WATER RESEARCH COMMISSION

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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

Wastewater treatment

Biologically enhanced primary settlement

A WRC-funded study investigated bioflocculant opportunities for locally grown crops and their associated waste in small rural wastewater treatment plants.

Wastewater treatment

South Africa's municipalities treat around 7,5 million m^3 of effluent on a daily basis. The operating costs to treat the effluent exceed R3-billion per annum and the capital replacement cost of the installed treatment capacity would be close to R40-billion.

Larger wastewater treatment works generally have a better skills base, use advanced treatment processes and have access to the necessary resources to optimally operate their plants, while smaller works often do not have the same skills and/or the necessary funds to refurbish and optimise processes to stretch capacity.

Plant capacity

Plant capacity is a major factor of concern in South Africa. Many works are receiving inflows that are at or exceed their design capacities. The cost associated with increasing the treatment capacity at wastewater treatment works is between R4-million to R10-million per mega litre per day (MLD) of treatment capacity and the operating costs are between R0,5 and R1,5/kℓ treated.

With estimates thus running into tens of billions of Rands to address the plant capacity constraints and limited skills at smaller and rural wastewater treatment works to deal with operations and maintenance, less capital intensive and more robust solutions are sought. If carbon loading is the capacity constraint, it is possible to increase the total plant capacity by as much as 30% due to higher nutrient removal in the primary settlers. A treatment process similar to chemically enhanced primary treatment (CEPT), may offer rural communities a simpler and more robust treatment addition.

Flocculants

The product that is most widely used for CEPT is ferric chloride (Ferric), particularly effective in removing phosphates, however, biological flocculants also have the potential to assist and, in some cases, simplify CEPT processes. Where viable, the cultivation and processing of biological flocculants may also create opportunities for rural development and help communities become financially self- sufficient with regard to their sanitation needs. There are many biological products available in South Africa that have proven flocculation abilities.

Laboratory tests

Moringa seeds, Chitosan, Fenugreek, Opuntia and tannins were used as biological flocculants in a laboratory-scale comparative study using the standard jar testing procedure to determine the optimal dosing rates and cost-effectiveness of the five flocculants. Simultaneous tests were also undertaken using ferric chloride as the primary flocculant as a benchmark to test the capabilities of the biological products.

Jar testing and extraction methods showed that the products tested were capable of enhancing the reduction in chemical oxygen demand (COD) of the water from around 30% to over 60% when compared with conventional sedimentation.

Microbial results

Moringa reduced the *E. coli* count by 85%, confirming its potential role as a combination sanitation flocculation agent. However, dosing rates higher than the optimal for COD removal would have to be used to de-sanitise the water to irrigation standards.

TE169, Ferric and unassisted settlement did not result in a measurable reduction in pathogen levels. Opuntia and Chitosan are also believed to have anti-microbial capabilities, indicating that these products could also be used to treat wastewater for fertigation purposes, but tests for the effect of these products on the microbiological characteristics of the treated water did not show any microbial activity.

Microfiltration of the flocculation water reduced the *E. coli* and total coliform count by 92% and 89% respectively. It may be possible to obtain a suitably low COD and microbial count in the water if it is flocculated using Moringa and sand filtered.

Sludge volume

Tests showed that Chitosan performed the best of all the flocculants with respect to sludge production, producing 18 mℓ/ℓ. The untreated sludge volume was 16 mℓ/ℓ. if one considers that primary sludge is usually around 60% of the total sludge produced, sludge production at a conventional BNR works extrapolates to around 27 mℓ/ℓ.

The use of flocculants Fenugreek, Moringa, TE169 and Ferric led to 18 mℓ/ℓ, 19 mℓ/ℓ, 21 mℓ/ℓ and 28 mℓ/ℓ of sludge in the primary settlement process respectively. The volume of sludge produced at wastewater treatment works should be reduced to minimise disposal costs. While an enhancement of COD reduction by 30% will by itself not meet the discharge standards applicable for small to medium WWTWs, in certain cases this may extend the capacity of the treatment works.

While it is expected that lower secondary sludge would result from BNR treatment after enhanced precipitation, the exact amount would need to be tested at plant scale to determine whether enhanced precipitation using biological flocculants increase or decrease the total sludge production rate. The biological flocculants performed better than Ferric in this regard. Moringa produced 32% less sludge and TE169 25% less than Ferric. However, the low sludge production of Fenugreek corresponded to its low removal of suspended solids.

Nutrient removal

No benefits could be gained from the biological products tested with respect to nitrogen and phosphate levels, with excessive dosing rates even leading to a build-up of these nutrients.

Performance comparison of tested products

Ferric has a far greater COD and P removal capability than the biological products tested. Some N removal was also measured. The tests showed that both TE169 and Chitosan are also able to achieve very high COD removal rates, but these dosing rates may not be economical.

As a minimum, it indicates that biological flocculants can be used in certain situations prior to a biological nutrient removal (BNR) system with low dosing rates. For micro and small wastewater treatment works, where irrigation with the treated water is an option, the biological flocculants were able to reduce the COD to below the maximum permissible level of 400 mg/ℓ.

Opuntia, as it can be grown in most parts of the country, can play an important role here as it can be integrated into the water treatment process as a 'constructed wetland'. When dosed simultaneously Moringa and Opuntia are able to produce water with an average COD of 303 mg/ℓ. This represents a 20% enhancement in COD removal over unassisted settlement or a 50% total COD removal.

The removal of suspended solids by most of the tested products indicates that the treated water could then be suitable for various types of filtration from sand filtration to microfiltration. Confirmation is required on the degradability of the sludges produced by the biological flocculants as some of them are formulated using chemical compounds.

Nitrogen and phosphate removal was minimal for all of the tested bioflocculants. South African discharge standards have limits on both N and P. For small treatment works maximum nitrate levels of 10 mg/ℓ, ammonia of 6 mg/ℓ and phosphate level of 6 mg/ℓ are permitted. Only Chitosan showed some P removal ability.

The use of some of the biological products (Moringa and Opuntia) led to rises in conductivity of the treated water. The standard allows for an increase of 150 mS during the treatment process. This does not occur at the optimal dosing rates, but may occur if bioflocculants are used to disinfect the water.

Low dosing rates did not result in the pH dropping significantly for any of the products tested, although the inlet pH was already close to the lower limit of the discharge standard on most occasions. Fenugreek requires a high pH to be effective, but does not reduce the pH of the treated water significantly. This would be a disadvantage should a plant be subject to an upper limit on pH of 7.5.

Techno-economic analysis

Flocculant production costs

This study was undertaken to make a first order estimate of the cost of producing biological flocculants. To complete this first assessment, many assumptions had to be made, and studies from abroad investigated. A comprehensive review of the costs based on local dynamics, extraction efficiencies and agronomic potential will be required prior to a full feasibility study. Fortunately, some biological products are available commercially and their pricing can also be used to make a direct estimate of their dosing costs.

Cost benefit analysis of flocculants

Based on the dosing rates and production costs of the various products, a cost-benefit analysis was produced. Only Fenugreek and Opuntia under the above assumptions can reduce the operating costs at BNR wastewater treatments works, but when the capacity is a constraint, and if they can actually bring about capacity improvements, Moringa, Chitosan and Ferric are also competitive solutions.

It must be noted that this analysis was for a mainly domestic wastewater with some unique characteristics. Tests should be undertaken at the works being targeted to see which product is the most cost-effective. Plants with higher COD influent concentrations than the norm CEPT may benefit more. The inverse would apply to lower CODs in the influent.

Some works that treat both domestic and industrial waste have very high COD levels. TE169 is not seen to be a cost-effective option at this time, but may prove beneficial for the treatment of certain problematic effluents, for example, oil bearing ones. Also, it may be possible to reduce the dosing rates by optimising the influent parameters such as pH or by synergistic dosing of flocculant aids. Moringa flocculant in the short term is viable. But it is cautioned that once the cosmetic oil market for Moringa is saturated, the true cost of the flocculant would have to be recovered for Moringa production to continue being viable. This could equate a dosing cost of as much as R2.00/kℓ.

Chitosan, Fenugreek and Opuntia are interesting products as they seem to offer cost-effectiveness in the long run. CEPT, in combination with membrane biological reactors (MBRs), wetlands and upflow anaerobic sludge blanket (UASB) reactors could be much more competitive from both a capital and operating perspective than CEPT and BNR. Electricity costs may be largely avoided.

Conclusion

The test work confirmed that the biological flocculants are capable of enhancing the primary settlement process to varying degrees. It could be beneficial for existing works that are constrained by capacity or have higher COD levels in their influents than is needed by the secondary treatment steps.

By comparing dosing costs to savings in electricity, only Opuntia and Fenugreek may be economical to dose. When capacity constraints also exist, and the biological flocculants can actually increase plant capacity, then Moringa and Chitosan are also cost effective. TE169, despite having high COD removal capabilities, is not a cost-effective option at this point in time.

The problem of the voluminous sludge production is overcome to different degrees by the products tested. The best performing product was Chitosan, followed by Moringa. Opuntia and Fenugreek also showed improvements over Ferric. TE169, like Ferric, led to a lot of sludge forming. It would seem that other secondary treatment options such as rapid sand filtration, BFs, wetlands and UASB reactors are better matched to the full potential offered by biological flocculants.

Of the five identified products, Opuntia and Fenugreek have the greatest potential for social change by creating opportunities for rural employment, but lag in terms of its advancement through research. Chitosan and tannin flocculants are already commercially available. The commercial value of the other components of the Moringa seed first needs to be proven before large quantities of flocculants become available.

Considerable energy savings can be realised at wastewater treatment works if the envisaged anaerobic treatment processes are viable. This could reduce the electricity consumption in the country by as much as 1%. The bio-flocculants post a potential to stimulate rural developments through the advancement of agri-processing businesses. Plant applications should be advanced through further research conducted at larger scales in the country.

Further reading:
To obtain the report, ***Biologically Enhanced Primary Settlement*** (**Report No. KV 248/10**), contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.