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Biodegradation of plastic after UV treatment by composting using vegetable waste

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Abstract

As time is going on the rate of use of plastic is increasing and there is a big challenge before us to degrade that plastic. The plastic is durable and take much time to complete degradation. It takes about 1000 years to complete degradation in natural environmental condition. The plastic could sometimes responsible for the cause of block in digestive system of aves and mammals and also affects the seed germination in plants. When we go through the literature, there are many plastic degrading technologies are developed, but the economic and eco-friendly method could be biodegradation using indigenous microbes. The objective of this study was to isolate the plastic degrading bacteria from the Pirana municipal solid waste dumping site, Ahmedabad and use that bacteria in degradation of UV treated plastic in developed aerobic composting bioreactor. The results from the study shows the confirmation of biodegradation of plastic sample which is analysed by surface change, comparing weight loss before and after the biodegradation experiment. Finally, it could be concluded that if we disturb the physical state (i.e.by reducing molecular weight), the biodegradation rate of the plastic could be increased.

Keywords: Biodegradation, plastic, UV treatment, composting, vegetable waste.

Introduction

The generation of municipal solid waste including plastic and many other pollutants is increasing regularly because of the increasing rate of industrialisation, urbanisation and changing way of living of human beings. No doubt this development helped human beings but mismanagement also created a new problem of accumulation of solid waste and other pollutants. In the management of wastes the technical skill acquired during the last century has posed a new challenge. The hazardous content of in pollutants exert a threat on environmental and health. In all over the world the pollution created by the heavy metals from different agricultural and industrial activities have a negative effect on human health and ecosystem[1].

More than 40 years old mountain like structure of waste had been observed during this survey. At Pirana the city Ahmedabad has one main landfill site with 84 acres of land which is receiving municipal solid waste for last 20 years. Around 1,100-1.200t/day total solid waste is generated by the city. Out of this approximately 1,000t/day which is about 95% of the total solid waste generated is dumped at the Pirana landfill site, and about 50t/day solid waste consumed for the composting by the excel factory.

There are many molecular mechanisms like chemical, thermal, photo and biodegradation which are responsible for the degradation of polymer. Biodegradability of the materials can be confirmed by weight loss, tensile strength loss, changes in percent elongation and changes in polymer molecular weight. Mainly this problem of solid waste generation and accumulation pose risk to metro cities[2]. There are many factors which governs the biodegradation process like characteristics of polymer, mobility, crystallinity, molecular weight, functional groups and substituent present in its structure, and plasticizers or additives, type of organisms and nature of treatment[3].

For cleaning up contaminated soil and water, bioremediation is considered as promising and less expensive compared to other methods[5]. High molecular weight and hydrophobic nature of polythene reduces its availability to micro-organisms to use it as sole source of carbon and its resistance towards biodegradation. If the degrading microbes form a bio-film on the polyethylene surface, the biodegradation becomes more efficient. The formation of bio-film on the surface of polyethylene is inhibited by the hydrophobicity of polyethylene[6].

Hence, the study was designed to isolate microorganisms from selected areas at Pirana landfill site and to study the degradation potential of them along with organic waste supplements in aerobic bioreactor.

Methodology

Sampling area: Ahmedabad located on the banks of the river Sabarmati in the northern part of Gujarat and the western part of India at 23.03°N 72.58°E spanning an area of 464 km².

Pre-treatment of the samples: Plastic sample (Polythene sheet) collected from the sampling site were kept in the UV chamber for UV Irradiation (365nmexposure) up to 4 weeks to establish reduction of average molecular weight (*MW*) to 5000 or less[9].

The molecular weight of samples before and after UV exposure was determined by using GPC. The treated plastic samples were introduced into the aerobic composting bioreactor to assess the composting process.

Aerobic composting bioreactor: The aerobic reactor consisted of plastic boxes having 1.5(l) x 1 (w) x 1 (h) feet in dimensions with a working volume of 15-kgs (Figure 1).

Figure-1: Aerobic Composting bioreactor.

Composting material: The materials (a layer of Coconut fibres, palm tree leaves up to a 1.5-inch height and the 3-inch layer of dried leaves and 2-5 mm size vegetables waste (200 to 300g)) with aeration were included for the composting and the moisture content was maintained up to 55 to 65%. On second day of composting, the microorganisms from ambient phase changed to mesophilic conditions that lasted for about one week and then changed to thermophilic conditions.

Assessment of Aerobic Biodegradability of Plastic Materials along with organic wastes: Plastic Samples of about 10 g were degraded in active compost with sea sand at thermophilicphase (ca. 400g).

Figure-2: Addition of plastic sheet sample.

The mix bacterial culture from acclimatized collected plastic samples (from the site) was introduced in the composting reactor. After this stage the aerobic bioreactor was shifted into incubator and maintained at temperature 56 +2^{0}C for a period of 8 weeks. The composting materials were manually turned every alternate day to maintained aerobic conditions. Every week the composting reactor was fed 200 gm of vegetable waste (> 2mm size). During the aerobic composting, the temperature, C/N ratio and moisture were maintained.

Figure-3: Composting process in bioreactor in incubator.

At the end of 8 weeks, reactor was removed from the incubator and allowed composting material to stabilize and mature for a period of one week.

Film culturing and harvesting: Reaching to the 8th week of composting, the added pre-weighed plastic samples were checked, removed from the bioreactor and washed with distilled water remove adhering microbes if any and dried at 45^{o}C for 24 hours in hot air oven.

Monitoring of plastic biodegradation in reactor: The percentage of weight loss was calculated as –

$$Percentage\ of\ weight\ loss\ of\ the\ material\ \frac{Weight\ loss\ of\ the\ sample}{Original\ weight\ of\ the\ sample} x\ 100$$

Analytical methods used for characterization of developed compost from plastic biodegradation: Standard procedures of APHA (1993)[7] were followed for the various parameters analyzed. The physico-chemical and biological parameters were determined for compost characterizations. All the quantitative estimations of the micronutrients of compost were carried out using an inductively coupled plasma spectroscopy (ICP).

Results and discussion

Biodegradation of plastic wastes by using indigenous microbial culture: Molecular weight of plastic sheet sample before UV treatment was found to be 70,000 Dalton. The sample treated under UV for 4 weeks, the polymer peak has been decreased and graph result indicate that the molecular weight of sample was found to be below 50,00 Dalton. After UV treatment sample shows brittleness, loss in elastic properties and reduction in molecular weight were observed (Figure-5).

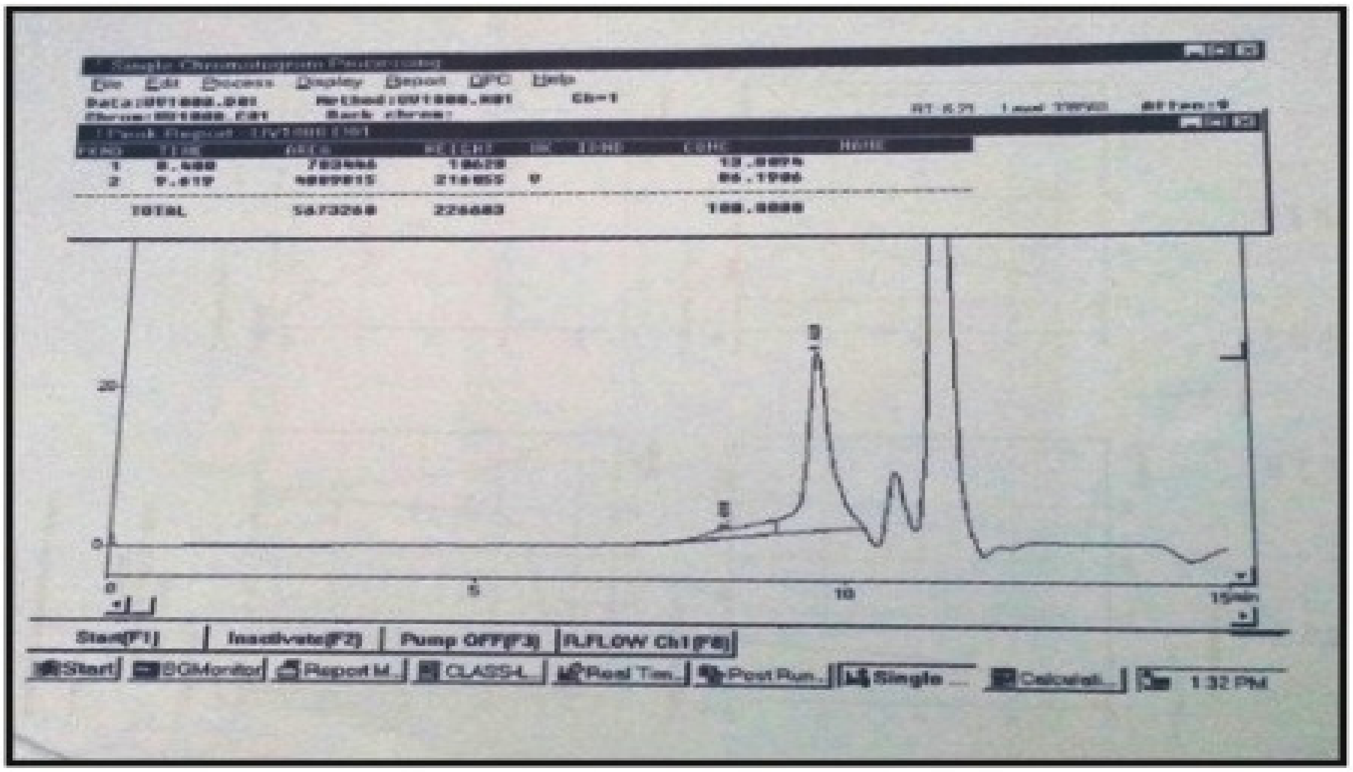

Figure-4: Molecular weight of plastic film before UV treatment is found 70000 Dalton (GPC Image).

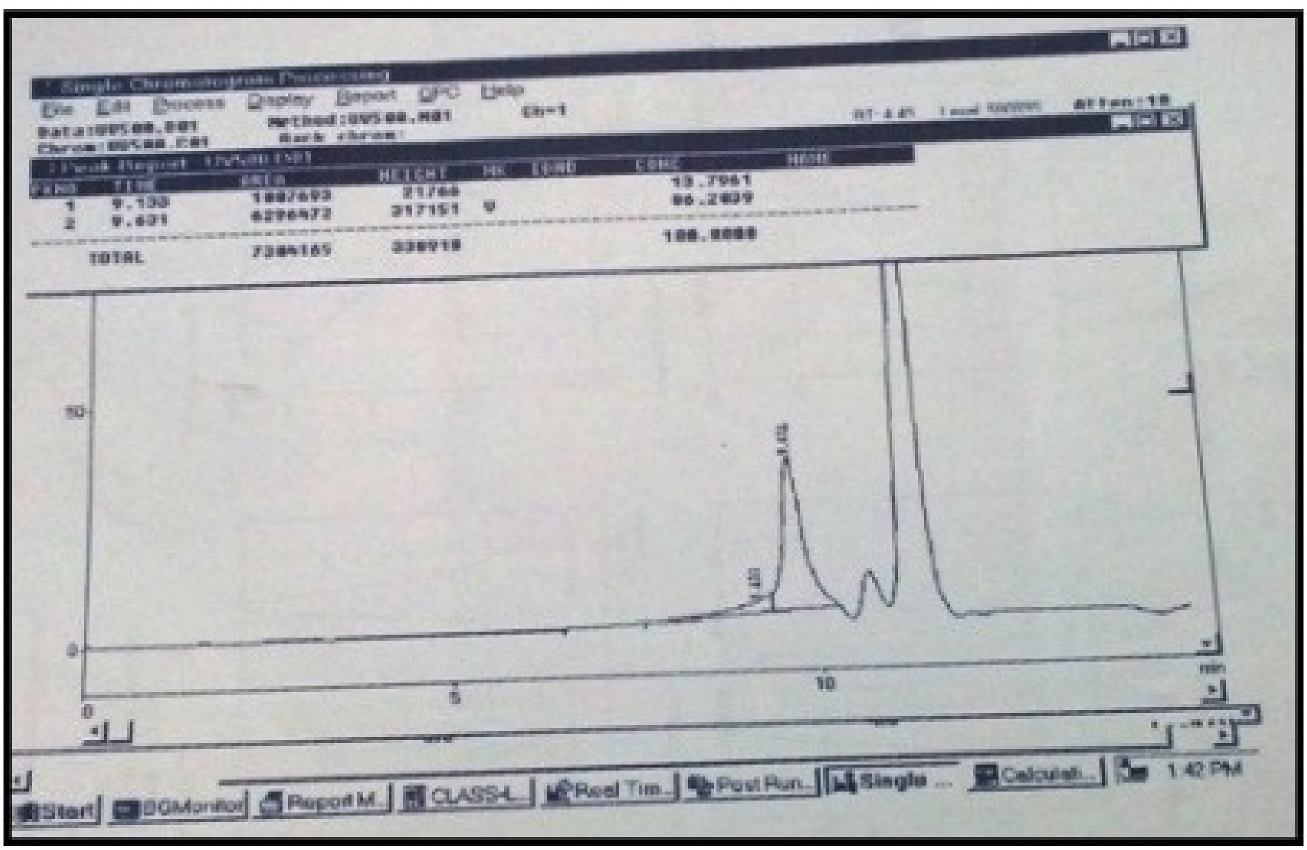

Figure-5: Showing molecular weight reduction (GPC Image).

The surface of the added plastic samples were turned to rough from smooth with visible cracks(Figure 6) .UV treated sample showed morphological changes when observed through microscope.

Figure-6: Plastic sheet sample before UV treatment.

Figure-7: Plastic sheet sample after UV treatment.

Biodegradation studies during composting process: Surface changes in plastic sample: Figures-8, 9 and 10 exhibits the surface changes observed after the degradation process. The biodegradation of polymer sample in the laboratory were conducted through mechanism which includes bio-deterioration that is occurring due to the microbial communities present in the process of composting (Figure-8).

After biodeterioration, bio-fragmentation starts in which the cleavage by enzymes released by the active microbes (Figure-9).

It is followed by assimilation and finally mineralization that leads to complete breakdown of the polymer.

The various surface changes in the samples were observed after composting. Sample showed signs of formation of bio film, puncture and brittleness (Figure-10).

Biodegradation analysis by weight loss: Biodegradation of sample was carried out with bacterial consortium isolated from dumping site. These organisms were able to degrade UV treated plastic sample under composting process at thermophilic stages and use plastic sheet as a source of carbon. At the end of 8^{th} week, pre-weighed plastic samples was collected, washed and analyzed for biodegradation/weight loss as mentioned in the methodology. The samples started becoming brittle, as the exposure time progressed. The initial weight gain of samples were observed that could be due to adhering organic materials from the compost mixture and the n slowly started the degradation due to the microbes in the composting materials. The decomposition of plastic also depends on physico-chemical structure, environmental conditions (temperature, moisture, pH and salinity) and microbial activity. A reduction of 70,000 to 50,00 Dalton could be attributed to the abiotic conditions such as UV or thermal conditions.

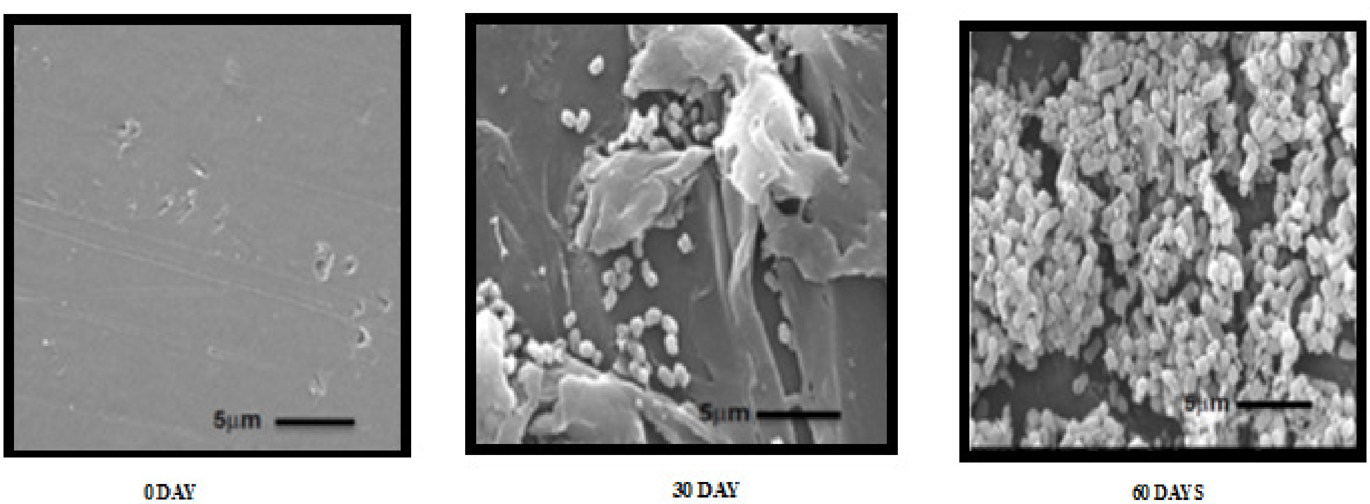

Figure-8: Scanning electron microscopy of bio film formed on the surface of UV photo-oxidised plastic sample.

Figure-9: Fragmented sample collected during composting.

Figure-10: Stereomicroscopic photographs shows formation of punctures on sample surface due to biodegradation under aerobic composting process.

Table-1: Weight of sample before and after biodegradation (After 8 weeks).

Sample	Initial weight before biodegradation (grams)	Final Weight after biodegradation (grams)	% Weight Loss
Plastic sheet	10.00	5.00	50

By considering of weight loss analysis**,** it becomes obvious that biodegradation has occurred. Also over 8 weeks of period there is 50 % weight loss, which indicates samples is biodegrading. It is therefore safe to assume that biodegradation will continue to accelerate. If the sample was continued in aerobic composting process under thermophilic stage, biodegradation rate would be continued. Consortium isolated from acclimatized plastic waste (collected from municipal solid waste site) was found efficient in biodegradation of plastic waste.

Final compost: The incubation period of 8 weeks in aerobic bioreactor resulted in quality compost which was removed from the bioreactor, mixed properly, dried, crushed and sieved (Images 11, 12, 13 and 14). The compost was characterised for physico chemical, macro and micro nutrients and heavy metals and compare with FCO standards prescribed by Ministry of Agriculture and Rural Development, Government of India and the comparison is presented in Table-2.

Physicochemical and nutrient analysis of prepared compost and its comparison with Fertilizer Control Order (FCO) standards: The end product of decomposition was dark brown in colour with unpleasant odour. The moisture content (19.67 ± 2.36 %) of the sample is within the permissible limit (15–25 %) as prescribed by the FCO standards. The average pH (7.15 ± 0.35) of the prepared final compost changed from neutral to slightly alkaline as standard values (6.5–7.5) recommended by the FCO standards. The high value of pH is responsible for acceleration of emission of ammonia from the compost. During the preparation of compost the temperature variation occurs due to the mesophilic and thermophilic microbial activity.

Figure-11: Final compost after 8 weeks.

Figure-12: Final compost after drying.

Figure-13: Final compost after crushing.

Figure-14: Final compost after sieving.

Table-2: Physicochemical and nutrient analysis of prepared compost and its comparison with Fertilizer Control Order (FCO) standards.

Parameters	Range	Average	Standard deviation	Standards (FCO)
pH	6.9-7.4	7.15	0.35	6.5-7.5
Moisture content (%)	18-21.34	19.67	2.36	15-25%
Electrical conductivity (ds/m)	1.20-1.33	1.26	0.09	≥4
Total Nitrogen (%)	1.87-1.91	1.89	0.02	0.5 (min)
Total Phosphorus (%)	0.96-1.13	1.04	0.12	0.5%(min)
Total Potassium (%)	1.99-2.15	2.07	0.11	1%(min)
Zn (mg/kg)	242-251	246.50	6.36	1000
Cu (mg/kg)	187-216	201.50	20.50	300
Cd (mg/kg)	2.13-2.25	2.19	0.08	5
Pb (mg/kg)	84-91	87.50	4.94	100
Ni (mg/kg)	29-34	31.50	3.53	50
Cr (mg/kg)	83-89	86.00	4.24	50

The electrical conductivity was observed to be lower than FCO standard values. The total nitrogen, total phosphorous and total potassium contents were higher than the minimum value prescribed by FCO standards. The heavy metals (Zn, Cu, Cd, Pb, and Ni) analysed in the compost were within the range and the average value of Cr was higher than the prescribed by the FCO standard.

Discussion: For the treatment of contaminants bioremediation is considered as one of the efficient technology that uses biological system with its central thrust depending on microbiology. This technology includes biostimulation, bioaugmentation, bioaccumulation and biosorption. The main non-biotic effects in this process are chemical hydrolysis, thermal polymer degradation and oxidation or scission of the polymer chains through irradiation (photo degradation). The whole mechanism of polymer degradation could be mentioned as environmental degradation as the biotic and non-biotic process are involved[7]. The degradation potential of upto 12% by *Asper gillusjaponicus and 8% by A. Niger* have revealed the presence of porosity and fragility of the fungal degraded polythene surface in one month period[11].The film sample containing the d2w pro-degradant additive has undergone significant degradation. The film sample containing the additive demonstrates a large change in carbonyl optical density measurement at the conclusion of the test[8]. The garden soil is rich in microbes having ability to degrade polymeric materials[9]. *Bacillus cereus* have been reported to be promising in reducing the polyethylene disturbance in nature[10].

Conclusion

The present study has revealed the utility of microbes that have potential in degrading plastic after UV treatment. It was visualised that the composting of the plastic wastes from the dumping site along with organic wastes in a bioreactor could be an efficient method to reduce the accumulation of plastic. A combined activity of microbes under ambient conditions can help in enhancing biodegradability and further researches can be conducted to develop efficient technology for plastic biodegradation in natural conditions at the dumping sites.

References

1. Nriagu J.O. and Pacyna J.M. (1988). Quantitative assessment of worldwide contamination of air, water and soils by trace metals. *Int. J. Sci*., 333, 134-139.

2. Artham T. and Doble M. (2008). Biodegradation of aliphatic and aromatic polycarbonates. *Macromol. Biosci*., 8(1), 14-24.

3. Gu J.D. (2003). Microbiological deterioration and degradation of synthetic polymeric materials: recent research advances. *Int. Biodeterior. Biodegrad.,* 52(2), 69-91.

4. Vidali M. (2001). Bioremediation. An overview. *Pure Appl. Chem*., 73(7), 1163-1172.

5. Kamaludeen S.P.B., Arunkumar K.R. and Ramasamy K. (2003). Bioremediation of chromium contaminated environments. *Ind. J. Exp. Biol.,* 41(9), 972-985.

6. Hadad D., Geresh S. and Sivan A. (2005). Biodegradation of polyethylene by the thermophilic bacterium *Brevibacillusborstelensis*. *J Appl Microbiol,* 98(5), 1093-1100.

7. Muller R.J. (1992). An interlaboratory investigation into the biodeterioration of plastics, with special reference to polyurethanes; Part 1: A modified sturm test. *Material und Organismen*, 27, 179-189.

8. Gnanavel G., Valli V.P.M.J., Thirumarimurugan M. and Kannadasan T. (2014). Degradation of polyethylene in the natural environment. *Int. J. Res. Eng. Technol.,* 2(1), 1-6.

9. Saminathan P., Sripriya A., Nalini K., Sivakumar T. and Thangapandian V. (2014). Biodegradation of plastics by Pseudomonas putida isolated from garden soil samples. *J Adv Bot Zool*, 1(3), 34-38.

10. Sowmya H.V., Ramalingappa M.K. and Thippeswamy B. (2014). Biodegradation of polyethylene by Bacillus cereus. *Advances in Polymer Science and Technology: An International Journal*, 4(2), 28-32.

11. Raaman N., Rajitha N., Jayshree A. and Jegadeesh R. (2012). Biodegradation of plastic by Aspergillus spp. isolated from polythene polluted sites around Chennai. *J. Acad. Indus. Res*, 1(6), 313-316.