COST ANALYSIS OF THE FUKUOKA METHOD LANDFILL SYSTEM IN NORTH KOLAKA REGENCY, SOUTHEAST SULAWESI, INDONESIA

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Abstract

Most waste disposal sites in developing country are still using open dumping and open burning. However, in developing countries, there are a lot of economic and technical problems with high level landfill technologies of first world countries, which make implementation of improvement is not feasible. Therefore, there is a significant need for transfer of landfill technology that is considered simpler, low cost, and that can be maintained locally. A method that provides these standards, which has recently gathered attention is the Fukuoka Method (semi-aerobic landfill).By life cycle cost analysis method, with the lifespan of the landfill is 20 years and an estimated volume of586,789 m3 (469,431tons), the required capital investment was about US$296,739 (natural clay liner)and US$463,406 (syntheticliner) or about US$0.63 and US$0.99/ton of waste. It is also calculated thatthe total cost of operation was about US$3,187,728 or US$6.79/ton of waste. The closure cost of the landfill was estimated to beUS$278,116 or US$0.59/ton of waste.

Keywords: ***cost, analysis, semi-aerobic, landfill***

Presenting Author's biography

Irwan Ridwan Rahimcompleted the doctoral programin2013 in Urban and Environmental Engineering Department, Kyushu University, Japan. His research specialization ismunicipal solid waste management.Besides being a lecturer in the Civil Engineering Department, Faculty of Engineering, Hasanuddin University, he also serves as a visiting researcher in Environmental System Analysis and Control Engineering Laboratories at Kyushu University.

1. Introduction

In many low-income countries, open dumps are still in operation. This also means that there is no emission control, the waste is notcompacted, the sites are not chosen in regard to reduce environmental damageand slopes may be very steep. This way of dumping creates various problems, as there are mechanical instability, fires, littering, odors, uncontrolled leachate and gas emissions, and so on. To a certain level, it is an enormous task to clean up these dumps in order to reduce their danger and to build new landfills using the experiences from those countries, which have long tradition in this field. Thus, mistakes made in the past should be avoided.

In industrialized countries, the problem of old landfills becomes more and more evident. Even after closure, leachate has to be treated and gas has to be controlled. The landfills have to be further inspected and, if necessary, repaired. These activities are highly associated with high cost, but they would be significantly lower if the landfills could have been operated,for example as a bioreactor reducing the emission potential as early as possible.

Like most developing countries, most solid waste landfill sites in Indonesia are practicing either open dumping or controlled dumping because proper sanitary landfill concepts are not fully implemented due to technological and financial constraints. This study aims to evaluate the feasibility of implementing a cost effective Fukuoka method semi-aerobic landfill system in North Kolaka Regency, Indonesia includingon the construction, operation, closure process for developing a new more beneficialsanitary landfill.

2. Cost analysis of semi-aerobic landfill

The semi-aerobic landfill structure was developed in a joint study by Fukuoka University and Fukuoka City. A leachate collecting pipe is set up at the floor of the landfill to remove leachate from the landfill in order to eliminate leachate from the site where waste is deposited. Natural air is brought in from the open pit of the leachate collecting pipe to the landfill layer, which promotes aerobic decomposition of waste. This enables early stabilization of waste, prevents the productionof methane and greenhouse gases, which make it an effective technology forglobal warming prevention.

The Fukuoka method semi-aerobic landfill concept can be implemented in developing countries under many circumstances for different purposes.These include developing a new landfill site, upgrading an existing landfill site, or conducting proper closure of a completed landfill site. A case study in North Kolaka Regency was carried out for a population of 137,139 people (2014) [3][4]with the projection of waste generation rate and targeted waste disposal method presented in Table 1.

Table. 1 Projection of total waste disposed at landfill site.

Year	Population	Waste generated (t/y)	Disposal methods (%)				Waste disposed of at landfill (t/y)
			1	2	3	4	
2014	137,139	44,049	1	1	78	20	8,810
2015	140,568	45,150	2	2	74	22	9,933
2016	144,082	46,279	3	3	70	24	11,107
2017	147,684	47,436	4	4	66	26	12,333
2018	151,376	48,622	5	5	62	28	13,614
2019	159,039	51,084	6	5	58	31	15,836
2020	163,015	52,360	7	5	54	34	17,803
2021	167,091	53,670	8	5	50	37	19,858
2022	171,268	55,011	9	5	46	40	22,004
2023	175,550	56,387	10	5	42	43	24,246
2024	179,939	57,796	11	10	38	41	23,696
2025	184,437	59,241	12	10	34	44	26,066
2026	189,048	60,722	13	10	30	47	28,540
2027	193,775	62,240	14	10	26	50	31,120
2028	198,620	63,797	15	10	22	53	33,812
2029	203,585	65,392	16	20	18	46	30,080
2030	208,675	67,026	17	20	14	49	32,843
2031	213,892	68,702	18	20	10	52	35,725
2032	219,240	70,420	19	20	10	51	35,914
2033	224,721	72,180	20	20	10	50	36,090
Total		1,147,565					469,431

Notes: 1, recycling; 2, composting; 3, others or uncollected; 4, landfill.

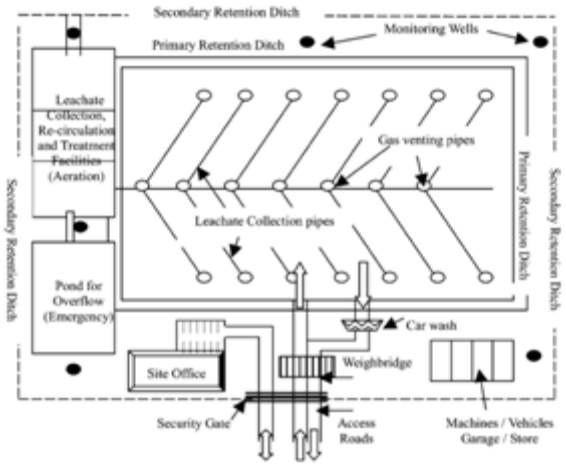


Fig 1 Conceptual diagram of a semi-aerobic landfill site[1].

Based onthe projection, the total waste expected to be disposed at the landfill site for the projected 20 years is about 469,431tons. Assuming that the specific density of waste is about 800 kg/m^3[5](common value used for compacted wastes at sanitary landfills), the total volume required for the landfill is as follows (eq.1):

$$469{,}431 \times 1000 \text{ kg} / (800 m^3) = 586{,}789 m^3$$

It was assumed that the use of cover materials is contributing another 15% of the volume; thus, the actual volume required is 88,018 m^3. In order to estimate the requiredlandfill area, it was assumed that the landfill has a depth of 15 m (3 layers of 5 m each), thus the landfill surface area required is (eq.2):

$$674{,}808 / 15m = 44{,}987 m^2 (4.5 \text{ ha})$$

Besides, other required areas for other facilities and some contingency space for wastes, 40% additional space was included to make the total area of about 7 ha. Detailed information on the design of the facilities such as the size and number of leachate collection ponds required, and the length and size of the main leachate collection pipes, branch pipes, gas pipes, and so on were calculated and the specifications are listed as below:

- Leachate collection and aeration ponds – 3 ponds, 5,100 m^3 each.
- Leachate main pipe –concrete pipe, 600 mm diameter • 135 m length.
- Leachate branch pipes – concrete pipe, 16 pipes, each 450 mm diameter • 50 m length.
- Gas venting pipes – concrete pipe, 30 pipes, each 375 mm diameter • 6 m length.
- Gravel – 688 m^3 (933tons).

Based on the calculated estimations and assumptionsmentioned above, a conceptual diagram of a newlydeveloped semi-aerobic landfill site is shown in Fig.1.The costs estimations were mainly conducted onfour different stages, namely the pre-preparation stage,construction stage, operational stage, and closurestage. The costs for each stage were estimated separatelyin order to have a clear impression of the development,operational, and closure costs of the entireFukuoka method. Some basic items considered on each stage are as follows:

- Pre-preparation stage contains a detailed environmentalimpact assessment (EIA). At this stage, costs include the cost for laboratory analysis, construction of boreholes, and so forth.
- Construction stage includes construction of facilitiesincluding foundation works. The costs involved are material costs, labor costs as well as other management expenses (Fig.2).
- Operational stage comprises application of cover materials, landfilling activities, maintenance, monitoring, inspection and some other miscellaneousexpenses (Fig.3).
- Closure stage includes activities such as applyingfinal top cover soil, planting vegetation, maintainingnecessary facilities, monitoring the qualityof the leachate and gas, and so on for a certain periodof time (Fig.4).

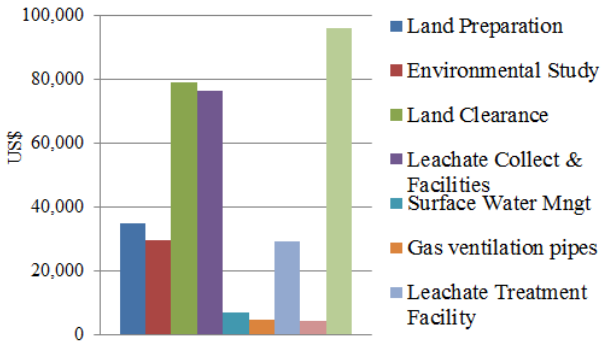
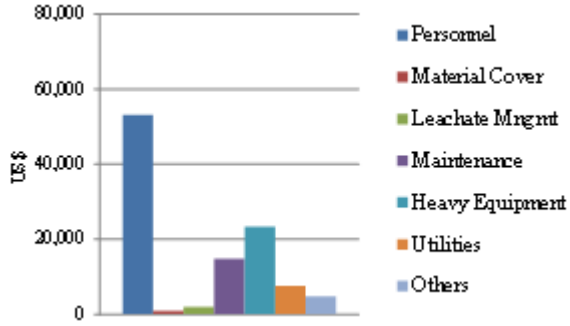


Figure 2Components of capital costs

For this study, the landfill site is assumed to operate for 20 years, while the time frame used for closure is assumed to be 10 years after the completion of landfill operations. The estimations were conducted based on information collected on the prices of local materials and labor in North Kolaka

Regency. It should be emphasized that the estimated capital costs are based on the assumption that the landfill site has natural clay soil with low permeability and thus a synthetic or geo-membrane liner is not required. Otherwise, the required overallcosts are expected to increase by about 80–150% due to shigh costs of liner systems [1].



According to the information shown in Table 1, the total wastes disposed of at this landfill is estimated to be 469,431tons; thus, the overall disposal costs required for each ton of waste can be calculated as shown in Table 2.

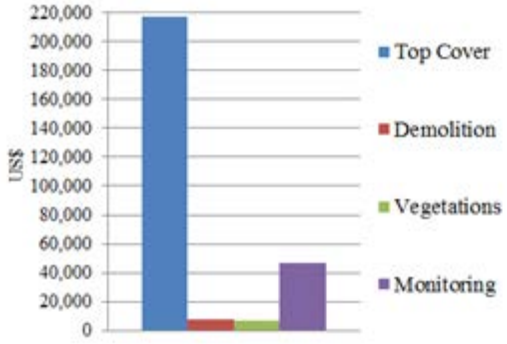


Figure 4 Components of closure costs

Table 2.Overall disposal costs per ton of waste

	Capital	Operating	Closure
NPV Costs (US$)	296,739	3,187,728	278,116
Total waste (ton)		469,431	
Average cost (US$/t)	0.63	6.79	0.59
		8.02	

Note: Total waste disposed at the landfill site is estimated to be 469,431tons.

3. Conclusion and recommendations

From the general findings of this study, it can be concludedthat the Fukuoka semi-aerobic landfill system isan available method to be used in developing countries such as Indonesia. This isbased on the calculated results forthe costanalysis of the entire implementation process, starting from thedevelopment stage to final closure. The overall cost ofUS$8.02/tons of waste is more expensive comparedtothe existing average tipping fees in some major cities, which is US$1.94-6.59/ton[2]. However, this method is considered relatively reasonablebecause it can suppress the negative impact on the environment with the treatment of odors, leachate, and methane gas emissions. This is veryimportant information to ensure that the developmentand operation of landfill sites in developing countries should take into consideration of proper development,operation and closure plans; therefore, a sanitary landfillconcept is operated and maintained efficiently. In addition,the results obtained from

this study also provideinformation that can be used when one would like to consider privatization of waste disposal system as a whole, to ensuremore effective and efficient operation and managementof a sanitary landfill.

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