Experimental Investigation of Eco-enzyme and Its Application for Removal of Foul Odour and Organic Impurities

AnoopNarain Singh, Anil Kapoor, and Maaz Allah Khan

1 Introduction

Fifty years ago, the world was facing a shortage of food grains and people in several developing countries were dying. At that time, the need of the hour was to save the people dying of hunger. The green revolution came and saved the day. Today, the environment has occupied prime focus due to pollution, which leads to climate change. The root cause of this pollution – higher temperature and climate change – is the generation of gases like methane and other toxic material, leading to spread of foul odour. However, least attention is given to this challenge. Municipal Corporations and Civic Bodies are struggling to remove the foul odour in drains, garbage dump yards, water bodies, meat and fish markets, public toilets, STPs/ETPs, etc. Partly, it was ignored because no remedy was available until now. Sewage water flows into drains and merges into rivers, ponds, and lakes. Garbage is dumped into landfills, rivers, and ponds. As a result, methane and other toxic gases are formed. Methane in its pure form does not create any foul smell. However, when mixed with other gases, it emits foul odour. It is a silent killer, polluting the area. News reports appear every other day about the deaths of sweepers when they enter the sewage drains, due to the formation of H_2S, methane, and toxic gases. Even electric and electronic appliances are affected and costly bathroom fittings are corroded due to toxicity of the emanating gases.

A. Singh
Rajkiya Engineering College, Azamgarh, Uttar Pradesh, India

A. Kapoor
The Art of Living International Centre, Bengaluru, India
e-mail: anilkapoor@ssrdp.org

M. A. Khan (✉)
Maharishi University of Information Technology, Lucknow, Uttar Pradesh, India

S. Awasthi et al. (eds.), *Sustainable Computing*,
https://doi.org/10.1007/978-3-031-13577-4_7

In this paper, effort has been made to highlight the methodology to reduce foul odour all around. In the last 3 years, we had conducted several experiments to reduce foul odour and stench emanating from different places. The indigenously made eco-enzyme was applied in diluted form in different proportions and observed that foul smell was greatly reduced, giving relief to the local populace. In the experimental investigation, the eco-enzyme is used for bio-remediation. It is an enzyme, produced by fermentation of raw kitchen waste. It is the application which makes it innovative and effective to remove foul smell. Also some laboratory results are presented which show the ability of the eco-enzyme to reduce organic impurities at a faster rate. Microbes and enzymes have a very close relationship. Microbes such as bacteria, fungi, algae, protozoa, and viruses are living organisms essential for life on the planet. Most of the microbes are harmless. They are essential for the cycling of nutrients in the eco-systems of the planet. Microbial activity is used for the benefits of human kind such as production of medicines, food, enzymes, cleaning up of sewage and other waste, etc. There are about 4000 types of enzymes and not even 10% of these have been identified. The exact functioning of enzymes is still an area of ongoing research. Enzymes are catalysts and promote the activity. These are classified for food, pharma, textile, paper, wastewater industries, etc. Enzymes fall under six classes according to their functions:

1. Oxidoreductases – oxidation
2. Transferases – transfer groups
3. Hydrolases – hydrolysis
4. Lyases – hydrolysis and oxidation
5. Isomerases – conversion into single molecule
6. Ligases – joining the molecules

Enzymes are classified based on their target substrates:

1. Proteases split proteins into amino acids
2. Lipases split fats into fatty acids and glycerol molecules
3. Amylases split carbohydrates such as starch and sugar into simple sugar such as glucose
4. Celluloses break down cellulose

Pollutants consist of various combinations of carbon (C), nitrogen (N), hydrogen (H), oxygen (O), sulphur (S), and other elements like CH_3, C_2H_5, H_2S, SO_2, NO_2, and NO_3. These pollutants serve as food for the microbes that eat away the solid material in the polluted water or dump yards and break down the pollutants and discharge free radicals of C, N, H, O, S, etc. The results indicate that the garbage enzyme can remove ammonia nitrogen and phosphorus in wastewater dilutions [1–3]. The BOD and COD values of the grey water were reduced significantly [5]. It is effective in aerobic as well as anaerobic conditions.

Dr. Rosukon P [4] of Thailand has developed a very innovative enzyme called garbage enzyme or eco-enzyme, a complex eco-enzyme produced by fermentation

of raw kitchen waste (fruit and vegetable peels), sugar (brown sugar, jaggery, or molasses sugar), and water. Since it is made of different vegetables and fruits, it contains different types of enzymes.

Generally, enzymes are available in the market cultured from one plant. Therefore, it can break down one type of pollutant, but this eco-enzyme has the property to break down pollutants of all types present in wastewater due to the presence of multiple types of enzymes. When it is diluted 1000 times in water (1 l of biosolution in 1000 l of water) and kept overnight, microbes multiply and become innumerable.

This eco-enzyme helps to produce a sustainable and pollution-free environment [5]. Microbes are used to meet effectively the crisis in both environment and energy sectors [6–15]. When such a large work force is employed, it speeds up the bioremediation process. Best results are visible from the 5th day onwards. The question that comes to mind is that such a large force may be harmful, wherever it goes. The answer is that the life span of these microbes is 5–6 days. If multiplication is there, depletion process is also at work. Nature balances the process. This is the cheapest technology available at the moment. One of the main concerns is whether this eco-enzyme is safe to use in water bodies. Bioassay test (Fish survival test) conducted by NABL-verified lab shows that it is safe to use this eco-enzyme and it does not harm aquatic life.

2 Materials and Methods

Eco-Enzyme was prepared by putting jaggery, kitchen trash (orange peels, green pea peels, etc.) and water in a weight ratio of 1:3:10 (100 gm jaggery, 300 gm peels, 1000 ml). The mixing was done in an expandable airtight plastic container. During the first month of the fermentation process, gases were emitted. To avoid bursting, the container's pressure was released on a daily basis. Every now and again, orange peels were pushed below. The container was stored somewhere cool, dry, and well ventilated. To manufacture enzyme, it was fermented for 3 months. The solid particles were removed from the brownish liquid produced by the fermentation. After 3 months, the fluid was filtered to get the enzyme solution. On the top surface of the solution, a white mould development was noticed. B complex yeast and vitamin C yeast are two examples. The enzyme solution obtained was pale brownish yellow in colour. The liquid was then poured into a plastic bottle. Enzymes have no expiration date. It gets stronger the longer you keep it. When water is introduced to the enzyme, its strength is increased. Garbage Enzyme can only be used externally. It should not be kept in the fridge. The features of pure Garbage Enzyme solution were investigated immediately after the enzyme solution was filtered (after 3 months of fermentation period).

3 Results

Results are presented in two sections, first section presents laboratory results which analysed the ability of eco-enzyme for reduction of solids and organic impurities and second presents field results which shows its ability in reducing foul smell and organic impurities from lakes, water bodies and dump yards.

3.1 Laboratory Results

The goal of this research is to use enzymes in wastewater treatment to reduce organic pollutants. As a result, processes for preparing fruit enzyme and conducting laboratory tests must be designed and carried out throughout the investigation. This research begins with the production of fruit enzyme, which takes 3 months. Following that, water samples are taken from various locations for laboratory testing and wastewater classification. The study's findings are based on laboratory testing of samples after enzyme treatment.

3.1.1 Sample Collection

Sewage was collected from the end of an open drain and from a manhole at Krishna Engineering College (KEC), Mohan Nagar, Ghaziabad, India. The samples were collected in the morning at around 10 a.m. (Fig. 1).

The water quality indicators were observed and the water quality condition was classified in a laboratory test. BOD, TDS, Ph, Conductivity, and Turbidity were measured in both raw and processed wastewater. The raw wastewater and the treated wastewater were compared.

Table 1 shows the parameters of pure garbage enzyme solution after 3 months of fermentation (immediately after enzyme solution filtration) and 60 days of filtration.

The characteristics of pure wastewater is given below in Table 2.

Characteristics of effluent following treatment with garbage enzyme solutions containing 5%, 10%, 20%, and 25% (60 days after filtration).

The wastewater was treated with garbage enzyme solutions containing 5%, 10%, 20%, and 25% garbage enzyme. Thereafter, they were left to digest. pH, TDS, BOD5, ammonia nitrogen, and phosphorus levels were all measured.

After 5 days of digestion, the effluent met the irrigation standards (as per E(P) guidelines). Table 3 shows the effluent properties following treatment with 5%, 10%, 20%, and 25% trash enzyme solution after 5 days of digestion. Table 4 shows the percentage reduction of several parameters following treatment with 5%, 10%, 20%, and 25% trash enzyme solution after 5 days of digestion.

According to the findings of the study, garbage enzyme solution is not suited for treating wastewater immediately after filtration. With time, the enzyme properties

Fig. 1 Sewage collection point at manhole, KEC

Table 1 Characteristics of pure garbage enzyme solution

Parameter	After immediate filtration	After 60 days of filtration
pH	2.85	3.8
TDS	2216	1130
BOD	1250	90.5
Ammonia	BDL[a]	BDL[a]
Phosphate	BDL[a]	BDL[a]

[a]Below detectable limit

Table 2 Characteristics of pure waste water

Parameters	Unit	Value
pH	–	6.15
TDS	mg/lit	525
BOD	mg/lit	192
Ammonia	mg/lit	9.6
Phosphate	mg/lit	115

Table 3 Effluent characteristics after 5 days of digestion

Parameters	5%	10%	20%	25%	Irrigation standards
pH	6.9	6.6	6.4	5.8	5.5–9.0
TDS (mg/lit)	258	233	410	532	2100
BOD (mg/lit)	78	68	91	96	100
Ammonia(mg/lit)	0	0	0	0	–
Phosphorus(mg/lit)	0	0	0	0	–

Table 4 Percentage reduction of various parameters

Parameters	5%	10%	20%	25%
pH	–	–	–	–
TDS (mg/lit)	54.55	58.80	27.19	5.51
BOD (mg/lit)	61.46	65.44	54.51	49.51
Ammonia(mg/lit)	100	100	100	100
Phosphorus(mg/lit)	100	100	100	100

changed. When the treatment was done 60 days after the enzyme solution was filtered, the treatment was effective.

3.2 Field Results

We have achieved unique success in removing foul smell from drains, ponds/lakes, STPs/ETPs, garbage dump yards, etc., in 3–20 days. In the last 3 years, we have applied it in drains, rivers, ponds, STPs/ETPs, public toilets, slaughter houses, garbage bins, etc. to eliminate foul smell, reduce BOD, COD, increase DO level, contain methane and other toxic gases. We have reclaimed land of dump yard at Ghaziabad, U.P., India. Leachate oozing out of dump yard is another problem since it emits terrible odour. Removed its foul smell and broke its combination. Results of the studies obtained at different location/site in India are as given below:

3.2.1 Barapullah Drain, Delhi (16 February to 9 March 2016)

The Art of Living organized World Cultural Festival near Sarai Kale Khan, Delhi in March, 2016. Barapullah Drain passes along the venue before merging into Yamuna River. It starts from Ashoka Hotel in New Delhi and the drain water is not very polluted. The drain passes through Lakshmi Bai Nagar, Defence Colony, Lajpat Nagar, Kale Khan, etc., and reached Sun Dial area before merging into Yamuna River. In between, there are several colonies and slum areas from which untreated sewage water and discharge from commercial establishments join in the drain. It contains harpic, cleaning agents, soap and detergents, grease and oil, etc., converting them into pollutants and toxic material. The drain is partially covered with concrete slabs, but when it opens up near Defence Colony area, it blows out methane and other toxic gases and emits a pungent odour. The problem continues further aggravating the situation until it merges into Yamuna River. Since a large number of dignitaries around the globe and foreigners were expected to attend the function, it was decided to remove foul smell through this eco-enzyme. It was poured into the drain for 15 days from 16 February 2016 at the rate of 200 l per day in concentrated form because it gets diluted into the drain immediately. From the 5th day onwards, foul smell started disappearing and by March 10, it completely disappeared and the

Fig. 2 Barapullah drain near Sun Dial, Kale Khan, Delhi – highly toxic

Fig. 3 View of drain before the treatment

event passed off well without any inconvenience to the foreigners, dignitaries, and audience (Figs. 2, 3, and 4).

3.2.2 Drains at Pune

Four rivers, namely, Mula, Mutha, Ram Nadi, and Pavana, flow through Pune city. Indrayani is another river flowing through Pimpri Chinchwad area and merges into Pavana River. Most of these rivers are now sewage drains as the discharge from

Fig. 4 View of drain after the treatment

households and industries goes into them. Pimpri Chinchwad is the industrial belt and big giants like Tata Motors, Mahindra & Mahindra, Bajaj Auto, Volkswagon, etc., are located there. There are 27 drains which carry polluted water and merge into Indrayani River. We decided to clean these drains and approached Pimpri Chinchwad Municipal Corporation (PCMC) with the request to allow us to conduct the treatment and clean the wastewater of these drains. PCMC allowed us to conduct trial on two drains carrying polluted water into Indrayani River. Three drums were installed on two drains with 5 l of eco-enzymes in the each drum diluted with about 1000 l of water and kept overnight. Next day, it was poured. Treatment was conducted from 2 to 19 May 2017. The eco-enzyme was poured for 12–14 h. Sampling was done by PCMC lab and it was found that the polluted water in the drain improved greatly with reduced COD and BOD levels after the treatment with the eco-enzyme within 17 days. COD content reduced from 272 mg/lit to 56 mg/lit in one drain and BOD from 105 mg/lit to 22 mg/lit. In the second drain, COD content reduced from 260 mg/lit to 40 mg/lit and BOD from 95 mg/lit to 20 mg/lit. Details are as given in Table 5.

3.2.3 Sanjay Park, East Delhi

Sanjay Lake is located in over 50 acres in Trilokpuri of East Delhi. It is a beautiful water body with beautiful pathways and GYM facilities. However, the administration is struggling to remove foul odour in the lake. It is under the control of Delhi Development Authority which allowed (August, 2017) us to treat with eco-enzyme. Central Pollution Control Board (CPCB) was also associated in the

Table 5 TSS, COD, BOD levels before and after treatment at PCMC drains (Pune)

		Parameters		
Location	Date	TSS mg/lit	COD mg/lit	BOD mg/lit
Near Symbiosis College, Kiwale	2 May 2017 (before treatment)	105	272	105
	19 May 2017 (after treatment)	5	56	22
Dehu Rear Pump House, Kiwale	2 May 2017 (before treatment)	28	260	95
	19 May 2017 (after treatment)	5	40	20

Table 6 COD, BOD levels before and after treatment at Sanjay Park, East Delhi

	Parameters					
Sampling date	Location	pH	COD mg/lit	BOD mg/lit	E-Coli	Total plate counts
07 Nov. 2017 (before treatment)	Near entry gate	7.84	83	25	Present	1.2×10 (5)
07 Nov. 2017 (before treatment)	Near tubewell	8.27	55	16	Present	1.4×10 (5)
23 Nov. 2017 (after treatment)	Sanjay Lake	7.68	78	21	Absent	1.6×10 (4)

project for conducting tests of water before and after the treatment. Two tankers of 30,000 l were engaged and 300 l of the eco-enzyme was added in each tanker and kept overnight to develop and multiply the microbes. Diluted 60,000 l of eco-enzyme was poured into the lake for 5 h on 8 Nov. 2017. CPCB and Sigma NABL Laboratory took the samples to measure the COD, BOD, and other parameters on 7 Nov. 2017. Again, the samples were drawn on 23 Nov. 2017 to compare the results of treatment.

The results of Sigma NABL Lab showed reduction in COD and BOD levels and increase in DO level. The most important change was elimination of E-Coli in the lake after treatment. Within a month, foul smell disappeared and the water became cleaner. Ducks and migratory birds, which hardly entered the lake water, are seen venturing into the lake more frequently.

Details of water quality parameters before and after treatment of sample at Sanjay Park are given in Table 6.

3.2.4 Ponds in Chennai

We are treating 108 ponds in Chennai. First pond was treated in Semmencherry Karunachaved, Chennai, on 10 June 2017. Before treatment, grey algae existed in the pond, which disappeared after 45 days as visible in Fig. 5.

Before Treatment with the Eco-enzyme (10 June 2017) and After Treatment (3 Oct. 2017) (Fig. 6).

Encouraged with the results, Greater Municipal Corporation sought our assistance to save fishes that were dying in Temple Pond at Sengeiamman Temple Pond,

Fig. 5 View of water body after the treatment at Sanjay Park

Fig. 6 View of pond water before and after the treatment at Semmencherry Karunachaved, Chennai

Table 7 DO, COD, BOD levels before and after treatment at Neelankarai, Chennai

	Parameters		
Sampling date	DO mg/lit	COD mg/lit	BOD mg/lit
28 September 2017 (before treatment)	0.13	195	57
4 October 2017 (after treatment)	2.80	72	19

Off East Coast Road, Neelankarai, Chennai, after they saw positive treatment results in other ponds in Chennai. Eco-enzymes solution (50 l) was poured in the water tanker (5000 l) and kept overnight. The treatment was done in the lake on 28 Sept. 2017. NABL tests were conducted on samples of pond water taken before treatment on 28 Sept., and after treatment on 4 Oct. 2017. Fishes had died in this pond because DO level reduced to 0.13 mg/lit and the water was polluted as shown by high COD and BOD contents. The results showed significant improvement in 6 days. DO level increased to 2.8%, which was the main reason for survival of fishes. The detail of DO, BOD, COD levels before and after treatment at Neelankarai, Chennai, is given in Table 7 (Fig. 7).

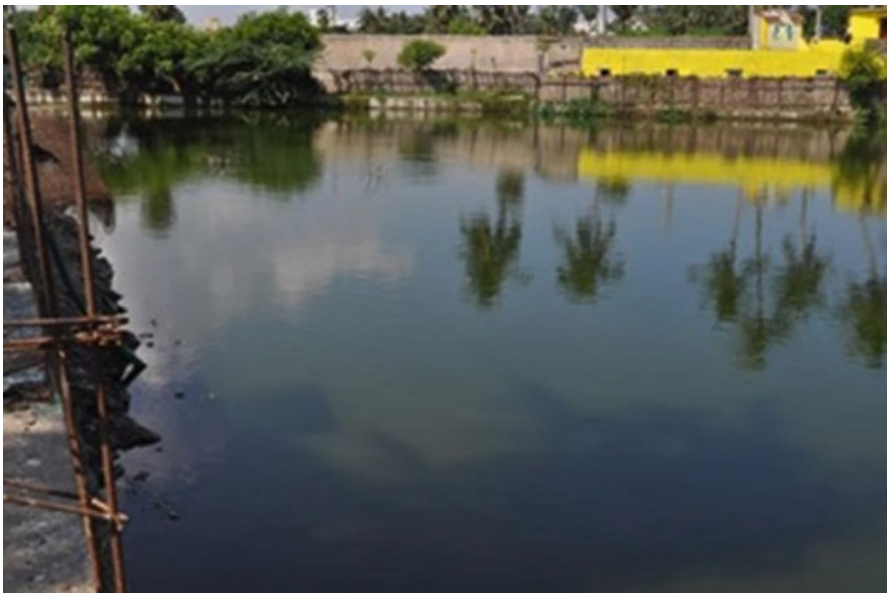

Fig. 7 View of pond water after treatment at Sengeiamman Temple, Neelankarai, Chennai dated: 2/10/2017

3.2.5 STP at Chandigarh

Eco-enzymes were tried on an STP in Trishala Residential Complex at Zirakpur near Chandigarh. 5 l of eco-enzymes were diluted in 100 l of water and poured daily for 20 days from 18 May to 5 June 2017. Foul smell disappeared from the discharge of STP water and significant fall was noticed in COD and BOD levels. COD level reduced from 404 mg/lit to 53 mg/lit and BOD from 149 mg/lit to 23 mg/lit.

3.2.6 Drains of Azamgarh City

Figure 8 shows the application of eco-enzyme trickling in a drain through a tank. We have achieved success in removing foul smell from the open drain of Azamgarh city, going through the main market of Mukeri ganj area and creating nuisance and discomfort for the people.

3.2.7 Garbage Dump Yard at Ghaziabad, UP

Foul smell, methane, and toxic gases are prevalent in garbage dump yards. It used to frequently catch fire and there was smoke from the dump coming out. A trial was conducted on a 4-acre dump yard near Haj House at Ghaziabad on 4 Jan. 2017 using

Fig. 8 Application of eco-enzyme at sewage drain (Mukeri ganj Nala, Azamgarh)

diluted bio-solution eco-enzymes in the ratio 1:1000 and kept overnight. Foul smell went off the same day and bio-degradable material vanished within 15 days. Only polythene, plastic, and cloth were left which were also removed later on. The land of the dump yard has been reclaimed (Figs. 9 and 10).

Fig. 9 Mayor inspecting the site during treatment with eco-enzyme, paper, cloth, and polythene left out

Fig. 10 View of reclaimed land

3.2.8 Two Garbage Dump Yards at Dehradun (Uttarakhand)

Foul smell was a problem in the Trenching Ground dump yard at Dehradun and agitation was going on by the residents surrounding the dump yard. Eco-enzyme (10 l) was kept in 10,000 l (Dilution ratio 1:1000) water tanker overnight and treatment was conducted on 6 April 2017. The foul smell disappeared within no time and those agitating were satisfied and testified to continue the treatment (Fig. 11).

Fig. 11 Eco-enzyme treatment at dump yard, Dehradun

Fig. 12 Akola dump yard before treatment (15 Aug. 2017)

3.2.9 Garbage Dump Yard at Akola (Maharashtra)

Foul smell, mosquitoes, and flies in Akola Dump Yard were also a problem as the population residing in the surrounding areas was protesting. A section of the dump yard was treated with the eco-enzyme (dilution ratio 1:1000, kept overnight in the tanker) on 15 August 2017. In 15 days, the size of the dump yard has reduced by 3.5 ft and foul smell and mosquitoes and flies have reduced. Now Akola Municipal Corporation has given us permission to manage the whole dump yard spread over eight acres (Figs. 12 and 13).

The results of experiments are based on trials conducted on ponds, drains, STP, and garbage dump yards. Methodology is dilution of eco-enzyme in the ratio 1:100–1000 and process is bio-remediation. The effectiveness of the process is with correct

Fig. 13 Reduced to height by 3.5 ft (30 Aug. 2017)

application, proper dilution and pouring or spray. In ponds, when it is poured once in a quarter (3 months), it is found that grey algae disappear in 45 days, DO level increases and COD/BOD reduces in the polluted water in 5–20 days.

In drains, the treatment is required to be done continuously because the polluted water is always coming from upstream. The enzyme flows down and its effectiveness is visible 3–5 km downstream. Foul smell and COD/BOD levels are reduced. The longer the treatment in the drains, the better the results obtained. Same is the case in STPs because of the continuous inflow of sewage water and sludge into the STP tank.

As regards garbage dump yards, methane and toxic gases are formed which produce foul smell due to the presence of bio-degradable material. It often catches fire. The spray of bio-solution prevents the formation of methane and other toxic gases. Like water, bio-remediation process takes place and the microbes eat away the solid waste. It results in reduction in size of the dump yard. The process is more effective in dump yards which have more bio-degradable material and slow where inert material (construction waste) is more.

4 Conclusions

According to the findings of the study, garbage enzyme solution was not adequate for treating wastewater immediately after filtering. The features of the enzymes

changed over time. The enzyme solution is more concentrated than previous concentrations. The treatment time was also cut to 5 days. It's important to keep track of how enzyme properties change over time. Only once the BOD levels of the enzyme solution are reduced is wastewater treatment with garbage enzyme solution shown to be effective. More research is needed to determine the effects of appropriate additives or activators on enzyme function. For reduction of high initial BOD and COD, studies on pre-treatment approaches prior to enzyme action should be investigated. More importantly, determining the components of the trash enzyme is a crucial step.

Our studies are based on ground-level work and trials conducted. The technology is very effective in removing foul odour, reducing BOD, COD levels, increasing DO level in polluted water of drains, rivers, and ponds, improving air quality and overall improvement in the environment. In dump yards also it is equally effective in removing foul smell, curtailing the formation of methane and other toxic gases, reducing bio-degradable material. Results are achieved in shortest possible time of 5–25 days. It is the cheapest solution available cost-wise. 1 l of bio-solution can clean one lakh litres of polluted water. 3 l of eco-enzyme in 3000 l can treat one acre of dump yard of 1 m height. Bio-remediation and use of enzymes are not fully explored and more research work needs to be done.

Acknowledgements We drew our inspiration from H.H. Sri Sri Ravi Shankar Ji and express our gratitude to Him for guiding us in our work and giving us strength and confidence to continue with our mission. Also we convey our sincere thanks to Dr. Rosukon P of Thailand for guiding us on the technology and its application.

References

1. Manual of Municipal Solid Waste Management, (2016), Central public health and engineering organization, Swachh Bharat Mission, Ministry of Urban Development, Govt of India, www.moud.com. Part II, p. 126
2. F.E. Tang, C.W. Tong, A study of the garbage enzyme's effects in domestic wastewater, World Academy of Science, Engineering and Technology. Int. J. Environ. Chem. Ecol. Geol. Geophys. **5**(12), 892 (2011)
3. C. Arun, P. Sivashanmugam, *Waste management, Journalhomepage*: www.elsevier.com/locate/wasman 44, p. 28–33 (2015)
4. www.enzymesos.com
5. F. Nazim, V. Meera, Bonfring, Treatment of synthetic greywater using 5% and 10% garbage enzyme solution. Int. J. Ind. Eng. Manag. Sci. **3**(4), 111 (2013)
6. P.K. Gupta, *Elements of Biotechnology* (Rastogi Publications, Meerut, 2000), p. 4. (ISBN 0-471-65071-4)
7. Q. Yang et al., Improving disintegration and acidification of waste activated sludge by combined alkaline and microwave pretreatment. Process Saf. Environ. Protect **91**(6), 521–526 (2013)
8. R. Uma Rani et al., Low temperature thermo-chemical pretreatment of dairy waste activated sludge for anaerobic digestion process. Bioresour. Technol. **103**(1), 415–424 (2012)
9. C.H. Shu et al., Purification and partial characterization of a lipase from Antrodia cinnamomea. Process Biochem. **41**(3), 734–738 (2006)

10. M. Perle et al., Some biochemical aspects of the anaerobic degradation of dairy wastewater. Water Res. **29**(6), 1549–1554 (1995)
11. O.H. Lowry et al., Protein measurement with the Folin phenol reagent. J. Biol. Chem. **193**, 265–275 (1951)
12. A. Ayol et al., Enzymatic treatment effects on dewater ability of anaerobically digested biosocial-II; laboratory characterization of drain ability and filterability. Process Biochem. **40**(7), 2427–2434 (2005)
13. H. Abbasnejad, et al., Anaerobic treatment of dairy wastewater in a hybrid UASB and bio filter reactor
14. American Public Health Association (APHA) Standard Methods for Examination of Water and Waste Water (2005)
15. B. Prakash, How to make and use garbage enzyme (2011). http://www.ecowalkthetalk.com