Biodegradation of Four Aliphatic Polyesters Studied by Biochemical/Chemical Oxygen Demands and SEM

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Solid consumer waste exerts a tremendous burden on the environment, from the leaching of toxic substances into ground water to harmful effects on wildlife. Many landfills in the US are near capacity, and land available for development of new landfills is diminishing at a rapid pace. In the present study, the potential for biodegradation of four polyesters was evaluated in tests of biochemical oxygen demand (BOD), chemical oxygen demand (COD), and scanning electron microscopy (SEM) analysis. The polymers studied were succinic acid/ethylene glycol (SAEG); two polymers of adipic acid/ethylene glycol (AAEG and AAEGti); and adipic acid/1,3-propanediol (AAPD) [1, 2].

The four polyesters were synthesized from commercially available dicarboxylic acid/diol starting materials using a condensation method in the absence of a solvent. All polymers but AAEG were produced utilizing Titanium (IV) Butoxide as catalyst, while AAEG was produced using phosphoric acid. BOD was determined using a BODTRAK II instrument (Hach Company) following OECD standard 301f [3], a manometric respirometry test, as modified by Hach, Klein and Gibbs [4]. BOD is a test of ready biodegradability, the most stringent biodegradability standard, and is one of the few tests suitable for materials that are poorly water-soluble. The process detects carbon dioxide, which is evolved in stoichiometric proportion to the oxygen utilized during microbial metabolism. Briefly, fine suspensions of the polymers (100 mg polymer/dL) were placed in the closed bottles to which was added Polyseed®, a commercially-available mixture of common environmental microbes. Biochemical oxygen demand was determined over a 5-day period. Chemical oxygen demand (COD) was determined by potassium dichromate digestion using a DRB200 chemical digester and interfacing uv-visible spectrometer [3]. Three samples (100 mg/L deionized water) were analyzed for each polymer. For SEM studies, aliquots of each polymer were buried either in soil (test) or sterilized soil (control) for 60 days. FEI Quanta 200 Environmental SEM was used.

Polymer BODs are shown in Figure 1 and Table 1. All of the polymers exhibited biodegradability, with the ethylene glycol compounds clearly more biodegradable than AAPD. The polymers' biodegradative potentials were in roughly the same order as their water solubilities (SAEG > AAEG > AAEGti > AAPD). AAPD was very poorly water soluble, and its BOD was less than half that of either SAEG and AAEG ($p<0.01$). The COD of SAEG was 1684 mg O_2/L; therefore, its BOD:COD ratio was 23%. The SAEG concentration-response relationship is shown in Figure 2 and Table 2. SEM micrographs are in Fig. 3 at about 200X magnification for all samples.

All polyesters demonstrated some degree of biodegradability in these studies. There was no evidence that non-enzymatic hydrolysis contributed to the BODs. An apparent increase in biodegradation was noted for SAEG and AAEG when compared with AAPD. However, BOD comparisons are more meaningful when expressed as a fraction of the COD. The SAEG BOD:COD ratio was 23%. CODs for the remaining polymers are in progress. Changes in polymer surface morphology revealed by SEM may reflect nonspecific hydrolysis, although microbial polymer metabolism is believed to be contributory. Studies are underway to further characterize the biodegradative potential of the polymers.

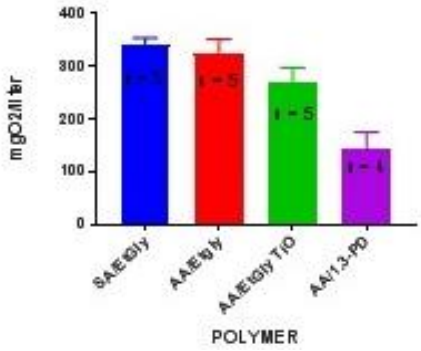


Figure 1. SAEG Biochemical Oxygen

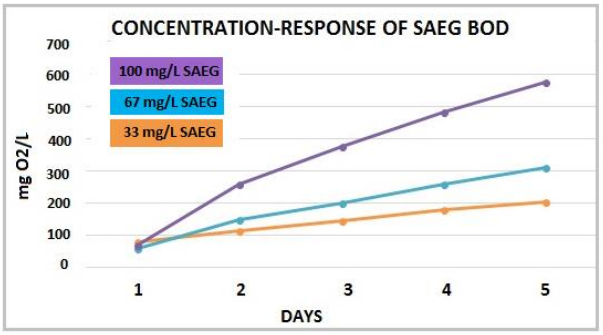


Figure 2. Concentration-Response of BOD

	SAEG	AAEG	AAEGti	AAPD
mean	339.6	325.0	270.6	143.0
S.E.	13.5	26.9	26.2	32.2

Table 1. SAEG BOD (mg O_2/L)

[SAEG]	33mg/L	67mg/L	100mg/L
Day 1	81	61	71
Day 2	116	149	260
Day 3	146	202	376
Day 4	179	260	483
Day 5	203	310	576

Table 2. Concentration-Response of SAEG BOD

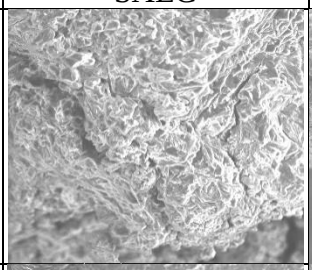
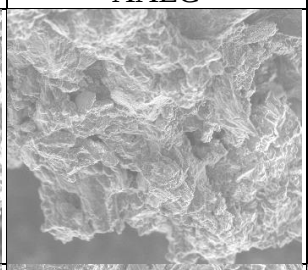
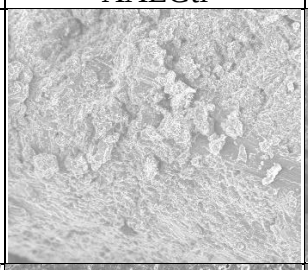
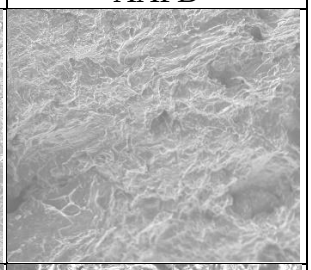
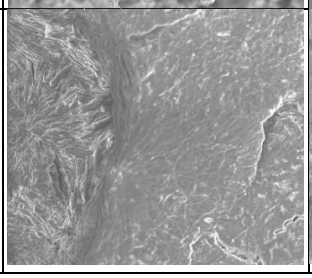
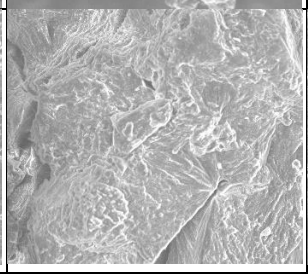
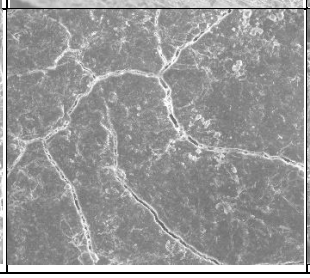
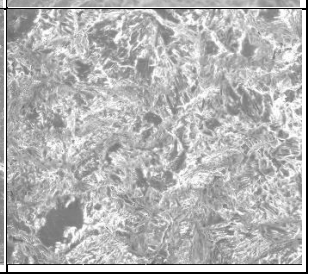
Polymer	SAEG	AAEG	AAEGti	AAPD
Control				
Test				

Figure 3. SEM viewgraphs of biopolymers buried in soil (test) or sterilized soil (control) for 60 days.

References:

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