Fig 1: Tunga St, Ngaliema municipality, Kinshasa 2018-01-31.

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VALORISATION OF WASTE IN KINSHASA, DEMOCRATIC REPUBLIC OF CONGO

Aim – *To plan and implement technical solutions for utilisation of waste in Kinshasa, Democratic Republic Congo.*

Kinshasa, Democratic Republic of Congo

Kinshasa is the capital of DR Congo and has experienced exponential population growth, from 1 million in 1970 to 12 million in 2015. The city's infrastructure, particularly with regard to waste handling, has not kept pace with the expansion, and there is currently no system in place for disposing of household and commercial waste. As a result, waste is dumped at roadsides and in ditches, with the associated problems with odour, vermin and disease. There is also a need for employment and energy supply for the growing population.

Proposal for waste valorisation

The scale of the waste problem is very large. This means that the investment in treatment facilities is large, but also that the potential for employment and value creation is also large.

It is proposed to implement recycling of waste fractions, with the value created used to provide employment and fund the further implementations. However, the initial demonstration project requires funding in order to start the cash flow and to demonstrate the viability of the processes. It is proposed to start with a defined neighbourhood of Kinshasa with a population of approximately 600 000, before transferring the methodology to the other districts of Kinshasa.

Collection and sorting system

A waste collection system does exist in some parts of Kinshasa, where households and businesses pay for waste to be collected in hand-drawn carts. With no facility to receive the waste it is transported to informal dumping sites. This collection system can be utilised and extended, with delivery to the location of the recycling station.

Fig 2: Existing waste collection system in Kinshasa.

The sorting of the waste into fractions provides employment for low-skill employees. Surveys of waste in Africa have documented the composition of waste as being dominated by organic waste, and this also is the main contributor to odour and vermin. Other fractions such as metal, plastic and dry combustible components can be separated for specific value streams. It is proposed to convert the organic waste to biogas and soil fertiliser, using anaerobic digestion.

Treatment alternatives

Process A: Incineration

Incineration could dispose of the large quantities of waste involved, with a Combined Heat & Power (CHP) facility producing heat (3650 GWh) and electricity (1520 GWh). However, it is considered that the need for heating is low in the region, and the conversion efficiency to electricity alone is low (25-30%). In addition, the costs of the incineration plant and appropriate emission treatment are significant compared with the value generated. Hence this is not considered a good fit to the local conditions.

Process B1: Landfill with biogas collection

The simplest option is to excavate a trench, line with geo-membrane and HDPE/PVC liner to prevent leachate escaping and fill the trench with the waste. After sealing the trench with a top liner, the degradation of the organic fraction of the waste produces biogas which can be collected.

The disadvantages of the landfill option are that it requires permanent reservation of a large area for storage of the waste, and there are restrictions on what this area can subsequently be used for. In addition, the yield of biogas from a landfill is lower (30%) than can be obtained from a tailored biogas reactor.

For disposing of the annual waste generated by Kinshasa in a landfill an area of 0,8 x 0,7 km would be needed, for each year, and this area is then unavailable for other uses. The existing waste that is deposited in the street will have been degraded over time. This means that the biogas producing potential is lower, and the other fractions (such as plastic) require cleaning to be used. In order to clean the existing waste from the streets and ditches a landfill can be a suitable treatment alternative.

Process B2: Wet Anaerobic Digestion (AD)

Traditional wet anaerobic digestion (AD) requires a moisture content of 85 – 95%, requiring addition of water to the organic waste to obtain a pumpable/stirrable slurry. The residual substrate is obtained as a liquid fertiliser, which restricts how far it can be transported for use on agricultural land.

Fig 3: Example of a wet anaerobic digester plant.

To handle all of Kinshasa's organic waste would require 1364 wet AD reactors of 30 m diameter and 6 m height, with a total footprint of 1,5 km². The wet anaerobic digestion could produce 323 MSm³/year of methane, and 35 Mm³/year of liquid fertiliser. In contrast to the landfill option this facility could process the waste amount for each and every year over the lifetime of the plant.

Process B3: Dry Anaerobic Digestion

A newer process for biogas production is the "Garage-type" dry fermentation, where water is not added to the organic waste, and the dry matter content is around 20-30 %. Recirculation of the permeate achieves the contact between the microbes in the water phase and the solid waste.

Fig 4: Example of a Garage-type dry digester plant.

The yield of biogas from the dry anaerobic digestion may be somewhat less (80%) than that from the wet anaerobic digestion, but there are cost savings in terms of the construction and operation costs. Given the lower amount of water involved, the size of these reactors is smaller than that of the wet AD process, with all of Kinshasa's organic waste being able to be processed by a facility with a foot print of 0,21 km². A full-size facility has been implemented in China, [3], providing data for planning purposes.

Process B4: Conversion of biogas to electricity

As with an incineration plant it is possible to convert the biogas to heat and electric power, but the energy efficiency is low unless the heat is used. Some of the heat could be used for drying by-products, such as the soil fertiliser residue, but this is likely to be a low value application. DR Congo has natural gas reserves, and a shortfall of electricity. There have been investigations of Combined Cycle Gas Turbines for converting natural gas to electricity, with an efficiency up to 60%. This can be more feasible for methane than incineration of mixed waste.

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Process B5: Upgrading of biogas to CNG

The biogas produced is typically 55% methane and 45 % CO2. For use as transport fuel, or for transport by pipeline or tanker, it is necessary to remove CO2 and hydrogen sulphide and compress (or cool) the gas. This would involve significant investment, of the same order of magnitude as the biogas production. Economics of scale would be possible by combining several biogas plants with one cleaning & compression plant. Note that CNG is not the same as LPG, and is less suited to household use.

Process C: Charcoal production

The 10% content of woody waste could be converted to biochar/charcoal with a pyrolysis reactor, [2], with a yield of about 20%, giving 44 000 t/y charcoal. In DR Congo 94% of households use charcoal for cooking, obtained from pyrolysis of wood, is contributing to deforestation.

Process D: Plastic recycling

Sorted (and washed) plastic can be processed into pellets for transport for forming into other plastic products. This can be a further profitable value stream. Apparently, investments costs for plastic pellets press are moderate and return on investment is good.

Estimation of the revenue generation potential

It is proposed to sort the waste with tailored processing of the fractions. Old waste can be placed in a landfill with biogas collection, for which the installation costs are low, to match the lower biogas productivity. Dry anaerobic digestion (B3) would be used on the fresh organic waste.

Product 1: Biogas

The 6 000 tonne/day of organic waste generated by Kinshasa could potentially produce 257 MSm³ of methane each year, representing an energy content of 2,8 TWh. Local utilisation without requiring transportation could use the biogas directly without separating the CO_2. Estimates of the value of unimproved biogas are needed.

Product 2: Digestate as Soil fertiliser

In addition, 500 000 tonne of soil fertiliser would be produced each year, which could address the acute need for improved fertilisation of agricultural land. The fertiliser value of the digestate from processing Kinshasa's organic waste could be US$20M, but it should be budgeted to sell at a lower price. The amount of digestate is equivalent to a 50 mm layer each year on Kinshasa's active horticultural land.

Product 3: Charcoal

Production of charcoal from woody waste would represent an important environmental contribution, reducing the extent of deforestation for cooking fuel production. A price of $US0,2/kg [2] applied to the potential production of 44 000 t/y would give a value of 9 million $US/y.

Product 4: Plastic pellets

The plastic content of the waste is estimated at 12,5%, from a study made at Matadi, DR Congo, [1]. This would give 275 000 tonne/y plastic waste. Manual sorting would improve the product value.

Product 5: Electricity

The methane produced could provide 1,7 TWh/y of electricity with a CCGT efficiency of 60%. The approximate sale price for electricity of $0,11/kWhe gives a value of US$190 million. The current installed electricity generation capacity is 600 MW, (5,2 TWh/y) and 42% have access to electricity.

Product 6: Compressed Natural Gas

If the biogas was cleaned and compressed to CNG it could be used in industry or in place of transport fuel. With a current LNG price in Africa of US$0,35/Nm³ the methane produced from organic waste could represent a value of over US$90M/year.

Value of Greenhouse Gas avoidance

The 6000 t/d waste produced in Kinshasa each day is left to rot in the open. This potentially generates between 1,3 and 11 million tonnes CO_2-eq each year, depending on how much is burnt and how much rots to methane. The current EU GHG emissions allowances rate is €9/t CO_2-eq, giving a value of the emissions avoidance of between 14,5 and 123 million US$/y. In addition, there is the value of the products replacing fossil fuel- derived products.

Implementation cost estimates

A landfill would have the lowest investment cost, but to handle 10 years of waste from Kinshasa would involve a cost of liners of at least 15 M$. A cost of 2,2 billion $ for wet biogas reactors to handle all of Kinshasa's organic waste is calculated from values in the literature [4]. The cost of the concrete for the garage type digesters to handle all of Kinshasa's organic waste would be 20,5 M$. Estimates for the additional equipment costs need to be obtained, but the dry digestion process looks to be the most interesting.

Suggestion for implementation

It is proposed to implement the dry digestion process with Garage-type digesters, as has been demonstrated in a full-scale implementation in China [3]. After pilot testing on the actual waste a demonstration plant should be built, with 8 garages, and a capacity of about 43 t/d. This can then be extended to cover one suburb of Kinshasa, with a population of around 600 000 and about 10 times the capacity of the demonstration plant. This installation can then be replicated to cover further suburbs to eventually cover all of Kinshasa.

After the construction and operation of the first two or so plants there should have been achieved sufficient transfer of technology and knowledge to locals (university, engineering companies etc) for them to perform further implementation by replication of the plants. The profit generated from the first plants will assist with the financing of the further implementations. When greater production capacity is achieved there can be established the basis for further processing such as to CNG or by gas turbines.

The implementation will also involve development of routines and systems for collecting and sorting the waste and developing processes for valorisation of other fractions such as metal, plastic and non-volatile organics that can be used for charcoal production.

Employment creation

Initial estimates indicate a need for at least 500 rickshaw drivers for collection of organic waste and potentially equally many involved in sorting. The biogas process itself would have low labour requirement, but the digestate fertiliser would give a significant boost to the agricultural sector productivity, and potentially support further employment there.

Funding required for developing Business plan

NORUT Narvik has developed the basic concept for the processing of the waste. A more detailed engineering design study is required in order to develop the specifications and economic parameters required for a business plan and investment proposal. Funding is being sought for a pre-feasibility study. Rough estimates of the potential value of products from Kinshasa's waste are:

- CO2-eq quota 14,5 – 123 mill. US$/y
- Electricity from gas 190 mill. US$/y
- Soil fertiliser 20 mill US$/y
- Charcoal 9 mill. US$/y
- Plastic recycling ?

Conclusions

The DR Congo and Kinshasa city represents an interesting practical implementation of technologies to both solve an environmental problem as well as generate revenue and employment for the region. There are also significant savings in Greenhouse Gas emissions that can make the implementation interesting in terms of emission trading schemes.

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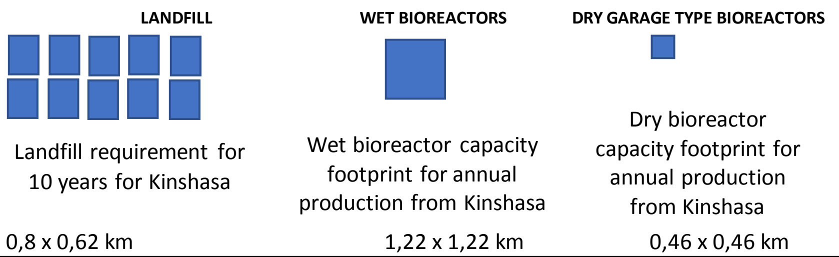

Fig 5.: Relative footprint requirement for three alternative processes for handling the organic waste production of Kinshasa (2,2 Mt/y) over a 10 year period. A new landfill is required each year, but the bioreactors are reused with batches of 30 – 60 days, hence require less area than the landfill over long periods.

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