumped. Given P_1, F_1 will undertake to procure Oc_1 of source-segregated organic waste from U (like vegetable markets). With P_2, a mixed-waste quantity of c_1-c_2 is composted by F_2. Assuming that V gets a price P_1 on its compost, the dotted area is the loss to V that must be supported by revenues from garbage collection charges and external grants. The remaining quantity c_V-O' must be dumped. If the budget available to M is given by the shaded area in Figure 2B, the uncollected waste will be c_V-c_D.

Figure 3 illustrates the competitive outcome when a single institution, say, a municipality [M], undertakes mixed-waste composting and dumping. In other words, M's objective will be to maximize joint profits from F_2 and D. For simplicity, we ignore V. Since dumping always implies a "loss," M will seek to keep dumping of W_C to a minimum. If M does not face a budget constraint, the quantum of mixed-waste composting and dumping will be c_1-c_K and O'-c_K respectively. Where a budgetary constraint exists, mixed-waste composting and dumping will be undertaken till, say, point c_2' and c_D' respectively, where marginal loss from mixed-waste composting is equal to that from dumping.

Other ownership combinations are possible, but for our analysis, we will assume hereafter that each unit acts independently as in Figures 2A and 2B.

This economic model articulates the complex situation prevailing in Indian cities relating to organic waste disposal. In Bangalore, for example, we find a combination of composting from source-segregated (vegetable market) waste, mixed-waste composting, composting undertaken by community organizations and civic groups (with grants from international donor agencies), dumping and uncollected waste. Figures 2A and 2B capture this outcome.

It is important to reiterate that our analysis refers specifically to the case of W_C. On the other hand, the analysis of Beukering et al (1996) is applicable to recycling of W_D and unable to satisfactorily explain the problem of organic waste disposal.

STUDYING THE EFFECTIVENESS OF VARIOUS POLICY INITIATIVES

The model presented above is also useful to study the effectiveness of various policy initiatives in alleviating the USW problem. A subsidy on price of source-segregated compost (from P_1 to P_1' in Figure 4) will increase composting of source-segregated W_C from c_1 to c_1'. However, thus far, our analysis indicates that F_1 will undertake composting of source-segregated W_C up to a maximum of O_U only. Subsidies could also motivate F_1 to 'cheat' by using *non-urban* segregated organic waste. The cost of monitoring abuse of the subsidy then needs to be taken into account.

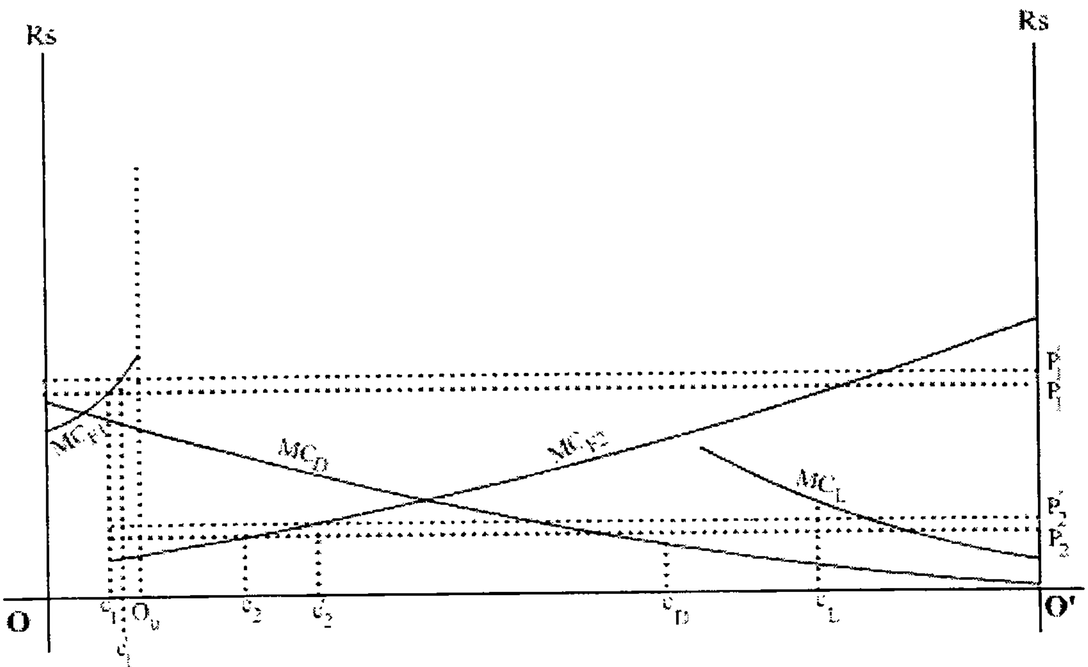

FIGURE 4
The effect of subsidies and sanitary landfilling on quantum of organic waste composted, landfilled and uncollected

On the other hand, a similar subsidy on price of mixed-waste compost can lead to more significant increases in composting of organic waste and a decrease in quantum of uncollected waste. The incentive to 'cheat' is also absent in this case. In Figure 4, with P_1, increase in P_2 to P_2', reduces the quantum of uncollected waste by c_2-c_2'.

It is also pertinent to mention here that removal of subsidies on chemical fertilizer could have a positive effect on price of compost and consequently on composting of W_C (Beede and Bloom 1995). Empirically, it would be interesting to ascertain the possible rise in compost prices if chemical fertilizer subsidies were to reduced or eliminated. However, our model indicates that the effect of a rise in price of compost (that is, if both P_1 and P_2 rise) would be more favorable for mixed-waste composting, not on source-segregated *urban* organic waste[xii].

The effect of introducing sanitary landfills [L] instead of dumpsites (an upward shift in MC_D to MC_L in Figure 4) could be an increase in uncollected waste by c_D-c_L if M's budget remains unchanged.

Mandatory recycling policies are being increasingly imposed on municipalities in economically advanced countries. In the U.S., "several states have enacted or are contemplating laws that would require municipalities to set up recycling policies" (Rechovsky and Stone 1994). In India, though it is accepted that "keeping the city clean is the responsibility of the civic administration" (Beukering et al 1999), there is no imposition of mandatory recycling on municipalities. It is clear from Figure 2A, that in case of a mandatory requirement on M to compost organic waste, it will have to resort mainly to mixed-waste composting.

We have also seen that initiatives like environmental awareness programs aimed at households to segregate W_C cannot provide a long-term economically sustainable and viable solution to the USW problem since they are mostly grant or fee-dependent (Furedy 1992). In fact, in Bangalore city, a number of community initiatives have been abandoned for lack of funds and other managerial reasons.

The above policy options then seem more or less ineffective in inducing source-segregated composting of W_C. Is there a way out of this impasse? We will return to this question below.

THE SOCIAL BENEFITS OF SOURCE-SEGREGATED ORGANIC WASTE COMPOSTING AND OTHER DISPOSAL OPTIONS

Any policy to increase composting of organic waste must ultimately be justified on the basis of the marginal benefit that accrues to *society as a whole.* We have already seen that composting of organic waste brings many environmental benefits in comparison to other options like incineration, sanitary landfilling or dumping. These positive externalities are maximum when organic waste is segregated at-source and composted. In the case of delayed segregation after composting, the positive externalities above must be discounted given the possibility of toxic elements entering the food chain.

In Figure 5, the marginal social benefit (MSB) curves MSB_{F1}, MSB_{F2}, MSB_D and MSB_L correspond to source-segregated composting, mixed-waste composting, dumping and sanitary landfilling respectively. Composting based on segregation at-source yields increasing marginal social benefits, initially at an increasing rate and then perhaps at a de-

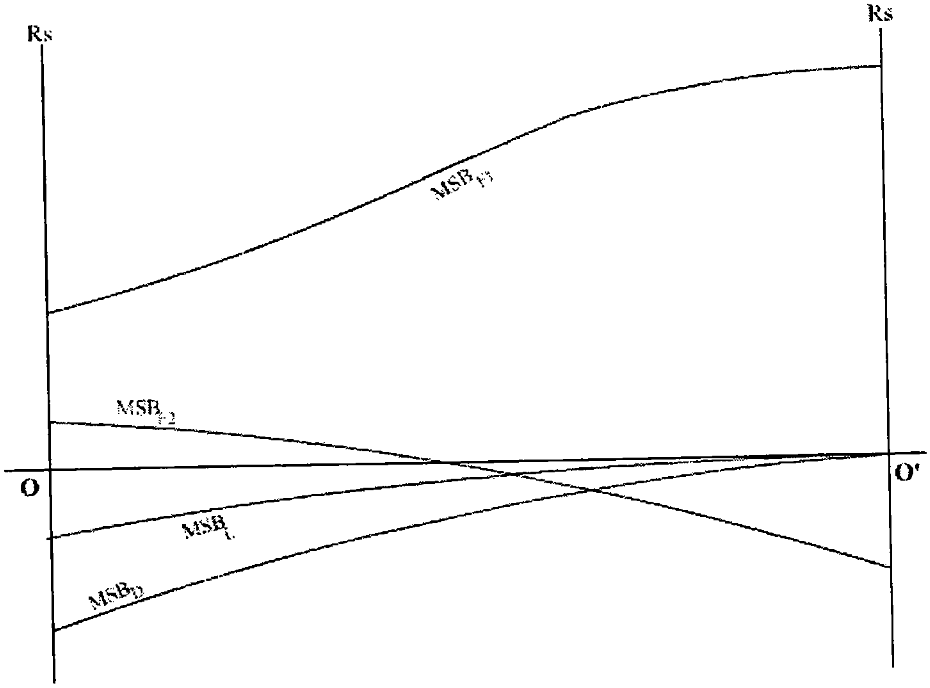

FIGURE 5
Marginal social benefits for different options of organic waste disposal

creasing rate. Where F_2 undertakes segregation at the end of the composting process, the marginal social benefits (MSB_{F2}) will be offset[xiii] with the possibility of toxic elements leaching into the compost and entering the food chain. The danger of this may actually warrant some to argue that landfilling and even dumping as a better option than composting mixed-waste.

Based on these marginal social benefit curves, we can unambiguously say that the market outcome in Figure 2A and 2B is sub-optimal. Social welfare can be increased if more source-segregated composting of W_C takes place.

RECOVERY/RECYCLING OF DRY WASTES

We had mentioned one additional benefit of segregating W_C at source, namely, easier segregation of different elements in W_D. Segregation of organic matter at-source can also significantly reduce the wet element in waste, making recovery of dry waste for recycling easier. In Mumbai, Beukering et al (1996) report that roughly 70% of plastic waste and 60% of paper is recovered from garbage bins. The segregation of organic (or wet) waste could further increase the recovery rate of these elements of dry waste from bins. When segregation takes place at the end of the composting process, recyclable dry waste fetches a comparatively low price.

In Figure 6, we show how the segregation of W_C could have a positive effect on the recovery of different elements (W_{Di}) in W_D for recycling (measured on the x-axis in the O-O' direction). MC_{Ri} gives the marginal cost of recovering W_{Di} with segregation at garbage bin or dumpsite and MC_{Ri}' gives the cost of recovering W_{Di} with 100% segregation of W_C at-source. Given the marginal private benefit of recovering W_{Di} (MPB_{Ri}), it is evident that segregation of W_C at-source will increase the recovery of W_{Di}. A reduced quantity O'-i_1' (instead of O' – i_1) remains to be disposed by M. For example, in Mumbai, waste collectors recover about 60% of paper from bins. If W_C were not present in the bins, it is likely that a lot more paper could be recovered and recycled.

Based on available data from varied sources, we make a simple calculation on the possible monetary benefits from higher recovery of dry waste when segregation of organic waste is carried out at-source. A composting plant working with approximately 17500 tons per year of mixed-waste collects Rs.8000 from dry waste recovery sales (Shah and Sambaraju 1997). If the content of waste paper in the mixed waste was even 1%[xiv] or approximately 175 tons, it could fetch ragpickers a total of approximately Rs.300,000 at a price of Rs.1610 per ton (Beukering 1996) if it had been recovered prior to composting.

THE USE OF PRICE INCENTIVES FOR SEGREGATION AT-SOURCE OF ORGANIC WASTE

It is clear that from a social standpoint, the market outcome of source-segregated composting of O-c_1 (Figure 2A and Figure 5) is inadequate or sub-optimal. Unfortunately, the market mechanism does not ensure 100% source-segregated composting and maximum social welfare. Why is this so? If we look back at Figure 2A, we realize that, unlike U, H re-

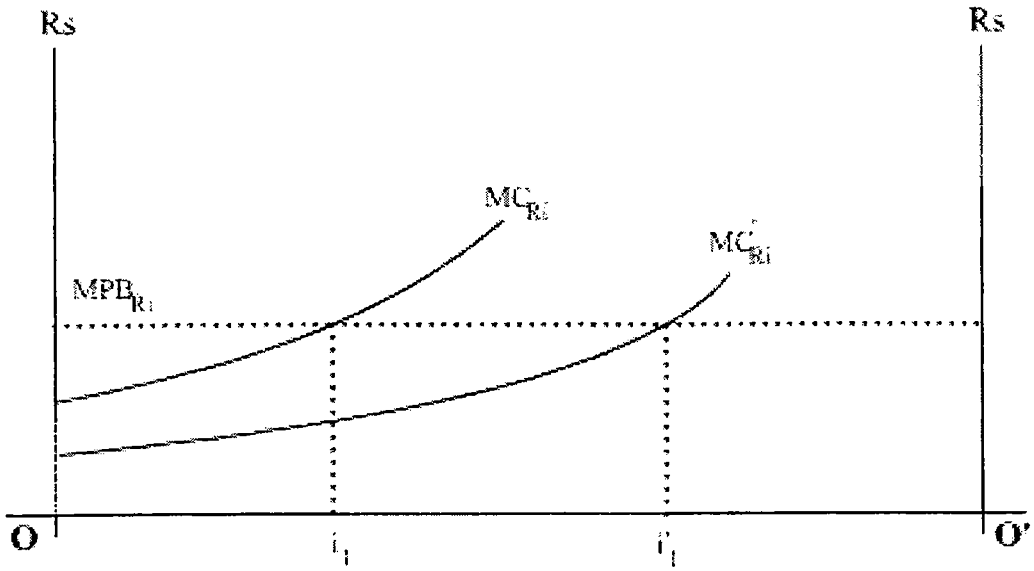

FIGURE 6
The effect of segregating organic waste at-source on recycling of dry waste

mains out of the market for source-segregated W_C. Is it not possible to induce H to segregate W_C at a price?

One is well aware that market incentives have been playing an important and effective role in the segregation and recycling of wastes like paper, plastic and glass (Beede and Bloom 1995, Beukering et al 1996, Shah and Bhuvaneshwari 1997). Given the high marginal utility from small increases in disposable incomes, such incentives could be useful in formulating a policy for organic waste disposal in countries like India.

How does a price incentive work in the segregation of waste? Assuming that there is a positive and increasing marginal private cost (MPC_S), however small, in separating W_C or W_{Di}[xv], segregation will not take place when the marginal private benefit (MPB) of this action to G is zero. This is illustrated in Figure 7 with the quantum of W_C segregated at-source by H measured in the O-O' direction.

In the case of R_{HQ} like newspapers, a marginal private

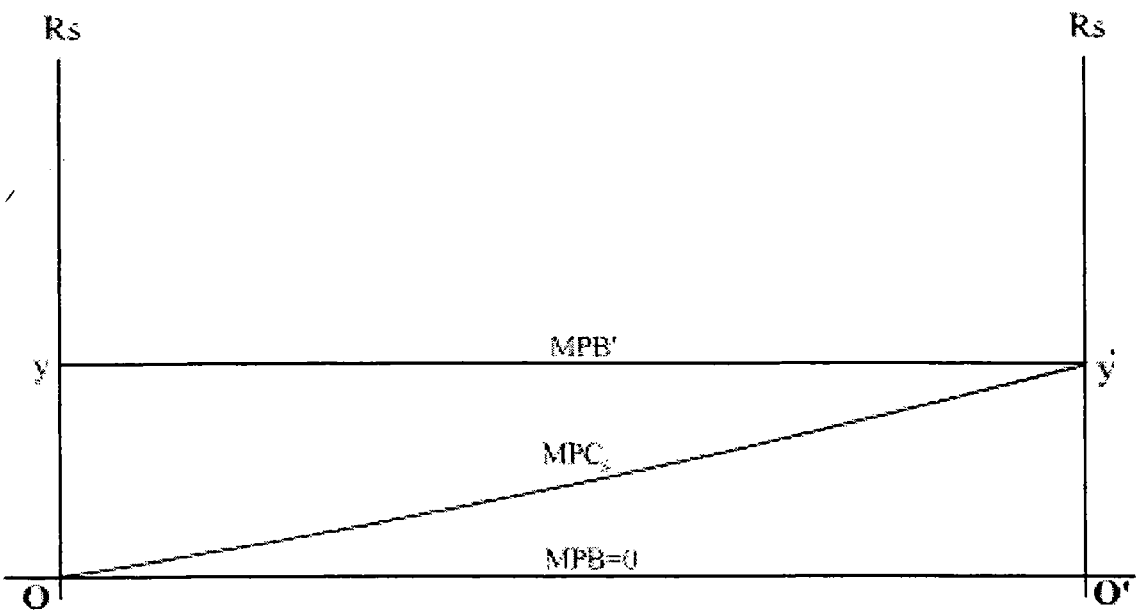

FIGURE 7
Using price incentives to induce households to segregate organic waste at-source

benefit of just about Rs.4[xvi] per kg, ensures that newspapers are almost never seen in garbage bins in India. In a study by Shah and Bhuvaneshwari (1997), it is interesting to note that each and every household they interviewed segregated and sold old newspapers. Beukering et al (1996) also report that 80% of 159 surveyed households in Bangalore separated recyclables like newspapers and bottles.

For households and other small-dispersed institutions [H], let us suppose that a positive marginal benefit of $y > x$ would then ensure 100% segregation of W_C (Figure 7). It is important to mention here that in our simple model, G undertakes to segregate W_C. In reality, it is likely that all G may not do so. However, domestic workers and/or informal sector waste collectors would take advantage of the positive marginal benefit (MPB' = y) to segregate W_C at-source or a point close to source. The total net private benefit from 100% segregation of W_C, which accrues to either G or a waste collector, is equal to the area (Oyy').

The incentive paid to H is only one component of cost to F_1 when it works with W_C segregated at-source. We must add to this the cost of collection, storage, transport and processing of segregated W_C, shown as MC_1 in Figure 8. MC_{F1}' (= MC_1 + y) then gives the marginal cost of utilizing source-segregated W_C from H. We have already seen in Figure 2A, that F_1 can procure O-O_U of W_C from U. The complete marginal cost curve for the composting plant F_1 using W_C segregated at source is given by MC_{F1}-MC_{F1}'.

With price of compost at P_1, the option for F_1 to procure source-segregated W_C from H is simply unviable and hence ignored in Figure 2A. Market failure to maximize social welfare, then calls for government intervention, wherein it undertakes to pay H the incentive y. With marginal cost to F_1 now equal to MC_1, it will undertake to compost (O-c_1) plus (O_U-c_1') of W_C (Figure 8). The total transfer to H is (O_U-c_1') times y. The government could charge a tax on H equal to the transfer. Apart from the transactions cost of organizing this scheme, there is *no net cost* to H or the government.

For a private composting unit (like F_1), Shah and Sambaraju (1997) have calculated the average cost price (collection, storage, transport and processing costs) as approximately Rs.5 per kilogram of compost and the average price of compost as Rs.6.40 per kilogram. Assuming a 5:1 conversion rate of W_C to compost, an incentive of Rs.4[xvii] per kilogram of W_C, works out to Rs.20 per kilogram of compost[xviii], which makes it unviable for F_1 to procure W_C from H. Subsidies on P_1 to cover such an incentive are unlikely to be granted.

A typical Indian household of 5 persons generates approximately 1 kilogram of compostable waste per day or 365 kilogram per year. If the incentive y is Rs.4 per kilogram of W_C, then an additional tax of Rs.1460 per year per household must be imposed. This is then "returned" to H as an incentive (y) for segregation of W_C.

Even though social welfare is not maximized (with reference to Figure 5), the incentive-based approach for segregation at-source of organic waste could significantly reduce the quantum of W_C for mixed-waste composting and dumping, which in Figure 8 is c_1-O_U plus c_2'-O'. This could also mean substantial financial savings to M. For example, Beukering et al (1999) report that the cost of land used as dumpsites by Mumbai municipality is priced at more than Rs.1.5 billion.

What remains crucial then in increasing the quantum of source-segregated composting is to make W_C available to F_1 at MC_1. Apart from the incentive component, this will also

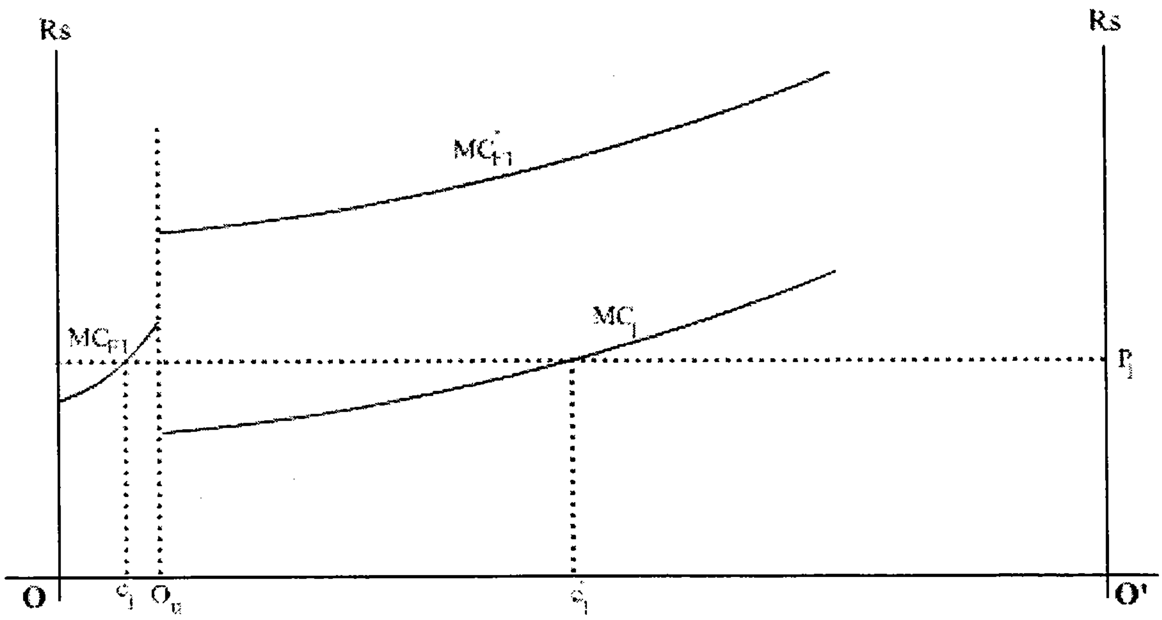

FIGURE 8
Increase in composting by F_1 when source-segregated organic waste is made available at MC_1

require collection, storage, transport and processing of organic waste to be carried out in the most efficient possible way so that finally the *average* cost to F_1 is either less than or equal to present levels[xix]. In the case of the old newspapers, where an efficient market for waste exists, "the margin between buying and selling price is generally low" (Beukering et al 1999). If a similar market could be developed for W_C, composting of source-segregated organic waste could increase significantly.

PRACTICAL ISSUES AND ARGUMENTS AGAINST A TAX-INCENTIVE INSTRUMENT FOR SOURCE-SEGREGATION OF WASTE

The theoretical analysis leaves many practical issues in implementation unanswered. However, it does show that an incentive could induce segregation of waste at-source. In situations where budget constraints facing authorities are severe, a tax, which is cost neutral for the stakeholders involved, could alleviate the problem. Moreover, the tax-incentive approach to segregation may help stakeholders achieve the widely accepted objective of source-segregated composting of organic waste more effectively than subsidies on price of compost (which would have a greater effect on mixed waste composting) or large spending on awareness programs.

Imposing a tax on households will obviously pose a major challenge especially considering that many urban households live below the poverty line in Indian cities. However, a progressive property tax collected by the state may be used as incentives for segregation so that poor households may actually be net beneficiaries.

The demand for source-segregated compost may also be an important limitation. Subsidized fertilizers act as a disincentive to compost use. There is a need to understand the attitude of farmers to compost and a more systematic marketing strategy to increase organic inputs in farming.

Finally, our theoretical analysis does not examine the difficulties that could be encountered in the actual working of such a scheme like, for example, the setting of transfer stations in residential areas, 'cheating' by H through inclusion of non-organic waste, measuring and monitoring segregation by households, and so on, which could impose significant transactions costs. Here, until such a scheme becomes functional, data on costs and benefits remain unknown.

A FRAMEWORK FOR THE EFFICIENT DISPOSAL OF USW

Studies (Beede and Bloom 1995) and experience (Mirzapur Report) seem to be leading towards a consensus on what an efficient waste management system may involve in a country like India.

- Collection services provided on a decentralized basis. Given that door-to-door collection of garbage by non-governmental organizations and civic groups (with rag-pickers as field workers) is already becoming standard practice in many cities, collection of segregated organic waste from households could be entrusted to such organizations. Rag-pickers must be organized as cooperatives under the guidance of non-governmental organizations in the task of collection of waste (Interim Report 1998).
- Consolidation into larger loads at transfer stations and transport by trucks to the processing facility could minimize costs. Such facilities presently do not exist for organic waste as in the case of waste paper or plastic. The problem of storage of organic waste, which is more complex than dry waste, must also be addressed.
- Given the need for standardized compost, large-scale scientific and mechanized composting is recommended (Interim Report 1998). It may also be more cost-effective for disposal and treatment facilities to be consolidated at a regional or metropolitan level (like F_1). When we take into account factors such the high opportunity cost of urban land, overheads for marketing and distribution of compost and benefits of professional managerial and technical services, small-scale decentralized units are at a clear disadvantage. Moreover, small-scale, neighborhood composting is being discouraged by local health officials after complaints of rodents (Einsiedel 2001), odors from garbage and other inconveniences to local residents.

Fitting in the tax-incentive approach for segregation of waste in such a system would then entail the close cooperation of both, private and public institutions. This is illustrated in Figure 9, which shows the monetary and physical (W_C) flows between the government [N], F_1, H and V.

If source-segregation of organic waste still remains impossible to initiate, it is advisable to look at the second best solution to source-segregated composting, i.e. mixed-waste composting, dumping or landfilling. This will depend on the shape and position of MSB_{F2}, MSB_D and MSB_L, which is not only an economic but also a scientific-environmental issue.

CONCLUSIONS

USW management in less developed countries cannot ignore the importance of dealing with organic waste. Even though composting of source-segregated waste is considered the best possible option for organic waste 'disposal', inducing waste generators to segregate organic waste remains a difficult hurdle to overcome.

One initiative in USW management, which is finding widespread acceptance in some developed countries, is mandatory recycling programs along with the use of market incentives, rather disincentives, through direct charges on waste generators proportionate to weight or volume of wastes generated (Reschovsky and Stone 1994, Miranda et al 1994, Beede and Bloom 1995, Devlin and Grafton 1998). By putting a price per unit of waste generated, these disincentives

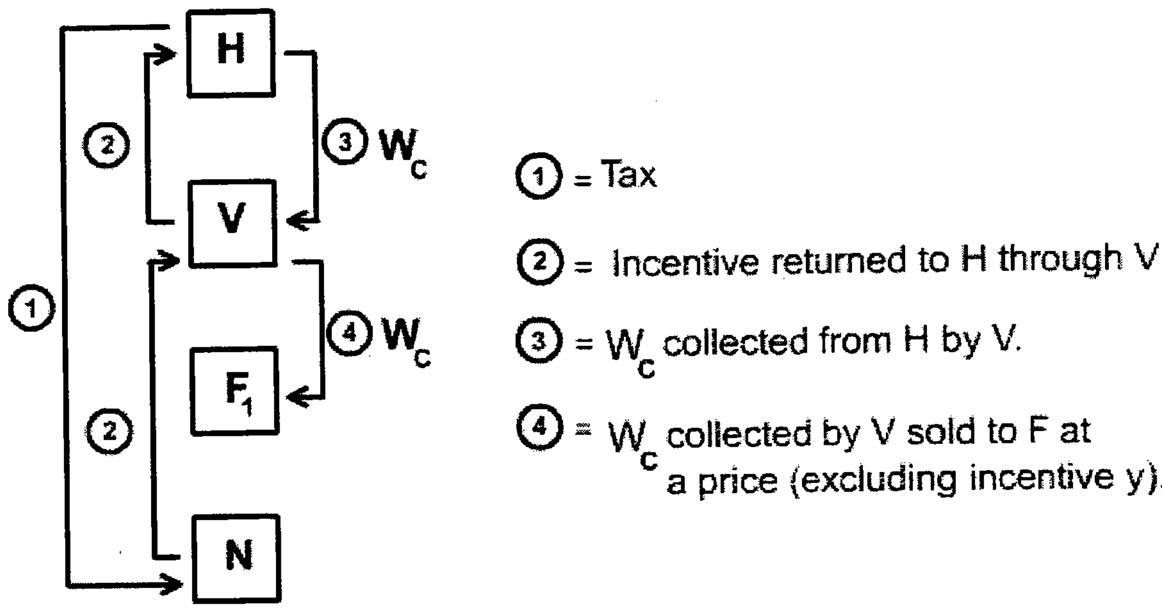

FIGURE 9
Flow diagram of tax, incentive and organic waste between stakeholders in an incentive-based organic waste management system

aim at reducing the quantum of waste. However, the cost of monitoring illegal dumping of garbage and the enforcement of penalties makes this policy useless in the Indian context (Beukering et al 1999). We instead propose considering using of a market incentive to induce households to segregate organic waste. Such incentives have been practiced extensively and successfully in the segregation of dry waste in less developed countries.

However, when incentives are paid to households, given the current price levels of compost, market forces are not likely to lead to increase source-segregated organic waste composting. Government intervention with the assistance of non-governmental and civic groups is required so as to make such waste available to composting firms at a 'reasonable' cost. A tax collected by the government from households to compensate it for payment of incentives will impose no net cost, except transactions cost, on the stakeholders in the USW management system.

As we have seen, alternative initiatives to increase source-segregated composting are short-term, ad-hoc and entirely dependent on external grants or fees collected from waste generators. If an incentive-based system for collection of organic waste cannot be implemented, it may be better to look at a second best solution to source-segregated composting.

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[i] Urban or municipal solid waste is defined as including commercial and residential waste generated in a municipal or notified area in either solid or semi-solid form excluding industrial hazardous wastes but including treated biomedical wastes (Gazette of India 2000).

[ii] Civic watch columns in newspapers regularly report problems of uncollected garbage.

[iii] Beukering et al (1999) report that on average approximately 30% of USW remains uncollected. The GOI (1995) reports, "in most cities nearly half of solid waste generated remains unattended." Moreover, USW management entails not just collection but also the issue of safe disposal.

[iv] An exception is certain biomedical wastes like body parts, etc.

[v] Other options for disposal of USW like power generation, pelletization and biomethanation have also not been recommended in the Interim Report (1998) because no such plants have been installed or working successfully in India. We ignore these as relevant options in our paper.

[vi] The article reports that an estimated 60000 MT of lead is recycled illegally ... this is done in small sheds with scanty provisions for environmental concerns.

[vii] This is likely to include organic waste suitable for use as fuel (coconut shells, wood, etc.)

[viii] Composting passes through three main stages: preparation, decomposition and maturation. Some large contraries may be removed at the preparation stage, "but generally screening to remove smaller contraries such as plastic or glass is not carried out until after maturation" (Waite 1995).

[ix] Graphs are not drawn to scale.

[x] A cautionary note: one unit of W_C results in much lower quantity of compost, usually about 5 times lower. When we measure the quantity on the x-axis in terms of W_C, the price of compost must also be in terms of W_C. If compost fetches a price of Rs.1 in the market, then in our graphs, P is Rs.0.2.

[xi] Source-segregated price is Rs.5.50 and mixed-waste compost price Rs.1.85 per kilogram.

[xii] There is a more technical question that needs to be answered here, namely, whether composted USW can be considered a substitute for chemical fertilizer. Unless the compost has a low C/N ratio it will have little nutrient value although it could serve as a soil conditioner. I thank the anonymous referee for this comment.

[xiii] The MSB_{F2} curve with delayed segregation after composting may actually be negative for large quantities of composted waste. India could produce approximately 3 million tons of compost per annum from USW and it would be dangerous for this to be polluted with toxic elements.

[xiv] The content of paper in public dustbins is about 3% (Beukering 1996). We assume that 66% is already recovered by rag-pickers leaving 1% in the dustbin and taken to the composting plant.

[xv] This cost will include ".... the household's valuation of time and inconvenience of preparing the item for collection ..." (Reschovsky and Stone 1994).

[xvi] $1 = Rs. (Indian Rupees) 45 approximately.

[xvii] This is the rate at which H sells old newspapers in the market. It may be necessary to increase this incentive price for organic waste given that handling of such waste is not as easy as segregating dry waste.

[xviii] Since y is horizontal, marginal cost is equal to average cost.

[xix] Shah and Sambaraju (1997) report at average cost of Rs.5 per kg. At this average cost, private firms currently undertake composting of source-segregated organic waste.