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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Sanitation

Towards safe and sustainable sanitation sludge management

A completed Water Research Commission (WRC) study investigated the costs, risks and rewards of entrenching pit latrine and wastewater sludges.

Background

Decent sanitation is fundamental to public health. The realisation of this truth and the implementation of measures to achieve it has arguably saved more lives than any medical advance in history.

While there are a wide range of sanitation technologies in use, they can be split into those which deal with the waste off-site using some form of wastewater treatment and those which retain the waste on site.

In South Africa, the two overwhelmingly dominant forms of sanitation are fully waterborne sanitation in towns and cities and the septic tank or pit latrine in non-sewered areas. An end product of both of these systems is an accumulation of what is termed 'sludge'.

Although the numbers vary considerably according to a range of factors and circumstances, with pit latrines and septic tanks, faecal sludge typically accumulates at a rate of 30 to 50 litres per person per year. At a wastewater plant, typically 1 m^3 of sludge is produced per day per Megalitre of sewage processed, although this volume can be reduced by up to 80% if it is further processed in anaerobic digestors.

Disposing of sludge

All this sludge accumulates and must ultimately be disposed of. There are various options for dealing with sludge, each with each own advantages and disadvantages. By far the simplest and most economical method for the disposal of sludge is simply to bury it as close as possible to the removal site.

Burial deals with the problems of odour and insects, and protects people from accidental contact with the pathogens in the sludge. Furthermore, the nutrients in the sludge can potentially act as fertilizer for crops (e.g. sugarcane, fruit trees or timber).

The possible risk is that the nitrates and phosphates in the sludge will leach into the groundwater and thus impact negatively on the environment. Another potential concern is that the pathogens in the sludge will remain active and will pose a long-term risk if the sludge is later dug up.

The WRC through research partners, Partners in Development and the University of KwaZulu-Natal, investigated the benefits and risks of sludge entrenchment.

The study

Five experiments formed part of the investigation. In the first two pit latrines were emptied at Inadi near Pietermaritzburg and the sludge was used to fertilise and condition the soil

Sludge burial in progress.

around fruit trees which were planted at the homesteads. Citrus and peach trees were the trees selected by the families, and particularly in the case of the citrus those trees which were planted with sludge grew noticeably larger and had more abundant fruit.

The size of this experiment was too small to be of much scientific significance, but perhaps the most important finding was that the planting of trees over faecal sludge and the consumption of the fruit that grew on those trees was not considered taboo.

In the second experiment 24 trees, 12 with sludge and 12 without, were planted in metre-high and 0.75 m diameter concrete towers, and closely monitored for six months. At the end of the six months the towers were broken up, and the total tree mass for each tower was measured. The pattern and density of the roots were also studied.

The 24 trees were split evenly between eucalyptus and wattle. In the case of the experimental trees, a core of pit latrine sludge was placed at the centre of the tower directly below the sludge. Throughout the experimental period the control trees, those without sludge, were given liquid fertiliser, while the experimental trees were given just water (the same amount as that given to the controls).

The growth response of the experimental eucalyptus trees was strikingly better than the controls, while that for the wattle trees was less so. In the case of the experimental trees the tree roots were denser around the outer edges of the soil where they were turned by the concrete wall, but the roots also grew into the sludge core below the trees.

In the third experiment over a thousand cubic metres of pit latrine sludge was buried on the site of an old oxidation pond in Umlazi, south of Durban. Eucalyptus and wattle trees were planted over the sludge and five monitoring boreholes were drilled between the site and the nearby Umlazi River.

No significant changes were detected in the groundwater over a two-year monitoring period. Samples of the sludge were taken from time to time and assessed for physical properties and pathogen content. After three years the sludge was hard to distinguish from the surrounding soil, the organic matter had virtually all decomposed and the pathogens (using *Ascaris* as a market) had all died.

In the fourth experiment some 360 m^3 of wastewater treatment works activated sludge was buried in a eucalyptus plantation near Howick, in the KwaZulu-Natal midlands. The two hectare experimental area was divided into 30 plots each, 30 m by 30 m in extent, and in 18 of these plots sludge was buried in a 20 m by 20 m section in the centre of the plot. Five treatment were compared, ranging from treatment with various loads of sludge, to sludge and trenches, to no sludge and no trenches.

With the growth of 900 trees having been observed for a period of 52 months, the plots with sludge showed a 50% increase in timber volume compared with those without. This site has also been closely monitoring for groundwater impact.

Only a small difference in nitrate levels was detected in the downstream borehole compared with the upstream borehole over the first year after planting, and after four years the nitrate content in the water sampled from the site rain gauge was significantly higher than that sampled from the boreholes or the piezometers used.

Samples of the soil taken after three years from around the buried sludge and from the sludge itself show that nitrogen is not retained in the sludge or in the surrounding soil, whereas potassium, phosphorus and other elements such as calcium and zinc are retained.

The final experiment, which remains ongoing, is looking more closely at the leachate emanating from buried wastewater treatment works sludge in a set of 15 one metre square plots, 12 of which have a layer of either 250 mm or 500 m of sludge. Six of these plots have been constructed with pan lysimeters buried some 500 mm below the sludge, which means that all the leachate, which seeps downwards from the sludge (and in this case instrumentation detects no lateral seepage) is captured and can be analysed.

After ten months of monitoring through the rain season 2013/14 less than 0.2% of the nitrogen and less than 0.003% of the phosphorous has been detected in the leachate. As the fourth experiment described above showed that within three years the nitrogen in the sludge is no higher than background soil levels, this evidence supports the hypothesis that most of the nitrogen that is buried in sludge returns to the atmosphere through the natural processes of nitirification and denitrification.

This study, therefore, provides at least answers to some of the questions regarding sludge entrenchments.

Conclusions

No other method of sludge disposal is more economical than simply burying it in the ground, especially if the burial site is close by the site where the sludge is collected. In the ground, sludge decomposes by natural biological processes and after a few years is barely distinguishable from the surrounding soil.

After three years even the hardiest pathogens such as Ascaris die off. Despite high loading rates no significant impact on groundwater has been observed in the trials to date over four years of monitoring, and there is evidence that the phosphorus and potassium in the sludge binds to soil particles near the point of burial while the nitrogen returns to the atmosphere.

When sludge is buried in close proximity to eucalyptus trees, which form a major part of the South African forestry plantations, growth is enhanced by up to 50% in terms of total timber volume, although after only four years it is too soon to say if the magnitude of this difference will be sustained over a nine- or ten-year growth cycle.

This additional timber volume will offset the cost of the entrenchment process by as much as a third or even half. The increased potassium and phosphorus levels in the soil will be lasting and will benefit future tree growth cycles.

Entrenchment provides a practical and beneficial technique to deal with the problem of disposal of potentially dangerous faecal sludge from pit latrines and wastewater treatment works. Unfortunately, it is still too little known or understood in South Africa, and it is improbable that permission will easily be obtained to adopt this method at scale.

It would be advisable to continue with the monitoring of the experimental plot at the plantation to see whether the enhanced growth in the plots with sludge is fully sustained to the end of the ten-year growth cycle, i.e. up to 2019. This would would not require a significant research budget, as all that would have to be done would be to measure the trees once a year and to sample the boreholes perhaps twice a year.

Meanwhile it is quite possible that other methods of sludge burial might yield better results compared with these trials. For example, smaller amounts of sludge could be buried but with a greater frequency – say once every three years in the same location. It is recommended that trials are conducted comparing different entrenchment methods to see which gives the best return on investment.

These trials have been carried out with agroforestry in mind. It is not recommended that sludge is used as a fertilizer or soil conditioner in close proximity to food crops, such as vegetables. However, South Africa and, in particular KwaZulu-Natal, has a large sugarcane industry.
It is recommended that trials be conducted with sugarcane as the associated crop. Entrenchment in a cane field would be significantly easier than entrenchment in a forestry plantation, due to the absence of roots and stumps.

Finally, more work must be done to fully understand the fate of the nitrogen and phosphorus in the buried sludge. On the strength of the evidence in this study, only a small fraction of these elements leach out of buried sludge.

This implies that a significant fraction of the remainder either stays where it is (adsorbed to the soil, in the case of phosphorus) or returns to the atmosphere (in the case of nitrogen). More rigorous and long-term work is required to prove these hypotheses.

Further reading:
To order the report, *Entrenchment of pit latrine and wastewater sludges – An investigation of costs, benefits, risks and rewards* (**Report No. 2097/1/14**) contact Publications at Tel: (012) 330-0340,
Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.