ON-SITE SANITATION

More than a decade of sludge management research behind new guide

A new report and guideline published by the Water Research Commission (WRC) on deep row entrenchment of sludge is the culmination of more than a decade of research on the topic. Article by Sue Matthews.

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In 2008, a research team from Partners in Development and the University of KwaZulu-Natal embarked on a WRC-funded study on deep row entrenchment (DRE) of pit latrine and wastewater sludges. The technique, pioneered in the United States in the 1970s, entails disposing of sludge by burying it in a trench under at least 300 mm of soil, which prevents odours and reduces attraction of disease vectors such as rats, flies and mosquitoes. Forestry or fruit trees, or even other crops like sugarcane and maize, can be planted on or between the trenches to take advantage of the sludge's high nutrient levels.

This initial project, published as **WRC Report No. 1829/1/12** in 2012, included trials at a number of different study sites, one of which was a two-hectare area of gently sloping ground in a Sappi timber plantation near Howick. In November 2009 the site was pegged out into 30 blocks measuring 20 m x 20 m and separated by a 10 m buffer zone. In all but six of these blocks, which served as controls, six trenches of 20 m length, 0.6 m width and 1.5 m depth were dug 3 m apart. Four different treatments were applied to the blocks with trenches, amounting to some 360 m^3 of waste activated sludge from the Howick Wastewater Treatment Works (WWTW) being entrenched in total. Eucalyptus trees were then planted across the entire site and their growth monitored over 52 months to May 2014, a follow-up project (published as **WRC Report No. 2097/1/14**) having allowed the research to continue. During that period, the plots with sludge showed a 50% increase in timber volume compared to those without.

Growth measurements were taken once again in September 2018, and the trees were harvested at the end of that year. In early 2019, new trees were planted on the site, although no additional sludge was entrenched. Monitoring then resumed twice a year between March 2020 and February 2022 as part of a WRC-funded Partners in Development project that not only researched the long-term impacts of sludge entrenchment (published as **WRC Report No. 2899/1/22**), but also resulted in the compilation of *Guidelines for deep row entrenchment of faecal sludge and secondary wastewater sludge* (**WRC Report no. TT 880/22**).

The results of this research proved that the trees were still benefiting from the sludge over a decade after its entrenchment. When the first crop was harvested in 2018, the volume of trees planted in blocks with sludge was 15 – 30% higher than those without. In the first two years after planting, the effect had been even more apparent, with as much as 77% higher tree volume. The project team suggest two possible reasons for the reduced impact over time – the roots probably grew beyond the shallow sludge layer after two years, but nutrients in the sludge could also just be more important early in the growth cycle.

With the second crop planted in 2019, blocks with the most sludge had 29% higher tree volume after 2.5 years than those with no sludge. The project team predict that the overall increase in timber volume will be approximately 10% by the time the crop is harvested, should the growth boost follow a similar trajectory to that of the first crop.

Of course, the monitoring wasn't limited to tree growth, because there are naturally concerns that sludge entrenchment could pollute the environment. In the initial project, groundwater monitoring was conducted with a variety of instruments, but the most useful measurements were from piezometers installed on drainage lines below the site, as well as two boreholes drilled further downslope. The samples were only analysed for the nutrients nitrate and phosphorus, and although there seemed to be a slight increase in nitrate concentration during the 18 months after entrenchment, this difference was no longer evident by the 2013/14 rain season.

Soil samples taken at the site in February 2013 were analysed for 10 different properties, and this revealed that the sludge itself still had elevated phosphorus, zinc, calcium, magnesium – and to a lesser extent potassium – levels. However, levels in the surrounding soil in and alongside the trenches were not significantly different from background levels just beyond the study site. And the fact that there was no significant difference in nitrogen content between the sludge, surrounding soil and background soil suggests that any nitrogen not taken up by the trees had been returned to the atmosphere through the process of denitrification.

For the recently completed project, a more comprehensive set of soil samples was collected and analysed for 24 different properties. The same two boreholes were used to collect groundwater samples for nitrate and orthophosphate analyses, and in May 2020 river-health specialists from GroundTruth carried out a survey on the stream flowing past the downslope end of the study site. Water samples were taken for nitrogen (nitrate, nitrite and ammonia) and phosphorus (orthophosphate and total phosphate) analyses, benthic diatoms were collected, and ***in situ*** water quality measurements were made with a multiparameter water meter.

The results revealed that the entrenched sludge has had a positive effect on soil health in the long term. The carbon in the sludge stimulated microbial activity and raised the soil's organic content, which can in turn improve structural aspects such as water-holding capacity. As anticipated from the previous project's findings, there was no evidence of nutrient contamination of groundwater or the stream after all these years.

Faecal pollution, which is typically assessed in freshwater systems through ***E. coli*** counts, was not investigated in this project. However, the previous projects had evaluated the health risk associated with pathogens in the sludge by analysing soil samples for helminth ova – the eggs of parasitic worms. While bacteria and viruses from human guts die off quite quickly once outside the body, the ova of the common round worm, ***Ascaris lumbricoides***, are particularly hardy, and are therefore used as an indicator of sludge safety. Samples analysed from both the plantation study site and another of the project sites where pit latrine sludge had been buried showed that most ova die off within two to three years, and survival beyond four years has not been observed. What's more, the ova are much larger than soil particles and will remain where they are buried if the ground is not subsequently dug up.

In producing the DRE Guidelines, the project team drew not

Google Earth

The sludge treatment blocks, clearly visible in satellite imagery from 2010, supported a mature crop of trees by 2018.

The layout of the 30 treatment blocks at the study site. Six trenches oriented downslope were dug in each of the 20 m x 20 m blocks.

The buried sludge can still be differentiated from the surrounding soil after more than a decade, and has a clustering of roots that can be attributed to elevated nutrient levels.

only upon their own research and experience on the topic, but also on findings from the early trials in the United States and more recent studies internationally. The recommendations are also in line with South Africa's national ***Guidelines for the utilisation and disposal of wastewater sludge***, published by the WRC for government in 2006–2009. Those guidelines introduced a sludge classification system based on three parameters – microbiological quality (faecal coliforms and helminth ova), stability (relating to the degradable organic matter content) and pollutant content (metals and elements).

The DRE Guidelines focus on entrenchment of sludge from both WWTW and pit latrines, and detail the various aspects to consider for commercial, decentralised and household entrenchment. Commercial entrenchment would typically involve a partnership between a municipal WWTW and a forestry or sugarcane company, and both an environmental impact assessment and a water use licence application process would need to be followed. Decentralised entrenchment refers to small tracts of land, particularly in rural areas, where sludge could be used to grow trees or other non-edible crops, rather than transporting it long distances for beneficial use or disposal. As its name implies, household entrenchment is the on-site burial of sludge from pit latrines.

The final chapter provides an introductory overview to the DRE Guideline Toolbox, an MS Excel workbook developed within the project to help users decide whether deep row entrenchment is a suitable option for dealing with the sludge under consideration.

"Sludge disposal by burial will not be appropriate everywhere," note the project team in the research report. "The relevance of sludge disposal as well as the nature of sludge disposal will rely on a variety of factors, such as available land, potential for reuse, soil and geology type, volume of sludge requiring disposal, etc."

They point out that even in the forestry industry, there may not be many opportunities for sludge entrenchment. Private timber companies have stringent safety and environmental policies, and the survival of helminth ova for the first two years implies that workers would need to wear appropriate personal protective equipment, such as masks and gloves, while weeding the young crop. And nowadays the harvested timber is not only used for poles, paper and board.

"The private forestry industry is moving further in the direction of high-value uses such as clothing and pharmaceuticals. These companies are therefore extremely reluctant to risk possible contamination of their timber, whether the risk is real or only perceived," note the project team.

They add that the findings from the forestry plantation site, where soils have a relatively high clay content, are not necessarily applicable to other areas with different soils or crops. This presents opportunities for further small-scale studies, and some other aspects should ideally be investigated too, such as the fate of carbon in the soil and the potential of using sludge to rehabilitate surface mines. They also suggest that a model be developed to allow a detailed cost-benefit analysis of options for disposing of WWTW sludge, incorporating the main approaches currently used by municipalities.

Indeed, municipalities around the country are exploring ways of reducing the enormous costs associated with sludge disposal. An industry brief produced by GreenCape in 2021 reports that the City of Cape Town (CCT) spends some R60 million per year to dispose of the dewatered primary and waste activated sludge its various WWTW generate at a daily rate of about 200 dry tonnes. This expense and some regulatory changes restricting liquid and organic waste disposal at landfills has put the CCT on a path towards anaerobically digesting its WWTW sludges in two biosolids beneficiation facilities (BBFs) that will be established over the next 15 years. The BBFs will produce digestate cake that is nutrient rich, odour free and so low in contaminants that it will be safe for unrestricted use.

Currently, the CCT's WWTW sludge production makes up 74% of the total for the Western Cape, according to the Sewage Sludge Status Quo Report 2020/21, published by the provincial government's waste directorate. Analysis of feedback from 107 WWTW, following an 80% response rate to a questionnaire sent to all municipalities within the province, indicated that most WWTW dispose of their sewage sludge by land farming (22%) or to general (20%) or hazardous landfills (10%), while 22% stockpile sludge and 11% make it available for composting, agricultural or irrigation use.

Similar trends can be expected in other provinces, but a year ago the City of Tshwane won the inaugural Green Economy

Change Champions Competition for its beneficiation of sewage sludge. The competition, organised by GreenCape in partnership with the Friedrich Naumann Foundation, aimed to highlight municipalities applying innovative and sustainable green technologies in contributing to improved service delivery. In 2010, the City of Tshwane awarded a tender to Agriman for a 15-year period to convert sludge to useful fertilizers. The process starts with mechanical dewatering, followed by solar drying, composting and stabilisation. The product is then granulated and disinfected, and subjected to more drying, screening and coating before being blended and bagged in a range of fertilizers and other prescription blends for agricultural use.

The WRC has been promoting the concept of a circular economy for municipal WWTW sludge and faecal sludge from pit latrines for some time. In a recent working paper on the WRC's new Sanitation Transformation Initiative (SaNiTi) research strategy, Sudhir Pillay and Jay Bhagwan note that the WRC began funding innovation development within the faecal sludge management supply chain as far back as the early 2000s. Later, it commissioned a study to optimise the Latrine Dehydration Pasteurisation (LaDePa) technology, which processes faecal sludge into pellets that can be used as a soil conditioner, fertiliser or fuel. It has also funded projects on using faecal sludge to make biochar briquettes and to raise black soldier fly larvae that can be harvested as a protein-rich poultry or fish feed. Research has been initiated on market demand for these and other products that can be derived from sanitation waste.

Furthermore, in light of South Africa's electricity supply challenges, the WRC has funded a review of technologies for energy recovery from wastewater sludge (**WRC Report No. TT 752/18**) and more recently a case study on the role of such technologies in transitioning to a circular economy (**WRC Report No. TT 883/22**).

Clearly, DRE is just one possible method for the productive disposal of sludge. This highlights the need for a detailed cost-benefit analysis of sludge disposal options. Given the expense of transporting sludge, there needs to be a method of determining the distance at which entrenchment becomes less financially feasible than alternatives.

"The economic case for DRE is most compelling where there is enough space to dispose of the sludge on the same site that it is originally produced, such as a site with a VIP toilet. Simply dig a trench, transfer the pit sludge to the trench, cover it up and then plant some trees along the trench to benefit from the nutrients and carbon-enriched soil," says David Still, director of Partners in Development. "There is a widespread belief that this practice will 'contaminate the groundwater', but there is no evidence to support that belief, which is based on a misunderstanding of the way buried sludge and soil interact, and also a misunderstanding of the characteristics of faecal sludge."

To download, *Guidelines for deep row entrenchment of faecal sludge and secondary wastewater sludge* (**WRC Report No. TT 880/22**), visit: https://bit.ly/3EQafSI

To download, *Long-term impacts of entrenchment of pit latrine and wastewater sludge* (**WRC Report no. 2899/1/22**), visit: https://bit.ly/3Tt8ChD

Lani van Vuuren

One of the greatest challenges of VIP latrine management is how to safely dispose of the sludge when pits are full. Deep row entrenchment could be a viable management option.