Benefits and costs of alternative health-care waste management: an example of the largest hospital of Nepal

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ABSTRACT

Background: Management of health-care waste is an essential task, which has important consequences for public health and the well-being of society. Economic evaluation is important for strategic planning and investment programming for health-care waste management (HWM). A cost–benefit analysis of an alternative method of HWM in Bir hospital, Nepal was carried out using data recently collected from primary sources.

Methods: Data were collected using mixed quantitative and qualitative methods. Costs and benefits were measured in Nepalese rupees. The values of all inputs were costs associated with the alternative HWM. Benefits were defined as the reduction in cost of transportation; money obtained from selling of recycled waste; and risk reduction, among others. Break-even analysis and calculations of benefit–cost ratio were used to assess the alternative HWM.

Results: The alternative HWM reduces the cost of waste disposal by almost 33% per month, owing to reduction in the amount of waste for disposal. The hospital earns 3 Nepalese rupees per bed per day. The results suggest that a break-even point for costs and benefits occurs when 40% of the total beds of the hospital are covered by the alternative HWM, if the bed occupancy rate is at least 68%. If the alternative HWM is introduced in the hospital system, hospitals can reach the break-even point at 40 to 152 beds, depending on their performance in HWM.

Conclusions: The results show the economic feasibility and financial sustainability of the alternative HWM. This alternative method of HWM is a successful candidate for replication in all public and private hospitals in Nepal.

Key words: Cost–benefit analysis, health-care waste management, hospital, Nepal

INTRODUCTION

Health-care waste, which is a by-product of health care, can cause serious harm if not managed properly, and is considered to be a major public health hazard.1–4 Owing to its infectious and hazardous nature, it can cause undesirable effects on humans and the environment.4–7 Health-care waste management (HWM) is an essential task, which has important consequences on public health and the well-being of society.4–7 The primary problem of HWM is that, owing to the negative externalities of health-care waste, unregulated market prices do not reflect the full societal costs of the transaction.8–10 Internalization of the external costs of HWM through allocation of resources is a way to respond to the issue of externalities.9,11,12 In low- and middle-income countries, however, policy-makers frequently give less priority to allocation of the required resources for HWM.5,12 for example, the Government of Nepal allocated 0.1% of the total budget of Bir hospital for HWM for the fiscal year 2010/2011,13 although it actually requires at least 3.2% of the allocated budget for the health institution.14

The most straightforward way to lower the cost of waste management is to reduce the waste load at source and to minimize the generation of waste.12,15 Cost reduction implies better utilization of available resources. Economic evaluation constitutes an important input of strategic planning and investment programming for HWM.11,16–18 Information from economic evaluation discourages wasteful use of materials and encourages waste minimization. Economic evaluation of HWM measures its economic feasibility and financial sustainability.9,19,20
In the literature on economic evaluation of HWM, cost–benefit analysis is the most popular method used to compare the costs and consequences of HWM, to assess whether it is worth undertaking an activity from the economic perspective, and its theoretical foundation on welfare economics. In this context, research using cost–benefit analysis of HWM is of great importance to enable policy-makers to answer the question as to whether it is cost effective to embrace HWM practices. Cost–benefit analysis is a full economic evaluation of health-care intervention; however, many published “cost–benefit analyses” have been only partial analyses and have not included components such as desirable (benefit) and undesirable (cost) consequences of the interventions. For example, a review of 95 economic evaluations labelled as cost–benefit analyses found that 60% did not measure benefits in monetary terms. Inappropriate design of cost–benefit analysis can be misleading for resource allocation. For low-income countries where limited evidence is available, the unit of analysis for cost–benefit analysis, and a design based on current practice, are crucial. The literature on HWM is surprisingly limited; however, most cost–benefit studies have used time (per year/month/day) or hospital size in terms of production of waste as the unit of analysis. The government allocates resources to hospitals based on the number of beds in each hospital. Most of the time, the central government does not have information on the production of health-care waste at each hospital while allocating hospitals’ budgets. The number of beds may be an appropriate unit of analysis when conducting cost–benefit analysis, because policy-makers can easily use this to allocate the required resources. Similarly, it is easier for the hospital management to predict when an intervention will be at a cost–benefit break-even point if alternative HWM is introduced.

This paper contributes to the aforementioned literature with an analysis of the costs and benefits of HWM, using the example of Bir hospital of Nepal. It uses data recently collected from primary sources. The study used the number of beds as a unit of analysis and its aim was to carry out a cost–benefit analysis of an alternative method of HWM in Bir hospital. The study has particular relevance for current HWM in Nepal.

**Health-care management practices in Bir hospital**

The study focused on HWM of Bir hospital, the oldest and largest hospital of Nepal, established in 1889. It is a tertiary hospital, located in the centre of Kathmandu. The hospital has 460 beds, generally with a 65% bed occupancy rate. Prior to introduction of the alternative HWM method, the hospital generated medical waste at an average of 332.97 kg/day. The volume of waste could be over 500 kg/day at full bed occupancy.

In Nepal, there is little infrastructure for dealing with health-care waste. Most hospitals have small-scale incinerators. The hospitals dump waste in their grounds or send it for disposal with the municipal waste. Before the implementation of alternative HWM in Bir hospital, medical waste was mixed with general waste without treatment or segregation. Empty saline bottles, cans of soft drinks, old buckets, trolleys, medicine bottles, papers, plastic and used syringes were highly visible on the Bir hospital premises. Medical waste, including syringes, plastic, bandages and even some human body parts, was thrown into municipal garbage dumps. For the management of indoor waste, the hospital was paying Nepalese rupees (NR) 36 000 per month to the private sector to take the hospital waste away to the nearest municipal container.

Almost 4 years ago, the waste generated from hospitals, particularly Bir hospital, was recognized as a serious problem that might have detrimental effects either on the environment or on humans, through direct or indirect contact. The Government of Nepal, the management of Bir hospital and the World Health Organization (WHO) country office tried to find a cost-effective method for treatment or disposal of these wastes. In 2010, Bir hospital introduced alternative HWM practices, with technical support from the nongovernmental organization (NGO) Health Care Without Harm (HCWH), and WHO Nepal country office. Technical assistance for the intervention was provided by the NGO Health Care Foundation – Nepal. The “do no harm” principle: managing waste safely from source to final disposal and reducing the toxicity of waste and hazards associated with it; and the “3Rs” principle: reducing waste production or the volume and toxicity of health-care waste, recycling waste and reusing materials were key features of the alternative HWM. The waste-management system was designed using a “zero waste” concept, in which every form of waste is managed. The concept is based on three pillars that support each other – waste management, injection safety and mercury elimination.

One of the objectives of alternative HWM is to reduce the amount of infectious waste by segregating it from general waste at its point of generation. The introduction of alternative HWM included a well-formulated plan and policy, and mandatory in-service education and training, with continuous waste audit. The cooperation of all staff has significantly reduced the amount of infectious waste incinerated. Total medical waste was reclassified and properly segregated after introduction of the alternative HWM. Before implementation of the alternative HWM, 78% of medical waste was categorized as risk and 22% non-risk; however, after introduction of the alternative HWM, the percentage composition of risk and non-risk medical waste was completely changed, with 25% risk and 75% non-risk.

**METHODS**

**Data-collection approach and sampling procedures**

A systematic approach was used to select the respondents for the survey. The study focused on hospitalized patients who sought care for any reason, and hospital staff. Data were collected between September and November 2011, using mixed methods (qualitative and quantitative methods). Several meetings and group discussions with the staff, implementing NGO and caregivers were conducted before designing the data-collection instruments.
Using predesigned and pretested structured questionnaires, quantitative data were collected from 32 randomly selected inpatients (more than 10% of the total inpatients of 20 wards) from the hospital list and 37 randomly selected medical staff (more than 25%) out of 134 medical staff working in specific wards. Questions on willingness to pay for the alternative HWM were included to estimate indirect benefits; participants were asked to select one of two answers. In addition to this, data were collected from secondary sources, such as hospital records, income–expenditure statements of the hospital, the medical waste record book, files, and the health management and information system, among others.

For the collection of qualitative data, two focus group discussions and five key informant interviews were conducted among the hospital staff and patients/caregivers to collect the required information. During the focus group discussions, one of the researchers performed the role of moderator and the other two performed the roles of transcribers. Standard guidelines were followed to collect the required qualitative data.27,28 The qualitative method provided the average cost from the undesirable impact of the alternative HWM, and the average benefits from the desirable impact of the alternative HWM, where the estimates of invisible costs and benefits were not straightforward.

The results are primarily based on quantitative data. Qualitative data play a supportive role in designing the instruments, understanding the process, and capturing the invisible benefits, among others.

**Estimation and analysis of costs and benefits**

**Conceptual framework of estimating cost and benefits**

The paper adopted similar methods to those suggested by other studies5,9,12,21–30 to conduct the cost–benefit analysis of alternative HWM in Bir hospital. The conceptual framework in Figure 1 illustrates the procedures for estimating cost and benefits; both are measured in the local currency, NR. The values of all inputs used to implement the alternative HWM are estimated using an “ingredients” approach. The market price of inputs and actual expenses were used to estimate the costs of inputs in monetary terms. The costs of inputs were obtained from the implementing agency. The expenses involved for the alternative HWM are salaries and costs of equipment, transportation, materials and administration, among others. The benefits from the alternative HWM are desirable impacts, which include reduction of the cost of transportation and inputs such as human resources; sale of recycled waste; reduction of hospital days; reduction of hospital day of patients; reduction of hospital cost; reduction of infection rate; risk reduction; and improved staff performance. Reduction of the actual cost of staying in hospital, the market prices of recycled waste, and willingness to pay for risk reduction and improvement of performance were used to estimate the benefits in monetary terms.11 Reduction of hospital days means reduction of the cost of the supply side (case-management cost of the hospital) and demand side (patients’ and caregivers’ costs) of health care. The average cost of supply of services and the average cost paid by the patients were used to estimate the benefit

![Conceptual framework](image-url)
can be written as:

\[ W = a + bB \]

where, \( W \) = waste generation; \( B \) = number of beds; and \( a, b \) are parameters.

The sum of direct and indirect costs gives the total cost of the HWM. Direct cost includes the costs of material, labour and transportation, among others. The costs vary with the volume of medical waste or number of beds. The costs can be predicted using a mathematical model that can be written as:

\[ C_i = q + pW \]

where, \( C_i \) is the cost component \( q \) and \( p \) are parameters and \( W \) is volume of health-care waste. Similarly, the cost equation can be written as:

\[ C_i = q + pB \]

The benefits can be estimated in a similar way.

This study sought to identify the break-even point with the number of beds; that is, the point at which the total cost is equal to total benefit after introducing the alternative HWM. The number of beds for the break-even point can easily be calculated by using the fixed cost, average benefits and average variable cost of HWM. Break-even analysis is used to give answers to questions such as “what is the minimum level of benefits that ensures the hospital will not experience loss?” To calculate the break-even point, the following formula is used:

\[ \text{Number of beds for the break-even point} = \frac{\text{fixed cost}}{\text{average benefits} - \text{average variable cost}} \]

This paper focuses on analysis of the short-term costs and benefits of HWM because policy-makers are trained for crisis management in resource-poor countries and give priority to short-term activities. Therefore, short-term economic analysis of the alternative HWM can support the policy-making process. The results of the short-term cost–benefit analysis can ensure that HWM is financially sustainable. The benefit–cost ratio is another method of showing the net benefit situation in terms of total benefit and total cost. If the benefit–cost ratio \( (B/C) \) is more than 1, there will be net benefit; however, if \( B/C \) is less than 1 there will be a net loss.

## Results

### Total waste generation

The rate of waste generation was 1.7 kg per day per bed in the hospital. It is clear that the size of the hospital in terms of the number of beds determines the volume of health-care waste. Table 1 clearly shows the strong association between total waste generation and the number of beds. The result is significant at the 1% level. There is a non-linear relationship between the total health-care waste generated and the number of beds in the hospital. The elasticity refers to the sensitivity of change in the volume of waste in response to a change in the number of beds. The result suggests that if there is a 10% increase in the number of beds, this will lead to a 7.3% increase in the total amount of health-care waste generated.

### Cost of waste management

Cost is the value of inputs to the waste-management process and activities. The total cost of waste management includes the costs of capital, material, human resources and training.

<table>
<thead>
<tr>
<th>Table 1: Total waste generation determined by the number of beds</th>
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<td><strong>Variables</strong></td>
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<tr>
<td>Total number of beds</td>
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<tr>
<td>Constant (intercept)</td>
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<td>Estimated elasticity*</td>
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*The percentage change in total waste generated for a 1% change in the number of beds.
The contribution of capital cost is higher among the cost components, at 36%, followed by the cost of materials at 30%. Similarly, the total cost of waste management is categorized into fixed cost and variable cost. The fixed cost primarily relates to installation cost and variable costs vary with the process and activities of the alternative HWM. The variable costs contribute 57% of the total cost. Most of the time, policymakers underestimate either the variable costs or fixed costs of HWM; consequently, HWM always faces a lack of required resources in public hospitals.

In the previous section, a mathematical model was developed to predict the generation of hospital waste based on the number of beds. Use of the number of beds is a logical approach to analysis of the cost of HWM. In other words, the number of beds is the proxy of volume of health-care waste. The nature of the cost function of HWM with respect to the number of beds, as suggested by Figure 2, has a positive slope. The fixed cost (or installation cost) is constant over the number of beds, while the variable cost is a function of the number of beds. Figures 3 and 4 reveal a downward-sloping average cost curve. It is logical and theoretically acceptable that the average cost of waste management has a decreasing trend as the number of beds increases (coverage of HWM).

**Benefits from improved waste management**

Most of the benefits from improved waste management were taken into account in the analysis. The average economic benefit was estimated at almost NR 9000 per bed, per year. Benefits from the reduction of risk are about 75% of the total benefits. The cost reduction of waste management contributes almost 20%. Other societal benefit such as external factors due to the reduction of risk inside and outside the hospital, and benefits to the municipality waste-management team, among others, are not accounted for in the estimated benefits. It is probable that, owing to this data limitation, the total benefits are underestimated.

Benefits are estimated per bed per year in NR. Based on the available data, the relationship between total benefits and number of beds is shown in Figure 5. As already discussed, the number of beds significantly determines the amount of hospital waste generated. Therefore, the benefits gained from introduction of alternative HWM are also estimated based on the number of hospital beds. The total benefits show an increasing trend, as the increase in number beds and average benefits curves have non-linear trends.

**Cost–benefit analysis**

The results suggest that for the alternative HWM, the fixed cost is NR 2050149, average benefit is NR 23 322 and average variable cost is NR 9648. By utilizing the given formula, 152 beds are required for the break-even point. Similarly, the intersection point of total cost and total benefit gives the number of beds required for the break-even point, as shown in Figure 6. Point B on the figure, the intersection of cost and benefit, shows the break-even point. The result shows that a maximum of 152 beds with 68% bed occupancy is needed to reach break-even point, if alternative HWM is introduced at the hospital. This does not mean that this alternative HWM will not be effective for hospitals with fewer than 152 beds. Such hospitals will have less problem with waste management and the cost will be lower. The break-even point would therefore be shifted towards the left. In general, the break-even point will be reached after covering 40% (for example, 152 out of 375 beds) of the total beds of a hospital. As mentioned earlier, societal benefits are not included in the estimated benefits. If these benefits are included in this analysis, the break-even point B
Figure 3: Total average cost
The equation for the line fitted is $y = -32 \ln(x) + 197749$; $R^2 = 0.9289$

Figure 4: Average variable cost
The equation for the line fitted is $y = -6662\ln(x) + 46159$; $R^2 = 0.9614$

Figure 5: Total benefits
The equation for the line fitted is $y = 8004x + 7061$; $R^2 = 0.9985$

Figure 6: Break-even point
will be shifted towards the left. Therefore, this break-even point encourages implementation of the proposed improved waste management method in both public and private hospitals.

Analysis of the break-even point suggests the likely point beyond which the average benefit will be higher than the average cost. Therefore, the net benefit can be obtained by covering 152 beds. The alternative method of waste management is highly profitable not only for public hospitals but also for private hospitals.

Sensitivity analysis

Sensitivity analysis is a sensible and suitable approach to gauge how the net benefits will change if some of the costs and benefits are changed. The available data provide limited scope for sensitivity analysis of this study. However, a sensitivity analysis has been carried out using “best case” and “general case” scenarios. The break-even point suggests the general case scenario and Figure 7 suggests the best case scenarios. For the “best case” scenario, costs and benefits are estimated by utilizing the regression coefficients. Figure 7 shows that the net benefit can be obtained when covering around 40 beds. The range of the number of beds also suggests that the net benefit to the hospital is in the range of 40 to 152 beds. If the efficiency of HWM is improved, the cost will be reduced; consequently, the break-even point will be shifted left. As mentioned earlier, societal benefits are not mentioned in this analysis; however, the costs of all activities are covered. Therefore, 152 beds for the break-even point of the hospital is the extreme break-even point.

DISCUSSION

HWM has not received sufficient attention in low- and middle-income countries. Recently, a number of studies have explored the problem of HWM and its impact on society, the health system and the individual.7,24,32–34 Some have suggested alternative waste-management methods. Cost–benefit analysis of HWM is rarely found in the literature; however, literature focusing on cost–benefit analysis of solid or municipality waste management are readily available. This study uses cost–benefit analysis to explore an appropriate alternative HWM method.

One of the objectives of alternative HWM is to reduce the amount of infectious waste by segregating it at its point of generation from that of general waste. The introduction of alternative HWM, including a well-formulated plan and policy, mandatory in-service education and training, continuous waste audit, and the cooperation of all staff, has significantly reduced the amount of infectious waste incinerated. This leads to significant cost savings in waste transportation, labour and spare parts; improvement of the working environment and efficiency; reduction of the infection rate; and earning from selling of recycled waste, among other benefits. All these benefits can be measured in monetary terms by utilizing universally acceptable methods such as market price, willingness to pay, and the cost of illness.

Second, the resources allocated for HWM are not sufficient. Policy-makers do not have evidence on the outcomes of HWM; however, they know the outcomes of other health interventions such as the number of children vaccinated, number of people treated in the hospital and number of deliveries conducted in public facilities. The evidence on the outcomes of the intervention encourages policy-makers to allocate additional resources when required. If this evidence is not available, the intervention is given low priority and receives a smaller proportion of the budget, and so the intervention cannot produce the desired outputs. This study provides evidence by comparing the costs and benefits using scientifically accepted methods. It ensures that this alternative method of HWM is a successful candidate for replication for waste management in all public and private hospitals in Nepal.

More than one third of the total waste is recycled with this method of HWM. One quarter of the total waste was food and other organic wastes. The cost of waste disposal is reduced by

Figure 7: Ratio of estimated values for benefits and costs (B/C) using regression coefficients
almost 33% per month, owing to the reduction of disposable waste. The hospital earns NR 3 per bed per day. The positive impact of the HWM can be seen in several aspects, such as prevention of reuse of syringes, infection control, cleaner rooms and surroundings, reduction of waste going to a landfill, reduction in mercury release and exposure, improved patient and staff attitude and hospital reputation, and reduction of the carbon footprint for hospital operations, among others. The changes are mainly due to the new definition of infectious waste, based on practical assessment of the possibility of spread of infection via the wastes.

The results of this study suggest that a break-even point of cost and benefit can be found after covering 40% of the total beds of a hospital, if the bed occupancy rate is at least 68%. If alternative HWM is introduced in the hospital system, hospitals can reach the break-even point at 40 to 152 beds, depending on their performance in HWM.

REFERENCES


