

# *Executive Summary*

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## *1 Background*

The KwaZulu-Natal region has the potential to attract a significant amount of new industry due to its coastal location and the availability of space. Since the province has an abundance of water, relative to the rest of the country, it is probable that some of the industries will be from the agro-industrial sector. One of the characteristics of this class of industries is high-strength organic effluent. Other classes of industries, which produce high-strength or toxic organic liquid effluents, could also develop.

The Department of Water Affairs and Forestry identified the need to advise industries with high-strength organic effluents on the most suitable treatment route to be followed. Anaerobic digestion has the potential to treat complex organic wastes such that they are either completely mineralised or that they could be further degraded aerobically.

Tracer tests on a number of existing anaerobic digesters in the KwaZulu-Natal Region indicated that the mixing volume could be as low as 50 % of the actual volume, i.e. as little as half of the total volume was actively being used for the degradation process. Two WRC research contracts undertaken by the Pollution Research Group aimed to increase the mixing efficiency of the anaerobic digestion process (WRC No. 648 - *The Application of Computational Fluid Mechanics to Improve the Design and Operation of Water and Wastewater Treatment Plants* and WRC No. 560 - *The Development of a Cross-Flow Microfilter to Improve the Performance of Anaerobic Digesters*). During these investigations it was found that there were a number of sewage works with under-utilised anaerobic digestion facilities.

Control of the wastewater treatment plants in the greater Durban area is currently (1997/8) being assumed by the Durban Metropolitan Council. This standardisation provides the potential for the utilisation of under-utilised capacity of some of the sewage treatment plants and alleviation of the *bottleneck* at plants operating at or over design capacity. This should result in a delay in the need for capital expenditure and an increase in the income from capital already expended.

The KwaZulu-Natal Region has a great need for the provision of sanitation. The increasing urban and peri-urban population will require the extension of sewage reticulation and an increase in sewage treatment capacity. The increased use and income from existing but under-utilised capacity will assist in financing the additional infrastructure in areas where it is needed.

## *2 Project Aims*

The main aims of the project were as follows:

1. To provide information that will allow for the rational location, in KwaZulu-Natal, of new industries that produce high-strength or toxic organic effluents;
2. To assist in the optimal utilisation of effluent treatment facilities in the region;

3. To identify under-performing digesters with a view to recommending courses of remedial action;
4. Identify industries in the region that produce high-strength or toxic organic effluents in order to allow rational decisions to be taken for their safe disposal;
5. To safeguard the aquatic environment through providing suitable industrial effluent treatment options; and
6. To promote the regional development of new industries or agro-industries that produce high-strength or toxic organic effluents by providing effluent treatment options.

This project was therefore initiated to investigate the utilisation of available anaerobic digester capacity for the treatment of high-strength or toxic industrial effluents. These effluents would normally be diluted prior to discharge to the local sewage works, discharged to sea or co-disposed into municipal landfill sites. The focus of the project was on undertaking a survey of available anaerobic digester capacity and the evaluation of the performance efficiency of each of the anaerobic digesters. A protocol was established to assess the anaerobic degradability and the potential toxicity of an effluent, on a laboratory-scale.

### ***3 Project Approach***

The local authorities were approached for information regarding the anaerobic digesters in the region. The digesters were visited and physical and operating data for each were obtained and used to calculate the performance efficiencies. This allowed for the identification of under-performing digesters and digesters available for the treatment of high-strength or toxic industrial effluents.

The regional pollution control officials were interviewed to identify industries producing high-strength or toxic organic effluents. Selected industries were contacted to obtain data on their effluents and the local authorities provided information on the proposed development of new industries. Possibilities for pollution prevention, waste minimisation and stream segregation were discussed. From these data, a matrix was compiled which identified potential anaerobic digesters for treatment of effluents produced in the vicinity.

Anaerobic digestion has the potential to stabilise the degradable fraction of high-strength or toxic organic effluents, either entirely or such that they can be further degraded aerobically. To achieve the research objective, a strategy, which can be applied to different effluents, was developed. The overall strategy follows two concurrent pathways, the first investigates the effluent degradability and the second evaluates the digester capacity and efficiency. A protocol was developed for the laboratory assessment of the degradability and potential toxicity of an effluent. The digester capacity and performance efficiency was assessed simultaneously. From these initial assessments, the feasibility of full-scale could be predicted.

The strategy was applied to determine the feasibility of using anaerobic digestion to treat a textile size effluent.

### ***4 Summary of Results***

A survey of 24 wastewater treatment plants was undertaken which included a total of 56 anaerobic digesters. The survey identified the availability of hydraulic or organic capacity. It was proposed that this available capacity could be utilised for the treatment of high-strength or toxic organic effluents, produced by industries in the

vicinity of the wastewater treatment works. Six of the investigated treatment plants had digesters that were not utilised at all with a total available volume of 21 223 m<sup>3</sup>. The average residence time of all of the investigated digesters was 61 d which was 36 d longer than the nominal retention time of 25 d. This indicated that the digesters were under-loaded. Using the design criteria of 25 d hydraulic retention time and 3 kg VS/m<sup>3</sup>.d organic load, on average the digesters were 32 % hydraulically under-loaded and 58 % organically under-loaded.

Industries producing high-strength or toxic organic effluents were identified and selected industries were visited. Disposal of these types of effluent is problematic if the General Standards for disposal into a sewer system are not met. The solution generally involves costly tariffs, dilution of the wastewaters with valuable potable water, marine discharge or co-disposal into municipal landfill sites. Anaerobic digestion has been shown to have the potential to treat effluents of this nature. Microorganisms have the ability to acclimate to xenobiotic or toxic substrates which provides the potential for the anaerobic degradation of most substrates. The survey concentrated on two regions, viz. Durban South and Pinetown, due to the availability of anaerobic digestion capacity at the Southern, and Umbilo and New Germany Works, respectively. Industries producing an effluent with a COD > 2 000 mg/l were included in the survey. A matrix was compiled in which available digestion capacity was matched with potential effluents for treatment. From the investigation of the industries and the composition of effluents it was concluded that there was the potential for the utilisation of available resources to effectively stabilise effluents which otherwise could have an adverse effect on the environment.

The laboratory-scale screening test was based on the method of Owen et al. (1979) which was found to be a suitable method for the easy assessment of the anaerobic degradability and potential toxicity of a compound. These assays facilitated the determination of whether the loading of a substrate into an anaerobic digester would be detrimental to its operation and provided information on volumes and concentrations of an effluent that could be treated effectively. Material and energy balances provided an indication of the efficiency of the digestion process in the serum bottles.

Detailed evaluation of the anaerobic digesters at the Umbilo Sewage Purification Works (USPW) identified available capacity in terms of both hydraulic and organic load. This was determined by investigation of the flow to the digesters and the properties of the feed sludge. The hydraulic load to the USPW was 75 % of the design capacity (it was designed to treat a flow of 23.2 Ml/d but was only treating 17.38 Ml/d) hence the load the anaerobic digesters was below capacity. The anaerobic digesters were high-rate digesters in that they were heated and mixed. They could, therefore, receive an organic load of between 1.5 and 3 kg VS/m<sup>3</sup>.d. The annual average feed to the digesters was 1.12 kg VS/m<sup>3</sup>.d which indicated that the digesters were organically underloaded.

The stability of the Umbilo digestion process was assessed by analysis of the characteristics of the digester sludge. Operation of the digesters was efficient. Similar analyses were performed at the other wastewater treatment works to determine the performance efficiency and highlight under-performance. This facilitated the recommendation for remedial action and the ultimate improvement of utilisation of digestion facilities.

Tracer tests are useful to assess the mixing and flow patterns within an anaerobic digester as well as the quantification of active volume. A residence time distribution test was performed on an anaerobic digester at the USPW. The tracer test indicated that the entire digester volume was utilised thus indicating the absence of dead volume. The mixing process was efficient with the reactor approximating a perfect completely stirred tank reactor (CSTR). A sludge bypass of 1.94 % of the flow was detected. This should be remedied to prevent the presence of undegraded substrate in the final effluent.

The laboratory-scale test protocol was applied to assess the anaerobic degradability of a textile size solution. The size solution was chosen due to its high organic strength (ca. 120 000 mg/l) and because the textile mill producing the effluent was located in the vicinity of the USPW. The effluent was being tankered approximately 40 km for marine discharge. The serum bottle tests showed that the size solution was anaerobically degradable. Interactions between microbial populations together with co-metabolism resulted in the efficient degradation of the substrate even though components of the size solution were found to be inhibitory to the biomass. Acclimation experiments were undertaken with the inhibitory size components since it is known that microorganisms have the ability to acclimate to inhibitory substrates so that they can be degraded at concentrations which were previously inhibitory. These results indicated the potential to treat of the textile size effluent in the available anaerobic digester capacity at the Umbilo Sewage Purification Works.

Cleaner production is *the continuous application of an integrated preventative environmental strategy to be applied to processes, products and services to increase eco-efficiency and to reduce risks for humans and the environment*. Segregation and concentration of the high-strength or toxic effluent components would facilitate cleaner production and eco-efficiency since the strength of the final effluent would be much lower, the concentrated waste could be recycled in the process or it could be treated in available anaerobic digester capacity thus reducing co-disposal in landfill sites and marine discharge. In terms of the *Cradle to Grave* concept, a waste generator must assume full responsibility for its waste, including the safe disposal.

## **5 Realisation of Objectives**

From the results obtained during the course of this project, it is evident that the objectives have been achieved. The survey of the anaerobic digesters and the evaluation of the performance efficiencies of the individual digesters provided an indication of the wastewater treatment plants with the potential to accept greater loads, in the form of industrial effluent. This information could facilitate the rational location, in KwaZulu-Natal, of new industries that produce high-strength or toxic organic effluents. The survey also identified under-performing digesters. Remedial action, which often involved simple solutions such as heating or mixing the digester contents to improve the degradation process, was suggested. Improvement of the degradation process would facilitate the optimal utilisation of the effluent treatment facilities.

Industries producing high-strength or toxic organic effluents were identified. Nearby wastewater treatment works were evaluated to assess the potential for treatment of the effluents in the available anaerobic digester capacity. The majority of the high-strength effluents were discharged to sea, thus the implementation of anaerobic treatment would safeguard the aquatic environment.

A laboratory-scale protocol was developed for the assessment of the anaerobic degradability of an effluent and its components. This research concentrated on the application of high-strength organic effluents, however, the protocol could also be applied to toxic organic effluents. Investigation of the high-strength textile size effluent allowed for the development of the protocol. The size solution contained toxic components thus acclimation techniques were investigated.

During the course of the project, two landfill sites in the greater Durban area were closed to co-disposal due to subsidence problems. Implementation of this research work would provide a safe treatment option for those industries producing high-strength or toxic organic effluents. This would provide a solution to the co-disposal problem, prevent dilution of the effluents with valuable potable water and would also protect the marine environment by preventing sea outfall.

## 6 Recommendations

1. The anaerobic digester performance evaluation should be extended throughout the country. The utilisation of these available resources would generate income which could be used for social improvement such as the provision of sanitation.
2. A thorough survey of industries with emphasis on the identification of point source emissions within the factories should be undertaken. This would facilitate the segregation and concentration of the high-strength or toxic effluent components on-site. These could then be tankered to a nearby wastewater treatment works for anaerobic treatment in available capacity.
3. Segregation of high-strength or toxic components on-site would promote cleaner production strategies such as recycling. Raw material substitution could also be implemented. This involves the replacement of recalcitrant components with biodegradable substitutes.
4. The information from the effluent survey could contribute to the proposed national database on effluent production and characteristics.
5. Assessment of the cost-effectiveness of the proposed treatment option and logistical considerations, such as road quality and maintenance with increased usage by tankers, should be undertaken.
6. There should be long-term monitoring of effluent degradation by the staff at the wastewater treatment works.
7. Research into the concentration, or thickening, of digester sludge for the efficient utilisation of digester volume should be carried out. Investigation of the computational fluid dynamics of an under-performing digester could also contribute to improved process efficiency.
8. The serum bottle test should be scaled up to a 20 l laboratory-scale reactor to provide more accurate information for prediction of operation in a full-scale digester. The set-up and operating procedure for these tests are presented in **Appendix E**.
9. The described protocol should be employed in the laboratories at the respective wastewater treatment works for the assessment of effluents prior to their acceptance for anaerobic digestion.
10. The closure of the Bulbul Road landfill site to co-disposal has necessitated the co-disposal of toxic wastes onto the unlined Springfield Park landfill. This poses grave environmental problems in terms of contamination of the groundwater and rivers. There is the potential for these effluents to be treated in available anaerobic digester capacity thereby safeguarding the environment.
11. Dedicated or specialised digesters could be developed to treat the toxic effluents on-site. Acclimation of the biomass would facilitate efficient pre-treatment of the effluent, which could then be discharged to sewer. The digesters would be under the control of the local authority who would monitor the effluent quality. This would reduce transportation risks.

## 7 Technology Transfer

The research facilitated interaction with, and contribution to, the following projects:

1. The residence time distribution test carried out on the Umbilo digester was modelled using IMPULSE, which was developed during the course of WRC Project No. 363 entitled *The Development and Evaluation of Small-scale Potable Water Treatment Equipment*.
2. The project was motivated by conclusions reached during the course of WRC Project No. 456 entitled *The Regional Treatment of Textile and Industrial Effluents* which identified the under-utilisation of anaerobic digestion facilities in the KwaZulu-Natal Region.
3. An Honours project (Department of Microbiology and Plant Pathology at the University of Natal, Pietermaritzburg) to isolate bacterial populations targeting selected industrial wastewaters.
4. A student laboratory project (Department of Chemical Engineering, University of Natal, Durban) applied the biodegradability and toxicity assays to ascertain the anaerobic treatability of ice cream waste.
5. The biodegradability and toxicity protocol will be applied by a number of B-Tech students (Natal Technikon) in order to assess a number of identified effluents.
6. A student laboratory project (Department of Chemical Engineering, University of Natal, Durban) assessed the baffled (compartmentalised) anaerobic digester for the treatment of a high strength organic effluent.
7. An effluent survey conducted by a research team at Natal Technikon.

The establishment of the KwaZulu Natal Water Research Network and the frequent meeting of its members has facilitated the exchange of ideas and collaborative research as well as the ability to use equipment in other laboratories.

Two paper and 5 poster presentations were made at various conferences.

One MScEng thesis (publication pending examination).