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REUSE OF A CLOSED LANDFILL SITE FOR INSTALLATION AND OPERATION OF A BIOMASS UTILIZATION PLANT

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ABSTRACT

The professional management of landfills during operation and after landfill capping is an important task to prevent environmental impacts. Landfill maintenance after closure can become economically favourable if landfill sites can be reused. Several approaches and experiences for reuse of capped landfills exist for example in livestock farming or installation and operation of solar power plants. Also the utilization for spare time activities after green capping and recreation or the industrial reuse for the development of a waste utilization plant is a common practice in Europe. The feasibility of reuse options depend on the site conditions including size and location of the landfill, the climatic conditions and the interests of the involved stakeholders. For the urban landfill site Gò Cát in Ho Chi Minh City (HCMC) experts from Germany and Vietnam developed a variant assessment for the preferred reuse options. One of three investigated options is considering the reuse of the landfill site for the development of a biomass utilization plant. In terms of the above described approach for Gò Cát the landfill operator is strongly involved in the landfill closure and long term maintenance works (leachate treatment, landfill gas utilization). Moreover, the operator can reuse the landfill site for an additional or new business. The design and operation criteria for the biomass utilization plant and best practice examples are presented. Beside the economic evaluation results of water and landfill gas balance will be discussed.

Keywords: landfill maintenance, capping, reuse, water balance, renewable raw materials.

1. INTRODUCTION

The fast urbanization in Vietnam causes that landfills nowadays are surrounded by residential areas, as the landfill Gò Cát in Ho Chi Minh City [1] which is in the focus of this investigation [2]. Concepts for future use of landfill sites rarely exist in Vietnam so far. The capping of the landfill Gò Cát is still incomplete and causes problems for efficient leachate treatment as well as capture and utilization of the landfill gas. In order to cope with the future challenges new approaches and proceedings are required [3,4]. The overall objective of this approach is to improve the management of landfill sites in Vietnam in a sustainable way. Options of future use for the landfill Gò Cát will be indentified with a focus on best practices measures on capping. The variant assessment is based on technical, energetic, ecological, economic and social aspects of the future use. One economically feasible option is to combine the maintenance of the landfill and the use of the landfill site for the development of a biomass and bio waste recycling facility. The overall objective of this option is to transfer the landfill into a low-emission state using economic measures. The reduction in the follow-up expenditure will be achieved by a site-specific surface sealing which further supports the requirements for a waste-economical reuse of the landfill site. Improved measures for the landfill have to be provided, as the revitalization of the gas collection system, which has to be part of the overall concept for the further closure and aftercare of the landfill.

2. MATERIALS AND METHODS

2.1. Initial situation at Gò Cát

Landfill leachate usually consists of precipitation and groundwater entering the landfill body and water leaking from the waste. A professional surface sealing and consequently minimization of leachate access into embedded waste is needed to protect human health and the environment from harmful effects that may arise from landfill leachate after closure. The structure of landfill cover used for the HELP-model calculations includes following components: 0.5 m clay layer; 2 mm HDPE geomembrane; 0.3 m gravel layer; about 21 m municipal waste; 0.3 m clay layer; 2 mm HDPE geomembrane; 0.2 m sand layer; 0.8 m loamy/clayey sand. For the conception of further measures for the closure and aftercare the actual state of the landfill as well as the landfill behavior have been investigated: Landfill operation, disposed amounts and composition of waste with special emphasis on organic waste, that characterizes the emission and landfill behavior decisively; Geological and hydrological site conditions; Structure of base sealing according to the legal requirements; Temporary surface cover on an area of 3.5 hectares out of a total of approximately 19 hectares; Collection and treatment of leachate; Technical condition of the landfill gas collection system and current utilization of landfill gas; Climatic conditions with an average annual precipitation of approximately 1,900 mm/a for 1999 - 2013.

2.2. Assessment of Water Balance for Gò Cát after Qualified Closure

The calculations of the hydrologic budget have been carried out with the HELP Model Version 3.95D [5]. Information relating to the landfill included landfill area, hydrotope characterization of landfill surface with an inclination that allows formation of surface runoff as well as area from which is collected surface runoff and discharged into drainage ditches. Beside the basic data, accurate information on the landfill profile is required. Calculations have been made for three different scenarios. The scenario 1 corresponds to an uncovered landfill body. The scenario 2 takes into account the already installed inter-mediate covering on the landfill cells 4 and 5 (current situation). The scenario 3 was calculated with a qualified covered landfill and well established grass vegetation cover. This paper present the results of scenario 3.

3. RESULTS AND DISCUSSION

3.1. Approach to the Sealing and Covering of the Landfill Gò Cát

The selection of technical measures for a qualified landfill closure is carried out with consideration of the site specific conditions and the objective of a reduced aftercare effort: a continuation of landfill gas capture and recycling, a continuation of the leachate collection and treatment, a continuation of the monitoring program and an installation of the surface sealing.

Sealing systems serve as a barrier to prevent the release and emission of pollutants permanently. In detail, a site specific sealing system has to reduce the infiltration of precipitation water into the waste body as much as possible to minimize mobilization and migration of pollutants by water, to prevent migration of pollutants by wind and water erosion, to avoid the uncontrolled discharge of landfill gas and to provide a reuse by greening.

In general a sealing system should consist of the following components (from top to down): recultivation layer with vegetation cover or technical functional layer adapted to reuse, drainage layer, sealing component(s), profiling layer and appropriate gas drainage layer, as required.

The sealing system should cover the entire filling area of the landfill with a total area of approximately 19 ha. The surface sealing will be tied on the surrounding trench enclosing the landfill body. Outside the main landfill body no waste disposal exists according to actual state of knowledge. In general, different sealing systems (mineral sealing, geomembrane, capillary barriers, etc.) are conceivable. At this point the cover variants with geomembranes are considered due to lower costs. Geomembrane should be covered with a drainage layer and a recultivation layer. The drainage layer may consist of a mineral layer or a drainage mat. Above the sealing component, a protective layer is maybe required, in particular to prevent damages, e.g. by coarse-grained drainage materials and to reduce the risk of dehydration of the sealing component. The used soil should possess a preferably high water storage capacity with corresponding evaporation performance. If compost material is available it can be appended to the topsoil layer to increase the water storage capacity, the evaporation capacity, and to optimize growth of vegetation. The recultivation layer thickness has to be designed in a way that a sufficient storage capacity is ensured and root penetration of underlying layers is avoided. The suggested sequence and dimensioning of the layers are summarized in Table 1. An estimation for material and construction costs for the installation of the sealing system is included in Table 2, respective a estimation for the required materials is illustrated in Table 3.

Table 1. Proposed sequence and thickness of layers.

Sequence of layer	Thickness of layer
Topsoil with 20 Vol.-% compost addition (degree of rotting V)	0.3 m
Soil with high field capacity (e.g. silty sand); construction as uncompressed in layers of 40 cm	0.5 – 1.2 m
Drainage layer (or drain mat 5 cm)	0.1 – 0.3 m
Geomembrane	0.25 cm
Optional: protection layer, if necessary with geotextile for geomembrane protection	(0.1 m)
Clay layer and profiling layer	0.3 – 0.5 m
Thickness of surface sealing system	1.2 m – 1.9 m

Table 2. Cost estimation for the surface sealing (without plantation), German price level.

Title	Estimated construction costs*
Preparing and finishing a level (base grade) and placing a levelling course respectively clay layer	9.00 – 11.30 USD/m²
Delivering and laying of the geomembrane including delivering and placing geotextile	19.20 USD/m²
Construction of drainage layer	10.20 USD/m²
Construction of recultivation layer	5.60 – 11.30 USD/m²

For the installation of a sealing system using a geomembrane the investment costs of about 50.70 to 62.00 USD/m² are estimated. For a similar landfill cover for Gò Cát significantly lower costs (approximately 50 %) are reported. About USD 4.5 million investment costs are considered for landfill cover.

Table 3. Cost estimation for the materials (average data) German price level.

Material	Unit	Delivery expenses	Installation costs
Topsoil	[USD/m³]	6.50 – 9.00	2.90 – 5.60
Compost	[USD/m³]	5.20 – 9.00	2.90 – 5.40
Subsoil	[USD/m³]	2.70 – 5.60	2.40 – 4.50
Drainage layer 8/32	[USD/m³]	19.60 – 31.60	2.70 – 7.00
Mineral sealing	[USD/m³]	12.70 – 25.00	5.00 – 15.80
Drainage mat	[USD/m³]	5.60 – 9.00	
HDPE geomembrane	[USD/m³]	10.20 – 14.70	
Geotextile	[USD/m³]	0.90 – 1.60	1.10 – 5.10
Protection layer/final fluting	[USD/m³]	5.60 – 11.30	

Following main amortisation potentials for landfill closure and aftercare exist:

- realization of construction services using own staff and machines,
- increasing efficiency of landfill gas utilization,
- reducing the quantity of leachate which has to be treated.

A further advantage of “active” closure measures is that the leachate landfill gas capture system as well as the bottom sealing are still in a controlled or rather maintainable condition. Moreover it can be assumed that qualified staff is still available that is aware of the location and landfills behaviour. The recultivation layer and vegetation cover forms the upper part of the surface sealing system. Both are interacting with each other and protecting the underlying sealing system. The sealing system must be protected on the long term from harmful climatic (e.g. dehydration) and biological (e.g. root penetration, digging activity) impacts and hydraulic pressure. Relating to the establishment of the cover, as shown in Table 4, at least 210 m³/a leachate will be generated.

Table 4. Results of the water balance for Gò Cát in a covered state (scenario 3).

	Water volume plateau [mm/a]	Water volume plateau [m³/a]	Water volume slope [mm/a]	Water volume slope [m³/a]
Precipitation	1,923	176,503	1,923	172,658
Surface runoff	816	74,896	14.3	1,283
Potential evaporation	1,687	154,864	1,687	151,490
Real evaporation	872	80,074	1,156	103,855
Drainage water from drainage layer No. 2	231	21,189	751	67,453
Infiltration from layer No. 4/ percolation	3.5	326	0.26	23.5
Drainage water from drainage layer No. 16	2.2	200.5	0.066	5.9
Percolation of base sealing	0.007	0.62	0.00006	0.005

Depending on the impact of the temporary surface covering and subsequent sealing on the water balance for organics (COD) and nitrogen-containing (N_{total}) compounds periods of at least 40 to 60 years are estimated until the leachate concentrations for direct discharge will be achieved. Present results of leachate load in recent years do not allow a hedged forecast calculation but only a qualitative statement on the expected development.

The landfill gas prognosis leads to the conclusion that the volume of generated landfill gas will roughly been halved by approximately 15 years after closure. This effect will not occur in this way due to technical impairment of gas collection system because:

a) Geochemical conditions of gas formation under anaerobic conditions are caused in the landfill body by accumulation of water in the landfill body are impaired. That means that there are prevailing insufficient oxidative conditions for the conversion of organic matter.

b) Currently, reliable forecasts to real landfill gas quantity at the landfill Gò Cát are practically impossible due to the present conditions. It is assumed that there are just a few data collected for landfill gas quantity, which can then be blended with theoretical gas forecast results. Probably the real volume curve looks significantly flatter because of the effects mentioned under a).

c) In the absence of an improved efficiency of the landfill gas collection system in connection with an appropriate surface sealing, there is no possibility to achieve the theoretical prediction curve at any time of the forecast. It can only be assumed that the correlation is similar but applies only to 10% of forecasted volume.

3.2. Aspects on Cultivation and Utilization of Energy Crops as well as Management Aspects

The plantation of the recultivation layer with aim of energy recovery from green biomass can take place for example by planting of *Miscanthus* or seeding of grass.

The planting of the recultivation layer is carried out to ensure the erosion protection shortly after completion of the sealing of respective sections. For planting *Miscanthus* rhizomes can be used [4,6], which are received by self-recovery on donor areas, seedlings of *in vitro* reproduction or pre-cultivated plants from rhizomes (landscaping company, nursery). About 1 kg *Miscanthus* having a water content of 14 % provides an energy content of about 4.4 kWh. It takes approximately 2.27 kg of *Miscanthus* for producing of 1 litre of extra light heating oil with about 10 kWh/litre. The planting areas (entire landfill body, about 19 ha) can later be harvested at least once a year for the utilization of the biomass. Depending on the type of utilization, *Miscanthus* is chopped with an existing technology or pressed into bales. During gasification the shreddered material is converted into a fuel gas that can be used for energy and high effective heat generation

Alternatively to the plantation of *Miscanthus* the sowing of grass can be considered as biomass source [8]. The silage from meadow grasses can be used as a fermentation substrate for biogas plants. The grass silage can be used as co-substrate together with organic waste and sewage sludge in a biogas plant, where it is converted together with the basic substrate into biogas through fermentation by bacteria. The resulting biogas can be used for energy needs (cogeneration). Gras silage provides a biogas yield from 170 to 200 m^3/t fresh mass (FM). The calorific value of biogas is given as 21.6 mJ/m^3. Therefore from 1 t FM approximately 3.7 to 4.2 GJ of energy can be obtained.

Residual materials with high water content are particularly suitable for biochemical conversion. In the process biomass is degraded with participation of microorganisms. Degradation can occur anaerobically and aerobically, furthermore possibility of alcoholic fermentation exists. Biogas can then be converted, either to energy, using for heat generation or used for the operation of gas-powered vehicles.

Example of a biogas plant: inserted amount of substrate: 130 m^3/day; produced energy: 7,000 kWh/day; land required: ca. 1,000 m^2; plant components: fermenter, gas storage, combined heat and power plant; construction expenses: approx. USD 1.1 Mio. in Germany (about 50 % of expenses have to be allocated for a comparable plant in HCMC: approx. USD 0.5).

The current costs for the treatment of the landfill leachate are assessed on the basis of information from the operator to be about 3.90 USD/m^3. For the first few years after the coverage it will amount to around 812.40 USD/y. Regarding the amounts of leachate it is considered that within the next years a final surface sealing at the entire landfill area will be applied. For the cost estimation following leachate quantities are taken as basis: Before sealing installation (current situation): about 137,560 m^3/a; After sealing installation: 210 m^3/a; 10 years after sealing installation: 105 m^3/a (consolidation, residual permeability).

After about six years the expenditure of establishing a landfill cover and biogas plants could amortized in case of concluding a new supply contract with better terms. Beside further benefits such as the use of biogas for gas vehicles and potential earnings from the sale of compost can be taken into account.

Potential earnings from electricity input (assuming an input fund of 0.03 USD/kWh)

Landfill gas	up to 6,900,000 kWh/a	207.000 USD/a
Biogas (example)	up to 2,555,000 kWh/a	76,650 USD/a
Sum	283,650 USD/a and 2,836,500 USD in 10 years.	

Potential earnings from electricity input (assuming an input fund of 0.09 USD/kWh)

Landfill gas	up to 6,900,000 kWh/a	621,000 USD/a
Biogas (example)	up to 2,555,000 kWh/a	229,950 USD/a
Sum	850,950 USD/a and 8,509,500 USD in 10 years.	

Potential expenditures for landfill cover and waste re-use

Investment costs landfill covering	4,500,000 USD
Investment costs biogas plant	500,000 USD
Total	5,000,000 USD.

The cost estimation does not consider the effort for the rehabilitation of an existing temporary cover and the removal of successive grown trees and shrubs on the landfill body. Anyhow, this will require special measures on risk control.

4. CONCLUSIONS AND OUTLOOK

In the case of the landfill Gò Cát a qualified covering is required to ensure long-term protection of the environment. The discussed option on "recultivation and construction of a biomass recycling centre" uses synergies and local advantages to cover after care costs (surface sealing installation) and expenditures (cutting landfill vegetation, operation of leachate treatment plant) by adjusted waste management reuse approaches (utilization of the landfill gas and fermentation of the biowaste). A potential analysis for the estimation of the availability of potential biowaste sources in the vicinity of Gò Cát can provide information about the long-term feasibility of the approach. The current activities and usages such as sorting and intermediate storage could be retained.

The feasibility of a qualified covering is related to a sealing layer with low permeability, a drainage layer of sand and a recultivation layer. Vita 34 is currently investigating a novel approach using mineral recycling materials instead of geomembranes as a sealing element. Feasibility and characteristics of this novel sealing system is tested and monitored in a trial test in greenhouse experiments. The results gained from long term monitoring will be compared to results obtained with a sealing system with geomembrane. The above described test systems were installed in autumn 2015 and is still operating. During the test phase the humidity, solar radiation and volume of precipitation is applied in the greenhouse based on climatic conditions in HCMC. Up to now the results of the test trial on the novel approach are promising.

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