Measuring the Environmental Cost of Landfill

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Abstract The lack of awareness of future environmental liability and the difficulty of measuring the cost of environmental damage in monetary terms are the main reasons that the environmental cost is not internalised in the full cost of landfill operation. This paper reviews the environmental impacts of landfill on both natural and social environment, respectively classified as physical impact and social impact. The economic costs associated with these two impacts are presented and a theoretical approach based on statistical techniques is developed to evaluate monetarily the environmental cost that is likely arise from the use of municipal solid waste (MSW) landfill. The principles of the evaluation methods are also discussed with suggestions for further application.

1. INTRODUCTION

Landfilling is by far the most common method of solid waste disposal in Australia, and will probably remain so. Each year more than 140 million tonnes of solid domestic, commercial and industrial waste are disposed in Australian landfills (Bureau of Industrial Economics, 1993). When the landfill cost is calculated, however, the environmental penalties such as the cost of groundwater contamination by landfill leachate, the cost of air pollution by landfill gas emission and the cost of social impacts of the landfill on the host community, are usually ignored due to either the lack of awareness of future environmental liability or the difficulty in quantification (Stanley, 1992). The result is an underestimate in the landfill pricing system with the following consequences: (a) low (or zero) tipping fee being charged, which does not reflect or cover the real cost of the landfill and acts as a disincentive to the national waste minimisation strategy; (b) inhibition of the development of other waste management options such as recycling, waste reduction and resource recovery, which would have yielded benefit to society in terms of reduced raw material consumption; and (c) discouraging the environmental improvements surrounding the landfill.

Although some efforts have recently been made to take into account environmental degradation when assessing the full cost of landfill, (Hirshfeld, 1989, 1992; Stanley, 1992; Cook, 1992), the evaluation approach to determining and quantifying the cost of environmental damage caused by landfill should be taken further (Bureau of Industry Economics, 1993).

This paper outlines the environmental impacts of landfill operation on the environment and its associated cost and then proposes a theoretical approach to evaluating monetarily the environmental costs that are likely to arise from the use of typical MSW landfills.

2. THE ENVIRONMENTAL IMPACTS OF LANDFILLS

The modern concept of landfilling, like other waste options (eg. incineration and biological treatment), is a waste processing facility, rather than a "black hole" into which material is deposited and from which it never leaves (Krol, et al 1994). This process shown as Figure 1 involves the input of solid waste, and following the decomposition of the putrescible further, the output of the final stabilised solid waste,

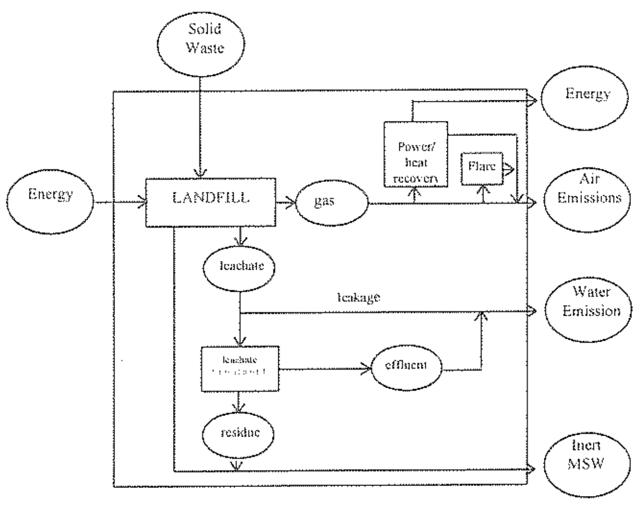

Figure 1. Landfilling Process

plus the gaseous and aqueous products of decomposition. These emerge as landfill gas and leachate. This process generally exerts two types of external impacts on the environment: physical impacts and social impacts (Hirshfeld et. al., 1992). These impacts are simply described below.

2.1 Physical Impacts

Physical impacts arise directly from the process of landfill operation, or from the products generated by the landfill such as the contamination of groundwater and surface water by landfill leachate, air pollution by release of landfill gases etc. Although most new landfills are well equipped with lining, capping, leachate treatment and gas collection systems, to prevent (or minimise) the physical impacts on the environment, past experience shows that these systems provide no guarantee that the potential environmental damage can be completely avoided. This is due to the limitations of technology and amongst other reason (Robinson, 1987). More likely, part of the leachate will be discharged directly into the underlying strata, from where it can contaminate the groundwater, and also part of the landfill gas will eventually be emitted into the atmosphere as (at best) a contributor to greenhouse gas. Therefore, the costs of the potential environmental damage could be categorised as two types: the cost associated with the implementation of new technology for environmental protection which is usually required by landfill regulations, and the cost associated with unavoidable environmental detriment resulting from long-term landfill operation, such as the potential cost of water contamination by possible leachate leakage and the cost of global warming contributed by landfill gas emissions. The first type of cost is normally included in the capital cost of landfill and is easy to identify. The far less tractable problem considered in this paper is how to take the second cost into account when assessing the real cost of landfill. Both costs are directly related to the tonnage of waste throughput and can be expressed in money values per tonne of waste.

2.2 Social Impacts

Unlike physical impacts, social impacts are the indirect factors effecting on the host community regardless of whether the landfill produces any physical impacts. Such impacts usually include the increased traffic, noise, unpleasant odours, aesthetic degradation and property devaluation in the landfill surroundings. The cost of social impacts reflect the value of the environmental disamenity which the host community have to suffer due to the existence of the landfill. It is widely accepted that this cost could vary with the size of the site, and hence indirectly to the tonnage throughput. Evidence from economic evaluation studies from the USA suggests that it is better expressed in terms of money values per household or per site, rather than money values per tonne of waste (Department of the Environment, 1993). Therefore carefully selecting the appropriate landfill site can decrease this kind of cost.

3. METHODOLOGY AND APPROACHES

One of the approaches to economic measurement of environmental cost which has been widely used is called related market valuation method (Pearce et. al., 1990), which considers degraded scenic view, worse levels of air quality or water quality etc. This may be done by looking for a surrogate market or by experimental techniques. The surrogate market approach looks for a market in which goods or factors of production are bought and sold, and observes their environmental costs (Pearce et. al., 1990). For example, if drinking water is contaminated by landfill leachate, it obviously poses hazard to the environment and public health. The related market valuation method considers this environmental cost as follows: the cost of remediation of the drinking water (related market 1) plus the cost of the impact of this incident on public health. This can be monetarily evaluated by health assessment techniques in health economics (related market 2) such as the maximum exposure individual method (Smegal, 1993). The experimental approach simulates a market by placing respondents in a position in which they can express their hypothetical valuation of real degradation on specific environment. In this second case, the aim is to make the hypothetical valuation such as the contingency valuation method (Wilks, 1993).

The principles of the measurement mentioned above will be employed to develop a theoretical approach to evaluate the environmental costs of landfills in later discussion.

3.1 Cost of Physical Impacts of Landfills

From the above discussion, the procedure for assessing the physical impacts of landfill operation on the environment can be shown as Figure 2. Its long-term associated environmental cost might be theoretically expressed as follows:

$C_{ep}=P(C_c+C_{hl})+C_{hg}+C_g$ (1)

where C_{ep} represents the expected cost of physical impact on the environment, P represents the probability of groundwater (or surface water) contamination by leachate; C_c represents the clean up cost of contaminated water, C_{hl} and C_{hg} refer the costs occurring as a result of landfill leachate and gas emission respectively, eg to public health ; and C_g is the cost associated with landfill gas as a contributor to the greenhouse effect.

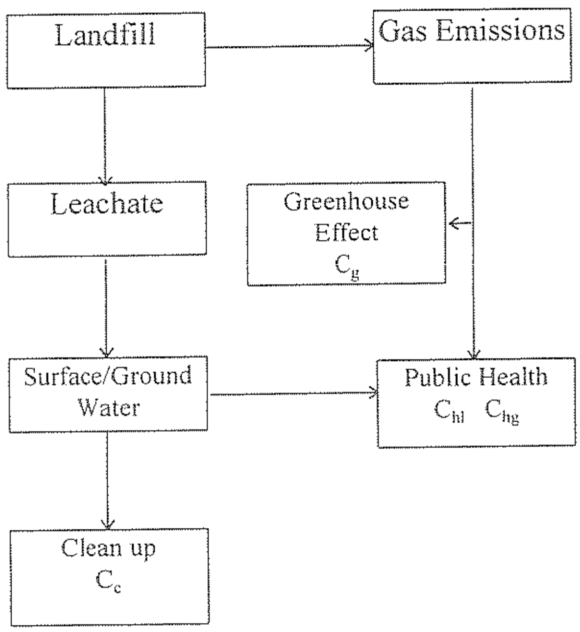

Figure 2. Physical Impact of Landfill on the Environment

The first two terms in equation (1) actually indicate the cost of landfill risks, which is generally regarded as extremely difficult to determine because of uncertainty and lack of quantitative data. For example, incident occurrence and severities significantly depend on leachate composition, landfill site, size and climatic condition etc. The "Subtitle D Risk Model" by the USEPA provides a starting point, to assess the impacts of nonhazardous waste landfills on surface water, groundwater and air. Overall risk in this model is based on the health risk for a maximum exposed individual multiplied by the total population using the groundwater within 1 mile of a facility as drinking water. Its final analysis of MSW landfill risks indicate that the aggregate risk from these facilities is about one cancer death every 13 years (Chilton et. al., 1992). This makes it possible to evaluate the cost of landfill risks monetarily in terms of the value of a statistical life. Porting this model to countries where water usage is significantly different from US practice clearly presents difficulty. UK researchers have approximately obtained values to C_c and C_g (within the boundaries of UK and EC respectively) based on the studies by Hordhaus [1991a, 1991b] and Morgenstern [1991] (Department of the Environment, 1993). Recently the NSWEPA roughly estimated the values of P, C_c, C_{hl} and C_{hg} for hypothetical landfills in order to assess the cost and benefit of their newly released landfill guidelines (Travers Morgan, 1995). Hence it is possible to provide some assessment of cost of physical impact of a landfill in dollar terms.

3.2. Cost of Social Impacts of Landfills

Like the physical impacts, there is no direct existing market on which to base the cost of social impacts of landfills. An effort has to be made to look for a related market as a basis for comparative evaluation. It may be assumed that the social impacts of a landfill on surrounding property values reflect the local effects of altered traffic patterns, air pollution, visual unattractiveness and noise pollution (USEPA, 1975). Thus, in this case the real estate market becomes the related valuer to measure the social cost.

Hedonic price technique, based on related market valuation, is one of the most common methods to assess the environmental cost in the area of resource economics (Streeting, 1990; Pearce et. al., 1990). It uses statistical analysis to isolate the environmental values which contribute to difference in product prices, typically those observed in real estate markets. With the use of appropriate statistical techniques the hedonic approach attempts to: (a) identify how much of a property differential is due to a particular environmental difference between properties, and (b) infer how much people are willing to receive by way of compensation to tolerate the decrement in environmental quality that they face and what the economic value is of the social damage.

The identification of a property price effect due to a difference in pollution levels is usually done by means of multiple regression technique in which data are taken on a large number of diverse properties at a point in time. It is well known of course that difference in residential property values can arise from many sources, such as the amount and quality of accommodation available, the accessibility of the central business district, the levels and the quality of local public facilities, the level of taxes that have to be paid on the property, and the environmental characteristics of neighbourhood, as measured by the levels of air pollution, traffic and noise amongst many others. A limited number of property variables (PROP), of neighbourhood variables (NHOOD), of accessibility variables (ACCESS) and the environmental variables (ENV) of interest are chosen to establish the related model by econometric modelling techniques, giving:

$$\text{Property Price (PP)} = F(\text{PROP, NHOOD, ACCESS, ENV}) \quad (2)$$

where F(...) simply means "is a function of". Empirical studies (Pearce et. al., 1990)show that the most common form of equation (2) is:

$$\ln(PP) = a.\ln(PROP) + b.\ln(NHOOD) + c.\ln(ACCESS) + d.\ln(ENV) \quad (3)$$

where ln signifies logarithm. By feeding in the observed value of each variables, a simple

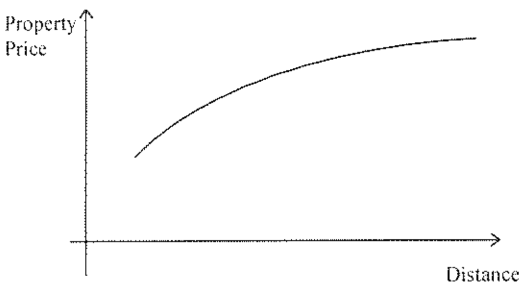

Figure 3. The Relationship between Property Price and Environmental Quality

computer program will generate the values of a,b,c and d. In this case, the value d will tell us how much property prices vary if the value of the environmental variable is altered. Provided the property price fully reflects the public willingness to accept environmental differences, then the social value of environmental change can be estimated. There are quite a few hedonic property price studies regarding the appearance of landfill conducted in USA, Baker [1982], Havlicek [1985], Kohlhase [1989], Mendelsohn et. al., [1992], Nelson et. al., [1992]. These results were shown either in terms of the relative change in a house price per mile from landfill or the absolute dollar change with distance from the landfill. Figure 3 shows a typical relationship between environmental quality and property values that might be uncovered by the hedonic price technique.

However, for landfills a simple model, equation (5), can be derived from equation (3) by assuming: (a) variables PROP, NHOOD and ACCESS remain unchanged whether the landfill is established or not, (b) the quality of nearby environment is completely negatively correlated with the distance from the landfill, and (c) the distance from the landfill site reflects a lumped index for all the ENV variables.

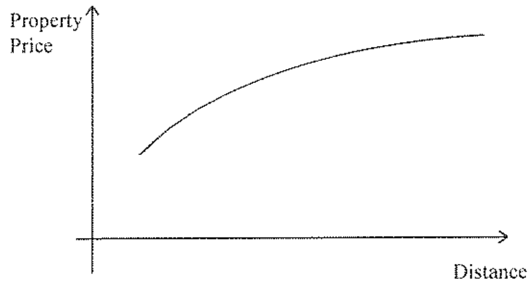

Figure 4. The Relationship between Property Price and Distance from Landfill

Then

$$PP = F(DISTN) \quad (4)$$

Namely, $$\ln(PP) = d.\ln(DISTN) \quad (5)$$

where DISTN refers to distance variables. Hirsheld et. al. [1992] examined the typical relationship between the property price and the distance from the landfill based on hypothetical landfill locations in the USA shown as Figure 4. Therefore if the changes of the property price are obtained from the real estate market, an evaluation of landfill social impacts becomes tractable.

In fact, considerable debate remains over the relationship between the real social cost of the environmental damage and the loss in value of property in the real estate market indicated by some studies. For example, a host of the issues associated with social impacts still remain largely unresolved, such as the loss of animal habitat, damage to flora, the opportunity cost of the land etc. Further, the effectiveness of this modelling method mainly depends on the following factors: (a) how to choose the appropriate variables, (b) how to measure these variables, and (c) the availability of the sufficient observed data.

4. CONCLUSIONS

Although landfilling is a well established waste disposal method, many municipalities significantly underestimate their landfill cost. This is primarily a result of failure to recognise cost of the environmental damage, which are associated with landfill operations. These environmental costs may be categorised as physical impact and social impacts. Physical impacts result from the natural generation of products of landfills particularly leachate and landfill gas, which have the potential to cause environmental damage. Social impacts are a consequence of landfill's existence, which primarily represent the environmental disamenity near the facilities.

It is very difficult to assess the full costs of both impacts accurately, but an effort must be made to do so. This paper summarised methods which could provide a starting point for placing dollar values on environmental cost associated with landfill operations. however rough, this still provides a better basis for decision making regarding alternative methods or locations for waste disposal, then unsupported arguments or short term political expedience.

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