Application of biochemical products as a bioremediation technique for domestic sewage treatment plants

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Abstract Biochemical products have been widely used for treatment of various types of wastewater. The treatment processes with the addition of biochemical products are quite attractive because of their simplicity, minimal use of equipment, they are environmentally friendly and are suitable for the removal of organic pollutants. The purpose of these products is to enhance the activities of beneficial microbes in order to improve treatment performance. This study was carried out to determine the potential of applying biochemical products in assisting and improving the performance of sewage treatment plants. In this study, four biochemical products, namely: Zeolite, Bio-C, Eco-B and Was-D, were applied to the sewage treatment plant. Analyses were carried out on several water quality parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), oil & grease (O&G), phosphorus (P), ammoniacal nitrogen (AN) and sludge thickness (ST). From the results obtained, it can be seen that the overall performance of the treatment plant improved with most of the parameters studied were found to fulfill the DOE Standard B requirements. The performance of Bio-C was found to give better results than other products.

Keywords Biochemical products; bioremediation technique; enzyme; treatment performance

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Introduction

Sewage has been identified as the major source of organic pollution in Malaysia's rivers. The sewage contains organic particles, dissolved matter, sulphurous and nitrogenous compounds, which can either directly or indirectly cause malodour production in some stages of wastewater handling (Kabbashi, *et al.*, 2001a; Gostelow *et al.*, 2001). Besides, the decomposition of organic matter produces gases that cause odours in domestic sewage. Major problems are still encountered in some facilities, such as odours and poor product quality operational problems including long processing and excessive moisture (Kabbashi, *et al.*, 2001b). In addition, untreated wastewater usually contains numerous pathogenic microorganisms that stay in the human intestinal tract (Metcalf and Eddy, 1991; McGhee, 1991). A review of sewerage infrastructure includes the need to upgrade or modify the existing treatment methods. Upon the implementation of the privatisation of sewerage services in 1994, approximately 70% of the sewage treatment plants (STP) taken over by the Department of Sewerage Services (DSS) is in a non-functional state either due to process failure or equipment breakdown (Indah Water, 1999). Major problems related to odour emission, instability in treatment processes and excess sewage production persisted until today.

Biochemical products were formulated to provide efficient bacterial growth for bio-degradation. The system treats the polluted wastewater naturally without the use of chemicals (Salim and Salmiati, 2006). Besides increasing the treatment plant capacity, the proprietary biochemical formulation is designed for use in sludge removal and oxidising organic matter in STP systems as well as eliminating expensive dredging cost,

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BOD reduction and odour controls. Higher concentration, varying compositions and rapid velocity of biological degradation are gained by using biochemical products. The biodegradation process includes two treatment stages under anaerobic conditions, i.e. (1) liquefaction and (2) gasification, as illustrated in Figure 1 (Shikoku Chemicals, 1999).

The biochemical products selected in this study are Zeolite, Bio-C, Eco-B and Was-D. Zeolite, when applied to the STP, functions as an adsorbent. The other products are made from biological products that employ bacteria and enzymes to improve STP performance. The concentration of bacteria and enzymes in biochemical products are more effective and efficient at digesting various toxicants in waste treatment systems, as opposed to natural or existing strains. The biochemical capacity is greatly improved by the addition of enzymes. The selected bacteria produce higher concentrations of enzymes and establish rapid flocculation with accompanying digestion rates, thus increasing the efficiency of the waste treatment system (Abdullah, 2002; Strata Bioremedial, 2003). The properties of the biochemical products are shown in Table 1.

Certain studies carried out thus far have indicated that the addition of some bacteria into the treatment plants could reduce the problems encountered by the system. Naturally occurring microorganisms could be harnessed to degrade the organic matters into more stable compounds. Thus, biochemical products as well as enzymes are the most potential aids in reducing the above mentioned problems when employed in STP. The selected bio-products are evaluated and proposed for full-scale implementation.

Methodology

The pond system selected consisted of two ponds which accepted sewage from a residential area with a population equivalent (PE) of 2500. The top water level in Pond 1 was 1.52 m and Pond 2 was 1.9 m. Each biochemical products had different procedure to apply into the STP. The zeolite in the form of raw and rock were thrown to the middle of the ponds, while the sand and powder forms were spread out along the edge of STP. The dosage plan of Bio-C and Was-D, in the form of solution, was implemented each day

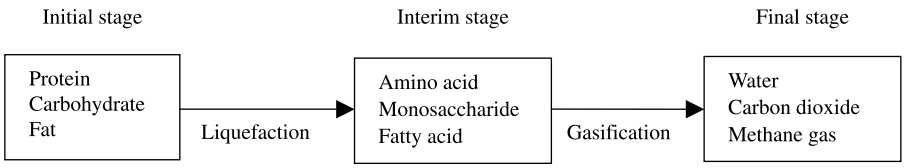

Figure 1 Treatment stage in anaerobic process

Table 1 The properties of the biochemical products

No	Biochemical products	Properties
1	Zeolite	Adsorb organic pollutants, phenol and alcohol, removes heavy metals, good ability for high heating and acidity
2	Bio-C	Reduces odour, improves soil permeability, reduces BOD and COD, reduces the volume of sludge.
3	Eco-B	Eliminates unnatural and unfriendly microorganisms, maintains the natural balance of wastewater, eliminates bad odour
4	Was-D	Reduces grease solid, BOD and SS, exerts a powerful effect odour and decreases the volume of sludge.

Source: Abdullah (2002); Strata Bioremedial (2003) and Shikoku Chemicals (1999)

with different volumes to achieve the best start up of bacteria. A measured quantity of biochemical products was poured at several points, as shown in Figure 2. This treatment was repeated according to a predetermined schedule.

The Eco-B dosage was chosen according to a ratio of number of standard Eco-B to volume of water treated, which was 1/0.69 for non-aerated conditions. The sum of Eco-B installation (see Figure 3) was 65 units.

Samples were taken at several sampling points as illustrated in Figure 4. The water sample was analysed before, during and after biochemical application. The field techniques involved sample collection and *in situ* measurements. For the chemical analysis, 2 L samples were taken from the STP by using a 1 L glass bottle and a 1 L plastic bottle. The sample in the plastic bottle was analysed for organic matters and the glass bottle sample was used to analyse O&G. Chemical analysis was carried out at the Environmental Engineering Lab and SS, BOD, COD and O&G analyses were conducted in accordance with *Standard Methods* (APHA, 1995). Samples from sampling points were taken in each treatment plant where the sludge thickness was determined before and after the products were used.

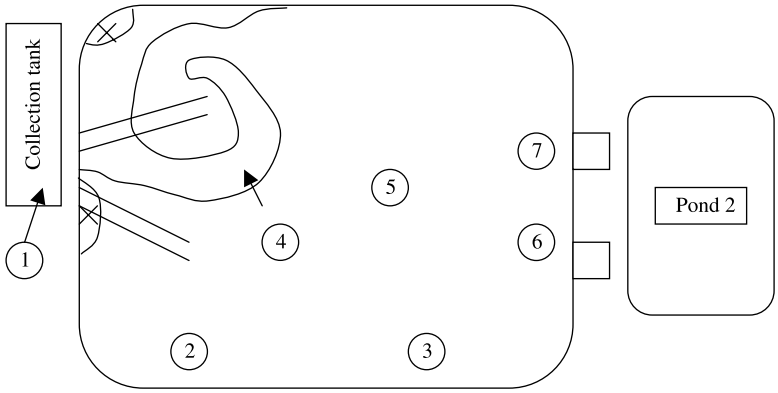

Figure 2 Bio-C and Was-D dosage places in STP

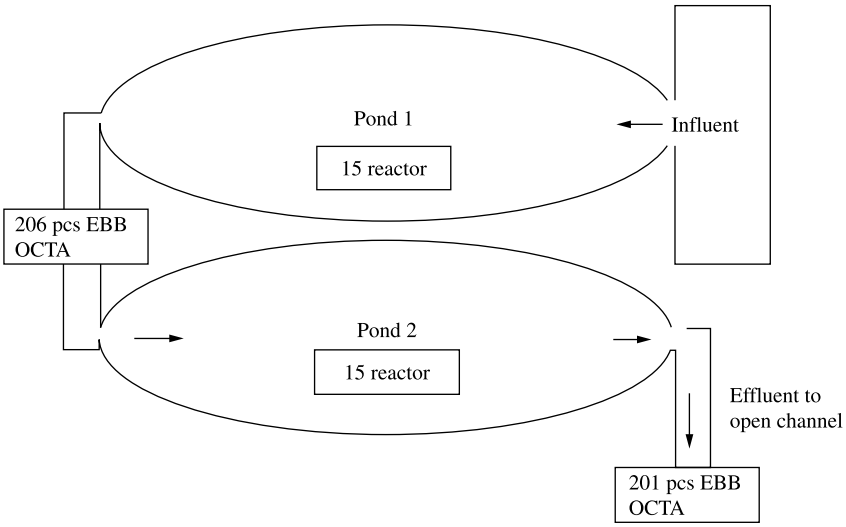

Figure 3 Eco-B applying at STP

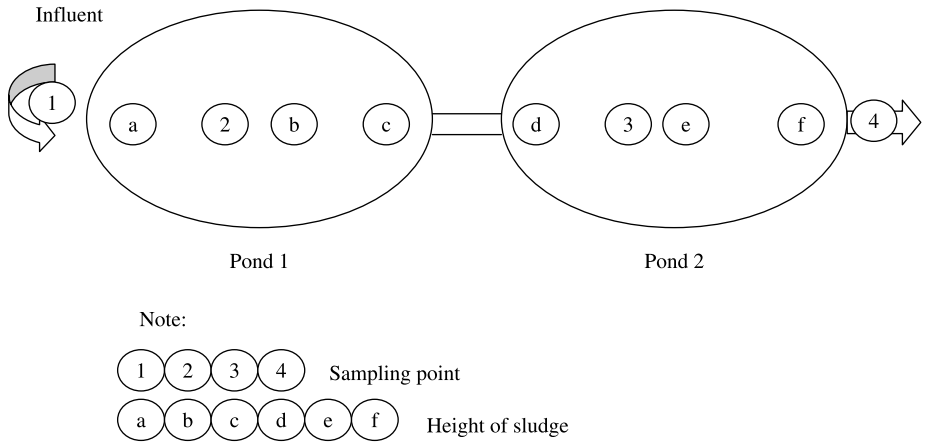

Figure 4 Sampling point for wastewater quality

Results and discussion

This case study highlighted some interesting aspects of STPs rehabilitation and their operation in justifying the effectiveness of the products. In some cases, these results could have been foreseen on the basis of the effectiveness of the products and system operation. In other cases, the results were quite surprising initially, but could become clear after a detailed consideration of the whole data had been analysed. Analyses were carried out by comparing the results with the standards in the Environmental Quality (Sewage and Industrial Effluents) Regulations 1979 of EQA 1974. The standards set governed the effluent contents flowing into the natural water system.

Referring to Table 2, the results of all organic matter were in compliance with the Requirement of Standard A and Standard B of Environmental Quality Act 1974. The concentration of SS did not fulfill Standard A at the initial stage/before the treatment; however, Standard B was fulfilled for all biochemical products after applying products (after treatment periods). As for the values of SS, it could be observed that all biochemical products do degrade suspended matter although scum build-up was observed floating at the upper side of the pond. This resulted in increasing SS values during the days 12 and 15 in the effluent. Normally, rising SS indicated the deterioration of wastewater quality and sometimes gave a bad impression. However, it was observed that all products were capable of degrading the sludge. The sludge was biodegraded in the liquefaction process (acid fermentation) of anaerobic treatment. These treatments could actually capture the pollutant in the STP, such as BOD, COD, and O&G, and also reduced the scum in the pond (Strata Bioremedial, 2003). Similarly, the concentration of BOD and COD fulfilled Standard A after treatment. However, the concentration of O&G only complied with the Standard B requirement after treatment.

Table 2 Comparison of parameters between STP and Standard A and Standard B Malaysian Environmental Orders, 1979

Parameters	Bio-C		Zeolite		Eco-B		Was-D		Standard	
	Before	After	Before	After	Before	After	Before	After	A	B
SS	53.4	8.0	55.0	10.0	138.0	6.9	102.5	20.5	50	100
BOD	31.4	6.7	21.4	20.2	24.3	12.0	52.9	25.7	20	50
COD	62.4	15.3	38.7	36.8	222	39	246	62	50	100
O&G	936.3	10	94.3	9.5	27.2	5.6	100.8	10	ND	10

Note: All values are in mg/L

Comparison of percentage removal

For this study, the monitoring program and sample collection were carried out according to the schedule of each product. Table 3 shows the average percentage removal from each biochemical product used in this study. Based on the results, Bio-C product was better than the others, and this could be seen from the BOD_5, COD and AN results, where the percentage values were high. However, for other parameters, such as O&G and P, better results were achieved by Was-D while for SS, Eco-B gave a better performance. From these data, it can be explained that Bio-C product was effective in assisting the performance of the STP. These results clearly indicated that the amount of microorganisms in the biochemical products were capable of degrading the organic matters into simple molecule or stable compound (Shikoku Chemicals, 1999).

All products were designed or formulated to provide efficient bacterial growth for biodegradation (Bio-C, Eco-B and Was-D) and ion exchange and adsorption (Zeolite) of some parameters, according to the claims made by each of the manufacturers. The system treats the polluted water naturally without the use of chemical and reduces the level of BOD, COD, ammonia, organic matter, SS and other pollutants present in STP. The system also eliminates the bad odour present in STP. Table 4 shows a comparison of results between the parameters as claimed by the manufacturers and those obtained during the application of the biochemical products at the STP. For the BOD concentrations, satisfactory results were established for all the biochemical products and similar conditions were also noted for the COD values. As far as the BOD and COD removal, good removal efficiencies were achieved by Bio-C product as compared to the other products. Based on the SS result, the claim made by Was-D and Eco-B was found to be successful, but not for the other products, Zeolite and Bio-C, where the the obtained results did not achieve what was claimed.

Table 3 Percentages removal of each biochemical product

Parameter (%)	Products			
	Bio-C	Zeolite	Was-D	Eco-B
BOD_5	73.1	58.0	70.6	65.5
COD	65.5	46.2	63.2	65.1
SS	17.1	32.2	68.1	69.3
O&G	24.2	56.5	82.4	76.4
AN	46.4	31.0	37.2	40.7
P	55.3	65.5	74.8	52.7

Table 4 Claims and results from each biochemical product

Parameter	Products							
	Bio-C		Zeolite		Was-D		Eco-B	
	Claims	Results	Claims	Results	Claims	Results	Claims	Results
pH	–	–	*	√	*	x	–	–
BOD_5	*	√	*	√	*	√	*	√
COD	*	√	*	x	*	√	*	√
SS	*	x	*	x	*	√	*	√
O&G	–	–	*	√	*	√	*	√
AN	*	x	*	x	*	x	*	X
P	*	√	*	√	*	√	*	√
Odour	*	√	*	√	–	–	–	–
Heavy metals	–	–	*	x	–	–	–	

Note: √: successful, more than 50% removal; *: claims; x: unsuccessful; –: no claims

Successful results were achieved for the O&G claims from three products (Zeolite, Eco-B and Was-D) and the best result was found for Was-D. For the AN concentration values, all parameters did not fulfill their claims, and the percentages removal were lower than 50%. However, for the P concentration, all of the biochemical products successfully achieved good removal with Was-D giving the highest removal. Based on the odour results, Zeolite and Bio-C successfully reduced the odour present in the STP. Although Zeolite was purported to be capable of removing heavy metals, the results obtained indicated otherwise.

Based on the results of the study, it could be concluded that:

- For Bio-C, only four parameters were successful out of six parameters claimed, however the best results obtained were for the BOD and COD concentrations.
- For Zeolite, there were five successful out of nine parameters claimed.
- For Was-D, five out of eight parameters were successful.
- For Eco-B, five results are successful and only one failed.

Comparison of costing

The cost for all of the biochemical products used in the study were calculated based on the optimum BOD_5 dosages. Comparison on the costing between the products was carried out to determine the most cost-effective product. The costing calculated is shown in Table 5.

The assumptions made during the calculation are:

1. the discharge of wastewater is through the STP
2. the dosage of biochemical products is determined by the manufacturers

The results described that the costing for Bio-C product was lower than that of Was-D products. However, based on the quality of effluent achieved during the study, Was-D was found to yield much better results than Bio-C. As for the other two products, Zeolite and Eco-B, the results obtained could not be quantified due to insufficient or no data available on the quantity of the products. Besides, these calculations were used for the products in liquid form, whereas Zeolite and Eco-B products were in solid form.

Table 6 lists the costing obtained from the product manufacturers. From the statistical data of the treatment analysis (Table 7), it is shown that the Was-D product gave a better result as compared to the other products. Similarly, based on the costing, the cost of Was-D was found to be the cheapest. However, the treatment of Was-D product was not quite effective because the Was-D products have to be applied every day for 30 days.

Table 5 The costing calculated based on optimum dosages of BOD_5

No	Biochemical products	Cost for 1 year (RM)
1.	Bio-C	126,720
2.	Zeolite	13,500.00 (Manufacturer)
3.	Was-D	242,360.00
4.	Eco-B	56,67.500(Manufacturer)

Table 6 The calculation of cost base on manufacturer

No	Biochemical products	Cost from Manufacturer
1.	Bio-C	19,320.00
2.	Zeolite	13,500.00
3.	Was-D	10,000.00
4.	Eco-B	56,675.00

Table 7 Analysis co-variance

Products	Prices	Parameter (%)						Band score
		SS	BOD	COD	O&G	AN	P	
Bio-C	19,320[2]	17.1[1]	73.1[4]	65.5[4]	24.2[1]	46.4[4]	55.3[2]	18
Zeolite	13,500[3]	35.2[2]	58.0[1]	46.2[1]	56.5[2]	31.0[1]	65.5[3]	13
Was-D	10,000[4]	68.1[3]	70.6[3]	63.2[2]	82.4[4]	37.2[2]	74.8[4]	22
Eco-B	56,675[1]	69.3[4]	65.5[2]	65.1[3]	76.4[3]	40.7[3]	52.7[1]	17

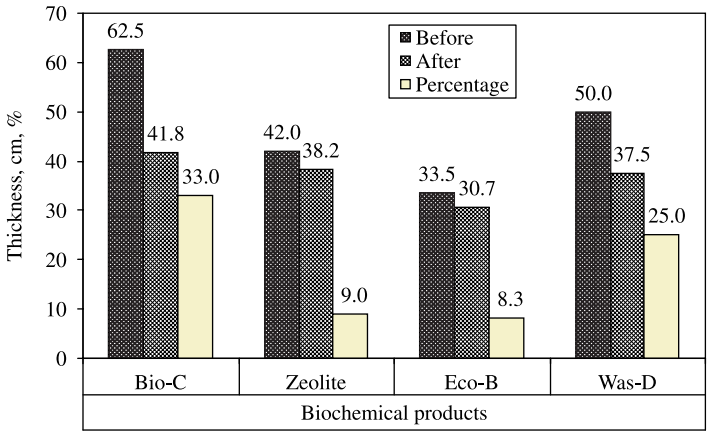

Figure 5 Sludge thickness profiles

Comparison of sludge thickness

Figure 5 illustrates the sludge thickness characteristics for the four biochemical products. This figure shows the average values of sludge thickness before and after treatment. The percentage reduction is also shown in the figure, it can be seen that the results obtained using the Bio-C product are better than the others. The percentage reduction for the sludge thickness using Bio-C product decreased up to 33% within the treatment periods.

Conclusions

The concentration for all parameters analysed for all biochemical products fulfilled Standard B under the Malaysian Environmental Orders (Sewage and Industrial Effluents), 1979. Percentages of COD were found to reduce by more than 50% after applying biochemical products. O&G and SS could be reduced by adding/applying the biochemical products. The sludge thickness values were eventually reduced after treatment. Based on the comparison of the percentage values, the Bio-C product was found to give better results than the other products. In short, the Bio-C product has the potential in assisting the performance of the STP. As for the SS, phosphorus and O&G removal, Was-D provides a better choice. The choice of biochemical products to be employed is largely dependent on the nature of waste parameters to be removed.

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