WASTEWATER TREATMENT

From waste to worth – converting wastewater sludge into high-value products

Sludge management forms a huge part of wastewater operations in South Africa. Whereas in the past, sludge was viewed as nuisance waste to be disposed of at significant cost, there is now a general consensus in the wastewater industry that sludge is a potential source of valuable resources and alternative green energy. This has been further reiterated by the 2017 World Water Development Report, which highlights improved wastewater management based on reducing pollution at source, removing contaminants from wastewater flows, reusing reclaimed water and recovering useful by-products. Article by John Zvimba and Eustina Musvoto.

Lani van Vuuren

Energy recovery is achieved through two primary pathways; biochemical conversion and thermo-chemical conversion, and these produce different end products. Some proven and well established technologies such as anaerobic digestion, gasification and pyrolysis fall into these two pathways, and are currently utilised for wastewater management.

The choice of technology is influenced by factors such as the quality of the feed sludge, the quality of and markets for the by-products, regulatory requirements and public perceptions. Apart from the proven and established technologies, emerging technologies based on hydrothermal carbonisation, such as Polymeric Carbon Solid (PCS) can also play an increasing role in energy recovery from sludge within the South African context and, more importantly, in supporting the circular economy.

The PCS technology is a catalytic thermo-chemical process that takes place in an aqueous solution to produce a biofuel at elevated temperature and pressure (optimal 240 ^{o}C and 3.3 MPa). While other technologies have used sub- and supercritical water to produce a biofuel, the reagents used by the PCS technology significantly reduces the temperature and pressures required.

As a result, the reduced temperature and pressure decreases both capital requirements and operating expenses. The technology is tolerant to impurities, and accepts a wide range of feedstock, including municipal solid waste, sewage sludge, animal manure, agriculture waste, wood products (including sawdust, lumber, bark, branches, forestry) and construction waste.

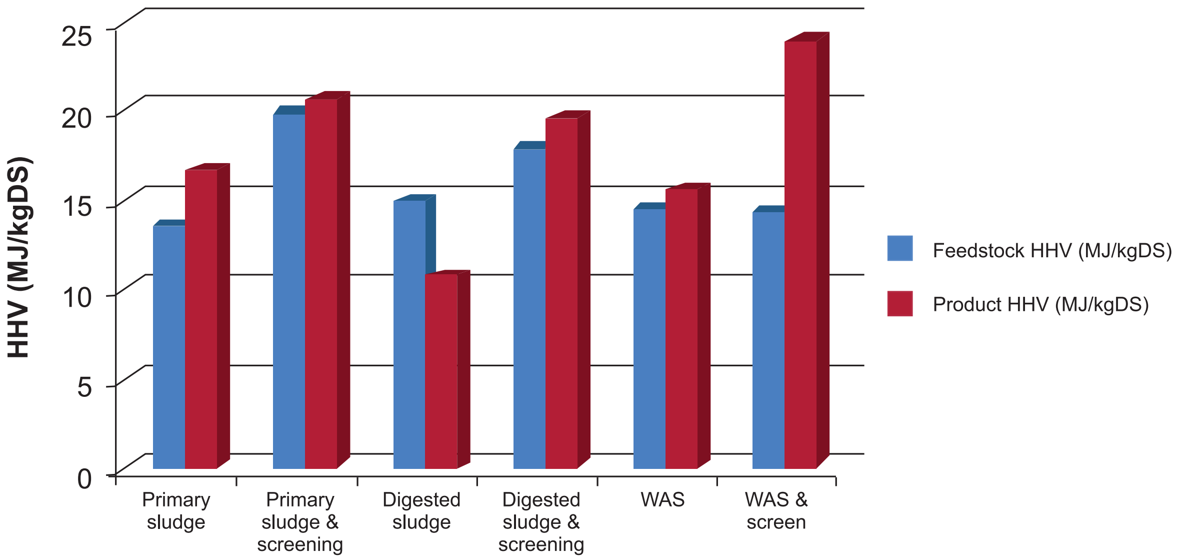
The technology is a carbon neutral process that recycles carbon dioxide and does not contribute to global warming while by-products produced have low toxicity. The simplicity of operation in PCS technology plants makes them suitable for installation in any setting where a significant amount of biomass is accumulated. PCS plants use specialised infeed systems for wet or dry biomass.

A typical plant consists of a mixing tank, pressure vessels where the chemical reaction occurs, and buffer tanks for storage of the end product and the excess energy. The pressure vessels are designed as a self-contained process to transfer maximum energy into the next tank with minimal start up energy and minimal odor or noise emissions. The exothermic energy is recycled so that PCS plants have a positive energy balance.

The PCS technology has numerous advantages over the current most employed mature and proven waste to energy technologies. The advantages of the PCS technology include:

- Carbon dioxide – neutral process with no methane production.
- Wet process – biomass can be used without expensive pre-drying as required in gasification.
- Accepts a very wide range of biomass types, and can safely process problematic wastes that currently require expensive disposal e.g. hospital and biological waste.
- Not in competition with food production as only agricultural and forestry waste is used.
- Exhibits the highest carbon efficiency value of all technology options (PCS = 100% / Biogas = 50%) and can be easily scaled up in continuous batch process.
- Intensive exothermic process converting biomass at molecular level with net energy gain in a self-contained process with little odor or noise emissions.
- Low investment and maintenance costs, operating at moderate pressure and temperature.
- No specialist skills needed in production process based on its straight forward technical operation.
- Environmentally friendly; residual water is sterile and harmless to the environment.
- Resulting biofuel is hydrophobic, easily dewatered and processed into high value products (bio-coal for combustion purposes and biochar for soil conditioning and improvement).

In South Africa, laboratory and pilot-scale studies on processing mostly municipal wastewater sludge carried out to date using sludge from wastewater treatment plants have demonstrated a net energy gain of 3 – 5 GJ/kg using the PCS technology.



Calorific Values (HHV) for feedstock and PCS technology processed product.

The data from these studies play a significant role as feeder into the design of full-scale plants for the recovery of high value products from wastewater sludge, as the main feedstock or in combination with other biomass within the South African context. In this regard, the benefits of adopting and applying the PCS technology for the treatment of sewage sludge within the South African wastewater sector are quite numerous.

The PCS process treats both sludge as well as sludge with screenings at short processing times of 1 hour and temperatures from 180 °C to 240 °C. Pilot-scale studies have shown that an optimal temperature of 210 °C need to be applied to give a high-quality product.

The process increases the calorific value of primary sludge and waste activated sludge to the level of low grade coal (lignite/sub-bituminous), which makes the product a clean useful biofuel with very low emissions compared to coal. However, the calorific value of digested sludge is generally low due to anaerobic digestion. The process reduces volatile and total solids by 40 - 62% and 22 – 37% respectively when processing sludge only.

The high solids reduction for digested sludge has shown that despite the product having a lower calorific value, the PCS technology can be applied to process digested sludge and further reduce the quantity of biosolids for final disposal thus saving on disposal costs.

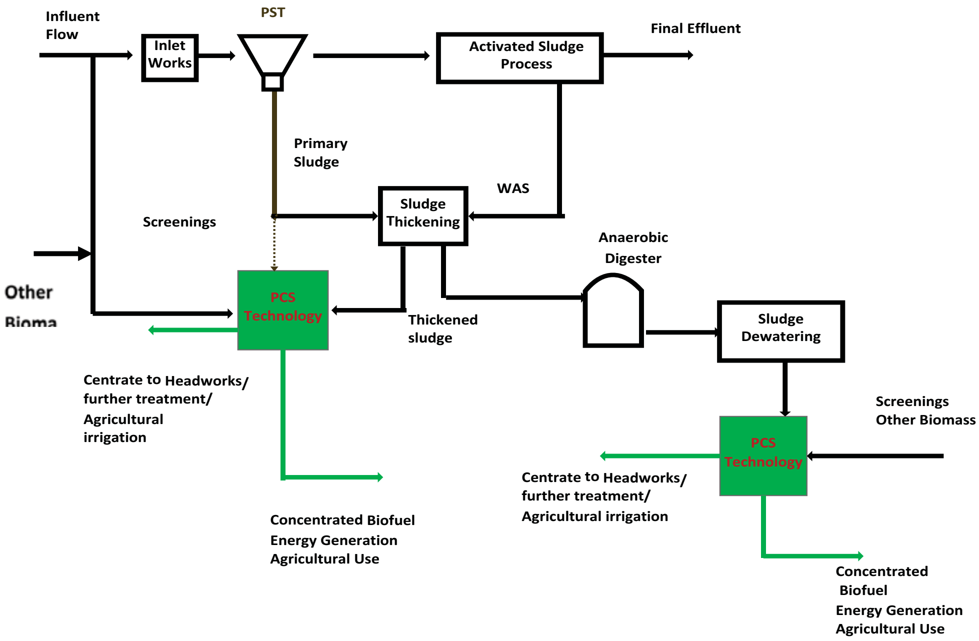
The processing of combined sludge and screenings increases the calorific value of the product by up to 35%. In this regard, the process not only provides a single solution for sludge and screenings handling at wastewater treatment plants but also presents an opportunity for co-processing wastewater sludge with other biomass (e.g. municipal solid waste, food waste, agricultural waste etc.) from the community.

More importantly, the process produces a sterile, inert product without any microbial activity, of a biosolids quality that is above the Department of Water and Sanitation requirements for microbiological Class A and stability Class 1. This therefore gives a wide range of options for beneficial use, for instance, agricultural (depending on metal content and pollutant class), commercial products (e.g. adsorption media, solid biofuel with metal recovery, brick making, cement making).

Generally, the pilot-scale studies to date have demonstrated that the PCS technology treats wastewater sludge to a higher quality than that achieved with the commonly applied biochemical conversion aerobic and anaerobic digestion processes widely applied in South Africa. Moreover, the PCS process also converts the sludge to a useful biofuel and commercial product.

In addition, the studies have also demonstrated that the technology can be applied to post treat digested sludge further reducing sludge quantity for disposal. This, therefore, provides an opportunity for technology coupling at treatment plants that already have sludge digestion processes thus avoiding making the existing infrastructure redundant. The ability to co-process sludge with other biomass offers a unique opportunity to produce a high value biofuel (and other useful commercial products) and the vison of converting wastewater treatment facilities into resource recovery centres a reality.

In this regard, a conceptualised schematic for incorporation of PCS technology into an existing typical South African wastewater treatment plant has been proposed.



Schematic layout of incorporation of PCS technology at a typical wastewater treatment plant.

The feasible incorporation of PSC technology into the existing South African wastewater treatment infrastructure presents further opportunities for supporting implementation of circular economy principles at wastewater treatment facilities as part of sustainable wastewater management. This can have significant benefits as it has potential of catalysing wastewater treatment facilities into integrated economic hubs, not only treating wastewater for effluent compliance, but key resource recovery centres, thereby fostering innovation and mutual beneficial partnerships with communities.

Moreover, this approach has potential of creating new business models and jobs, including developing new skills and investments in communities as well as reducing the carbon foot print, thereby mitigating the impacts of climate change.