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# Economics of Household Waste Management in Kolkata: Proposed Steps towards Improved Efficiency

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**Abstract**

The city of Kolkata generates more than 4000 tons of solid waste per day. As a group, households are the single largest generators of municipal waste and account for more than 50 percent of the total waste in the city. As open dumping is no longer viable, the Kolkata Municipal Corporation is trying alternative modes of disposal such as composting. However, in the absence of incentives, households do not separate

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organic waste from regular waste; this, in turn, increases the processing cost of compost producing units in Kolkata. Using a simple static general equilibrium model, we consider the optimal policies that would induce source separation of post-consumption waste at the household level. It appears that a deposit refund system coupled with a subsidy on organic manure would be the optimal outcome. However, from the point of view of the local bodies, a user fee coupled with a subsidy on compost output is the first best outcome though its efficiency can be questioned given the possibility of illegal dumping.

**Key Words:** Environmental taxes and subsidies, solid waste, government policy

**JEL Classification:** H23, Q53, Q58

# 1 Introduction

Presently, more than 4000 tonnes of municipal solid waste is generated in the city of Kolkata. As per official estimates, as a group, households are the single largest generators of municipal solid waste and contribute 53 percent of the total waste in the city. A substantial part of the household waste in Kolkata is disposed off through the Municipal Conservancy Service (MCS). In the existing system, the Kolkata Municipal Corporation (KMC) disposes off the collected waste by means of open dumping in crude landfills near Dhapa, Noapada, and Garden Reach. As there is no provision for collection of pre-sorted waste, the disposed off waste mostly consists of kitchen waste along with household toxic waste, inert materials like ash and coal etc. However, households separate items like plastic, paper, metal, glass etc. from their regular garbage because these can be re-used or sold in an informal market. The buyers of these items are itinerant vendors who pay households for the items.

Given the fact that per capita waste generation per day in the city is well over 700 grams and there is a shortage of dumping space, management of this huge quantum of waste is a serious problem for the local body. Moreover, the possibilities of ground water contamination and adverse health consequences have made open dumping an almost non-viable mode of disposal. In fact, for biodegradable waste composting may be considered as an alternative as this process converts a domestic "bad" into an agricultural good. For Kolkatans, nearly 41 percent of their total waste is in fact biodegradable (Times of India, June 2, 2004). However, the adoption of alternative disposal methods such as composting runs into a problem: the waste is *not* properly segregated (see Banerjee and Sarkhel (2003)). This is because a household's source-separation activity is limited to items that can either be re-used or have an exchange value in the market.

In designing efficient strategies of waste management for Kolkata, one important feature of the city should be kept in mind. Due to unplanned growth in most wards of KMC, both industrial and residential units co-exist. In addition, in some wards the hospital waste is also dumped in public vats. The composition of waste increases the difficulty involved in its management. The industrial waste is mostly chemical and non-biodegradable whereas the hospital waste is highly toxic. To handle such waste, installation of effluent treatment plants, incinerators etc. may be useful. On the other hand, domestic waste is mostly biodegradable and composting remains an alternative mode of waste disposal. The major difficulty faced in its widespread use, as indicated already, is the absence of source-separation at the point of garbage production. For the production of quality manure, properly sorted waste is necessary. If the households do not separate waste at source, the compost producing firms must do so and this increases their average cost of production. In addition, huge government subsidies for synthetic fertilizers such as urea act as a deterrent towards the increasing usage of organic manure.[2] This paper will discuss the alternative policy choices open to the regulator for better management of municipal solid waste (MSW) generated from domestic sources *only*.

## 2 Household Waste Disposal in Kolkata

Private households in Kolkata mostly use the MCS for disposing off organic waste.[3] However, a substantial amount of recyclable items such as plastic, glass, and metal along with household appliances (which may include toxic waste) are also disposed off along with the regular garbage. The collection system of residential waste is *not* designed to collect pre-sorted waste. In some parts of the city, households simply dispose off their garbage in concrete vats or into metal bins and containers.[4] These are then loaded into tipper trucks and carried to the dumping grounds. From 1995, house-to-house collection of residential waste has also started in certain areas of the city. While there

[2]In fact, Eastern Organics Fertliser Pvt Ltd, a compost producing unit in Kolkata, is finding it difficult to market its products because of the reasons cited above.

[3]This section is based on the results of a primary survey of 674 households in 131 wards of Kolkata conducted by Ekta Ecological Foundation (EEF) in 1997-98 (EEF, 2002).

[4]There are 276 vats and 280 container points spread across Kolkata (Sarkar, 2002).

remains no provision for collection of source-separated waste, households also do not face economic incentives for practicing source-separation. The charge for MCS is included in the consolidated property tax and so the marginal cost of waste disposal to the household is zero. Naturally, waste reduction effort in terms of source-separation is not undertaken for waste materials that have no exchange value in the informal recycling market. Of course, the social cost of dumping co-mingled waste is quite high.[5]

Itinerant buyers provide the linkage between households and the informal recycling sector. It is estimated that there are at least 2500 to 3000 itinerant buyers operating in the city of Kolkata. On an average, these traders recover 75 to 105 metric tons of household waste material per day. Among the materials recovered, paper and glass have the highest recovery rate, followed by plastic and metal.[6] Among the materials sold by households, plastic fetches the maximum price and glass has the lowest value. Accordingly, there is maximum incentive to segregate plastic waste at source. Not all items are accepted by the itinerant traders. The unaccepted items include un-recyclable multi-layered or multi-material packaging such as tetra packs, medicine packaging, squeezable tubes, bottles and packets made out of plastics like polyethylene

[5]The decomposition of carbon contents from unsorted MSW gives rise to landfill gases that consist of carbon dioxide and methane. In fact, landfill gas emissions account for nearly one half of the world's total anthropogenic sources of methane. As a green house gas, methane is 19 to 21 times more potent than carbon dioxide (Hoornweg *et al.* (1999)).

[6]An alternative estimate of the extent of household recycling in Kolkata is provided by NEERI (1995). They analyzed the composition of recyclables in waste samples, both at the source of generation as well as at the disposal site. On an average, about 40 percent paper, 35 percent plastic, 45 percent glass, and 50 percent metal are found to be recycled by households. This implies that the recovery rate is highest for glass and metal. However, as in EEF (2000), plastic has the lowest rate of recycling.

terepthalate (PET) etc. Following the ban on poly bags with thickness less than 20 microns, carry bags are no longer in demand by the informal sector for recycling. Finally, it is common for households in Kolkata to litter or indiscriminately dump some waste items. This results in clogging of sewage drains and water logging in the city area during the monsoon.

# 3 Economics of Source Separation

The choice between conventional (or mixed waste) disposal and source separation depends on the relative resource costs of the two activities. Mixed waste disposal is associated with a lower resource cost (time cost, storage cost etc.) than separating waste at source. Thus, in the absence of any volume or weight based fee, private behavior will surely lead to mixed waste disposal except for source separation that is induced by the re-use and recycling motives.

On the other hand, source-separated waste is an intermediate input in the production of goods such as compost. A higher degree of source separation provides individuals with both environmental and health benefits in terms of displaced landfills and higher compost production. To see this, consider figure 1. Given the price of synthetic fertilizers, note that the demand curve facing compost producers is fairly elastic. Assume now that the cost of producing compost is increasing in the amount of contrary materials present in the waste stream. This implies that the supply curve of compost output is positively sloped ($S_0S_0$). If wastes are source-separated, more compost will be supplied at a given price and the supply curve shifts to the right ($S_1S_1$). As a result, compost production increases from $W_C^0$ to $W_C^1$.

Since segregation of waste at source imposes a resource cost on households, an incentive scheme must be worked out to induce optimal disposal behavior. Before laying out the details of this incentive scheme, it is instructive to pay some attention to the literature dealing with efficient solid waste management. Here, the social planner broadly divides the instruments into two categories: she either targets the reduction of waste content inherent in the pattern of consumption through *upstream purchase relevant* instruments or she introduces policies to encourage proper disposal of garbage through *downstream discard relevant* instruments.[7] In fact, in some situations, when the transaction cost of implementing either of these pure instruments is exorbitantly high, some combination of hybrid policies may turn out to be equally efficient and more easily implementable (Dobbs (1991), Palmer *et al.* (1997), Choe and Fraser (1998), Fullerton and Wu (1998), Calcott and Walls (2000)).

The downstream discard relevant instruments in the literature do *not* focus adequate attention on the advantages of source separation. Instead, emphasis is generally placed on encouraging re-use and recycling. In contrast, this paper makes a distinction between biodegradable and non-biodegradable waste and, for the former, composting is viewed as the relevant management option. The rest of this paper is structured as follows. Section 4 presents a simple choice-theoretic general equilibrium model while section 5 discusses alternative policy options. Section 6 concludes.

[7] An important example of an upstream purchase relevant instrument is the concept of product design. The packaging of a product is directly related to its waste content, and the possibility of re-use and recycling may affect the ultimate waste creation to a significant extent.

# 4 The Model

The objective of the regulator is to enlarge the choice set of feasible disposal options available to households by including segregation of waste at source. In the absence of any intervention, the waste generated by households is either recycled and sold to itinerant buyers or disposed off as mixed garbage. Since garbage is a public bad and the municipal authority incurs a cost in managing it, the social cost of the garbage disposed off is far higher than its private cost. This leads to excessive waste generation by households and, therefore, the regulator may impose a tax on the generation of mixed garbage so as to obtain the social optimum. If the regulator designs appropriate policy instruments, households may be induced to transform part of their garbage into source-separated waste. The biodegradable part of the separated waste is used for composting and the local body landfills the remaining portion of the refuse. Thus, the cost incurred in source separation can be perceived as an abatement cost. Intuitively this suggests that the tax on source-separated garbage should be less than that on mixed garbage so as to induce households to incur the separation cost.

To formalize the foregoing discussion, assume that there are $n$ identical households in a locality. Households consume a composite commodity, $c$, and generate post-consumption waste, $g$, such that

$$g = g(c), \;\; g' > 0. \tag{1}$$

The regulator has to expend resources to landfill this waste. Assume that the per-unit resource requirement for such disposal activity is constant, say $\gamma$. However, the resource cost of landfill activities is reduced if the household sends less waste for dumping, and this can be achieved if the biodegradable and inert waste is separated at source. Assume that $\theta$ fraction of $g$ consists of biodegradable waste, say $b$. More formally, we denote the amount of organic waste by

$$b = \theta g, \quad \theta \in (0, 1). \tag{2}$$

Suppose that a household requires $k_s$ units of a resource to separate out the biodegradable part of the garbage, say $b^s$.[8] The source-separation activity can be characterized by the function

$$b^s = l(k_s), \;\; l' > 0, \; l'' < 0. \tag{3}$$

Inverting the above function, we get

$$k_s = m(b^s), \;\; m' > 0, \; m'' > 0. \tag{4}$$

We assume that $m'(0) = 0$, which follows from the imposed restriction that $l'(k_s) \to \infty$ as $k_s \to 0$.

Given $k_s$, the remaining portion of the garbage (that is, $(g - b^s)$) is landfilled and creates a disutility for the household in terms of health and aesthetic costs. We assume that it may not be efficient to source separate *all* of the organic waste, so that

$$0 \leq b^s \leq b = \theta g. \tag{5}$$

The source-separated waste, $b^s$, is costlessly procured by compost-producing firms. They convert $b^s$ to organic manure, say $z$, by the fixed-coefficient pro-

[8]In practice, households also separate recyclables from regular waste. However, the market for recyclables clears and we do not consider the environmental impact of the recycling process. Instead, we focus on the disposal choice between source separation and mixed waste disposal. Unlike recycling, source separation is a non-market activity in the sense that households do not receive any direct payment for source-separated waste.

duction function,

$$z = min\{\alpha b^s, \beta k_z\}. \tag{6}$$

In this case, $b^s$ is a given and firms only choose the other input such that the input ratio is $\frac{\alpha}{\beta}$. The ratio $\frac{\alpha}{\beta}$ can be interpreted as the constant per unit cost of compost production.

Compost production provides considerable environmental benefits (for example, the retention of water in the soil improves and the usage of chemical fertilizers is partially replaced). Thus, $z$ is a source of positive externality to households. Accordingly, the utility function of a households is written as

$$u = u(c, G, Z), \;\; u_c > 0, \; u_G < 0, \; u_Z > 0, \tag{7}$$

where we define $G = n(g - b^s)$ and $Z = nz$.

To dispose off the garbage, producers of the garbage disposal service use resources $k_g$, where

$$k_g = \gamma(g - b^s), \tag{8}$$

and $\gamma$ is the unit cost of mixed waste disposal.

The firm that produces the composite commodity, $c$, uses the organic manure, $z$, and another input, $k_c$, in the production process. The production function is assumed to exhibit constant returns to scale,

$$c = f(k_c, z), \;\; f_{k_c} > 0, \; f_z > 0. \tag{9}$$

As $z$ and $k_c$ are considered to be substitutes in the production activity, $k_c$ can be interpreted as the resource spent in using a synthetic fertilizer (say, urea).

The total resource endowment for the community is denoted as $K$. This resource is owned in equal shares by the $n$ identical households. Let $\bar{k} = \frac{K}{n}$.

Then, $n\bar{k} = n(k_g + k_s + k_z + k_c)$. This means that the aggregate resource constraint for the economy can be written as

$$\bar{k} = (k_g + k_s + k_z + k_c). \tag{10}$$

The social planner maximizes the utility of the representative household in (7) subject to the production constraints (1), (4), (5), (6), (8) and (9) and the aggregate resource constraint (10). Thus, the necessary conditions for a Pareto optimum is obtained by maximizing the Lagrangian

$$L^s = u(c, G, Z) + \delta[f(\bar{k} - m(\frac{z}{\alpha}) - \gamma(g(c) - \frac{z}{\alpha}) - \frac{z}{\beta}, z) - c] + \mu(\theta g(c) - \frac{z}{\alpha})$$

with respect to $z$ and $c$. The first order condition with respect to $c$ is

$$u_c + nu_G g' + \delta[-f_{k_c}\gamma g' - 1] + \mu[\theta g'] = 0. \tag{11.1}$$

Given the non-negativity restriction on $z$, the first order condition with respect to $z$ is

$$-n\frac{u_G}{\alpha} + nu_Z + \delta[-f_{k_c}\frac{m'}{\alpha} + f_{k_c}\frac{\gamma}{\alpha} - f_{k_c}\frac{1}{\beta} + f_z] + \mu[-\frac{1}{\alpha}] \leq 0, \tag{11.2}$$

$$z[-nu_G + \alpha nu_Z + \delta[\alpha f_z - f_{k_c}m' + \gamma f_{k_c} - f_{k_c}\frac{\alpha}{\beta}] - \mu] = 0, \quad z \geq 0. \tag{11.3}$$

Note that $\delta$ is the social marginal utility of income and $\mu$ is the shadow price of source separable organic waste.

If source separation is indeed desirable from society's point of view, then at the optimum $z$ must be strictly positive. In fact, if the unit cost of mixed waste disposal exceeds the cost of composting from the point of view of the society, $z = 0$ can never be Pareto optimal.[9] To see this, note that $z = 0$

[9] The author is grateful to the anonymous referees for pointing this out.

implies that source separation has not taken place (that is, $b^s = 0$). Since $c > 0$, we have $\theta g(c) > b^s$ and hence $\mu = 0$.[10] At $z = 0$, the left-hand side of (11.2) reduces to $\frac{1}{\alpha}[-nu_G + nu_Z + \delta[-f_{k_c}m'(0) + \alpha f_z + f_{k_c}(\gamma - \frac{\alpha}{\beta})]]$. Further, if it is assumed that the unit cost of mixed waste dumping is higher than that of compost production from the point of view of the society, then $(\gamma - \frac{\alpha}{\beta}) > 0$. Thus, the term $[-f_{k_c}m'(0) + \alpha f_z + f_{k_c}(\gamma - \frac{\alpha}{\beta})]$ is positive; this, together with the given sign restrictions on $u_G$ and $u_Z$ implies that evaluated at $z = 0$, $\partial L^s/\partial z > 0$. We have thus contradicted a basic requirement at the optimum and, hence, $z = 0$ cannot be optimal after all.

In the private market, the individual maximizes utility in (7) subject to the budget constraint[11]

$$p_k(k_c + k_g + k_z) = p_k(\bar{k} - k_s) = p_k(\bar{k} - m(b^s)) = c + (p_g + t_g)(g - b^s)$$

and $b^s \leq \theta g$. Here, $p_k$ is the per unit price of the resource, $c$ is the numeraire good, $p_g$ is the per unit price of the garbage disposal service, and $t_g$ is the tax rate on garbage disposal. If households consider $Z$ as given and ignore their own contributions to the landfilled waste, the first order conditions are

$$U_c + \lambda[-(p_g + t_g)g' - 1] + \psi[\theta g'] = 0, \tag{12.1}$$

$$\lambda[-p_k m' + (p_g + t_g)] + \psi[-1] \leq 0, \tag{12.2}$$

$$b^s[\lambda[-p_k m' + (p_g + t_g)] + \psi[-1]] = 0, \quad b^s \geq 0. \tag{12.3}$$

Note that $\lambda$ is the private marginal utility of income. Now, in the absence of

[10] The Kuhn-Tucker condition for $\mu$ reads as follows: $\mu \geq 0$, $(\theta g(c) - b^s) \geq 0$, and $\mu(\theta g(c) - b^s) = 0$. Since $(\theta g(c) - b^s) > 0$, it must be that $\mu = 0$.

[11] We assume that households have a lump sum share in the profits of firms. Thus, the budget constraint also includes a constant term that disappears in the market equilibrium.

incentives, say if garbage is collected without charge (that is, $p_g + t_g = 0$), surely $b^s = 0$: source separation at the household level is not practiced.[12]

In the product market, compost-producing firms practice average cost pricing.[13] Hence,

$$p_z = AC_z = \frac{p_k}{\beta}, \tag{13}$$

where $p_z$ is the per unit price of organic manure.

In the market for good $c$, the firm maximizes $\pi^c = f(z, k_c) - (p_z + t_z)z - p_k k_c$, where $t_z$ is the per unit tax on $z$. The two first order conditions are as follows:

$$f_z - t_z = p_z, \tag{14}$$

$$f_{k_c} = p_k. \tag{15}$$

Using (15) and (13), (14) can be written as

$$\beta f_z - f_{k_c} = \beta t_z. \tag{16}$$

Similarly, assuming that producers of the garbage disposal service earn zero profits, we obtain $p_g(g - b^s) - p_k k_g = 0$. This implies that $p_g \frac{k_g}{\gamma} = p_k k_g$

[12]For $p_g + t_g = 0$ and $\lambda, \psi > 0$, the weak inequality in (12.2) is actually strict; so $b^s$ is equal to zero by (12.3).

[13]In the case of Kolkata, a company called Eastern Organics Pvt. Ltd. carried out the project of producing manure out of municipal waste. In many ways, the firm resembled a natural monopoly providing a local utility service (for example, incurring huge fixed costs for setting up its facilities). At the same time, the firm was regulated and had a revenue sharing arrangement with the local government. For a regulated natural monopoly, setting price equal to the average cost would have been the next best alternative to marginal cost pricing.

and, so, $p_g = \gamma p_k$.[14] We can therefore substitute marginal products in place of prices in the first order conditions for the decentralized market equilibrium to make it comparable with the necessary conditions for a Pareto optimal outcome.

# 5 Policy Options

Clearly with no government intervention (that is, $t_g = t_z = 0$), equations (12.1)-(12.3) do not match the conditions for a Pareto optimum. However, for $\delta = \lambda$ and $\mu = \psi$, equations (11.1)-(11.3) match equations (12.1)-(12.3) only if $t_g^* = -\frac{nU_G}{\lambda} > 0$ (the optimum tax rate on garbage disposal is positive) and $t_z^* = -\frac{nU_Z}{\lambda} < 0$ (the optimum tax rate on the usage of organic manure is negative).

If households are taxed on garbage disposal, the relative price of mixed waste disposal increases and households switch to the relatively cheaper disposal option of source-separation. The supply of source-separated waste may not match the demand for organic manure. This is because the per unit price of organic manure, $p_z$, fails to reflect the benefits from the production of organic manure in terms environmental gains from sustainable agricultural practices. Thus, there must be a subsidy on the usage of organic manure. Given $p_k$, the producers of commodity $c$ substitute more $z$ for $k_c$ and the first best outcome is achieved. This result confirms the long-standing demand for a subsidy on organic manure by compost producers. Notice, however,

[14] Since the garbage disposal activity is produced competitively at constant cost, no profit is involved in its production. Though empirical evidence for constant returns to scale in garbage disposal services is available for other communities (see Stevens (1978)), we assume it in the case of Kolkata for expositional convenience.

that to achieve the first best outcome, the subsidy on organic manure usage must be coupled with a per unit tax on garbage disposal that reflects the net aggregate externality from mixed waste disposal.

In practice, the KMC does not collect any user charge from its residents. Charges for waste disposal services are mostly collected as flat fees that fail to affect the household's disposal behavior at the margin. However, any alternative policy instrument that makes mixed waste disposal dearer than source-separation can guarantee socially optimal disposal behavior. For instance, a per unit subsidy on source-separated waste would also raise the relative price of mixed waste disposal. Unfortunately, this also implies that there is an implicit subsidy on consumption as the cost of waste disposal declines. Hence, there is socially excessive consumption and more total waste, resulting in a higher aggregate net externality. Thus, to maintain proper relative prices in general equilibrium, consumption must be taxed. To derive these multiple policy instruments formally, rewrite the consumer's budget constraint as

$$p_k(\bar{k} - m(b^s)) = (1 + t_c)c + p_g(g - b^s) - t_b b^s,$$

where $t_c$ is the per unit tax on consumption. Again for $\delta = \lambda$ and $\mu = \psi$, the decentralized market outcome will match the social optimum for the following two tax rates:

$$t_c^* = -\frac{nU_G g'}{\lambda} > 0, \quad t_z^* + t_b^* = \frac{nU_G}{\lambda} - \frac{nU_Z}{\lambda} < 0.$$

This is essentially a deposit refund system with deposits collected on consumption and refunded on source-separated waste. However, this time it is not necessary to subsidize the compost output directly - a subsidy on source-separated waste could bring about the optimal level of compost production (that is, with $t_b^* = \frac{nU_G}{\lambda} - \frac{nU_Z}{\lambda} < 0$ and $t_z^* = 0$). Alternatively, instead of subsidizing innumerable households, the regulator may decide to subsidize fewer compost firms. In both cases, the first best level of outcome is achieved.

# 6 Concluding Observations

Though solid waste management is a State Subject, by the 74th constitutional amendment, local bodies such as municipal corporations have been bestowed with the responsibility of collecting and disposing off residential waste. As the constitutional power of local bodies is limited, they may fail to implement all of the proposed policies in the model. For instance, a subsidy on the price of compost can be administered by the union government while a tax on consumption (which is basically a sales tax) falls under the purview of the state government.

Some adjacent municipalities of Kolkata (for example, Kanchrapada, Bhad reshwar, and Kalyani) have started subsidizing source separation activity at the household level. These local bodies are providing storage containers to households at no charge to facilitate separation of wet waste and dry waste at source. However, in view of the imminent crisis of areas for landfills and the rising cost of compliance with environmentally sustainable landfill designs, such a policy induced increase in welfare would be a short run phenomenon. In the absence of incentives for source reduction (that is, with $t_c^* = t_g^* = 0$), pressure on existing landfill sites is bound to increase in the long run. In this respect, a more efficient policy option for the local government would be to opt for a per unit tax on garbage collection. In our model, $t_g^* = -\frac{nU_G}{\lambda} > 0$. Consistent with received wisdom, notice that the optimal tax rate is equal to the marginal social damage created by the garbage disposal activity.

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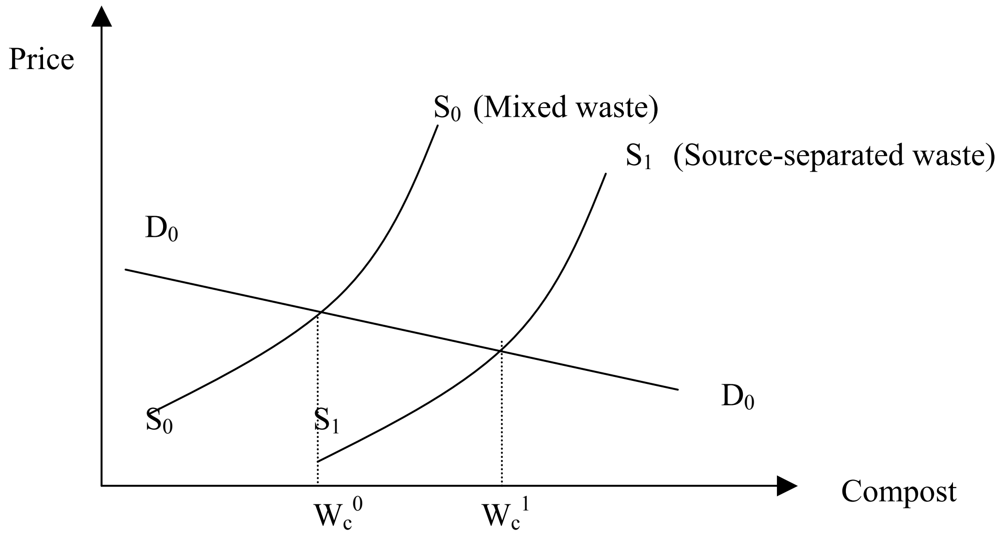


Figure 1: Source separation and compost production.