Ecological Assessment of ECM Plastic

February 16, 1999

Prepared for: **Microtech Research Inc.**
7234 Lakeshore Boulevard
Mentor, Ohio 44060

Prepared by: **ChemRisk, A Service of McLaren/Hart Inc.**
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SCIENCE • STRATEGY • TECHNOLOGY • SOLUTIONS

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The Undersigned attests that the information provided is true, accurate, and complete to the best of my knowledge.

Timothy R. Barber, Ph.D.
Supervising Environmental Scientist

In Testimony Whereof, I have hereto set my hand and official seal at Cleveland, Ohio this 16th day of February, 1999.

Notary Public, State of Ohio

Commission Expiration:

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1.0 INTRODUCTION

During the past 25 years, plastic materials have gained widespread use in the food, clothing, shelter, transportation, construction, medical, and leisure industries. Plastics offer a number of advantages over alternative materials – they are lightweight, extremely durable, and relatively unbreakable. However, plastic materials also have several disadvantages, one of the largest being that plastic does not break down in the environment. Materials such as wood and paper are subject to breakdown from microorganisms (biodegradation). Plastics are composed of petroleum-based materials called resins (e.g., polyethylene, polypropylene) – materials that are resistant to biodegradation. Because of this resistance, plastics that are disposed of in landfills will remain in their original form in perpetuity. Every year, large volumes of plastics are disposed of in U. S. landfills – in 1995 alone, an estimated 20 million tons of plastic products were disposed of in landfills. This burden can be limited through the development of biodegradable plastics.

In the past 10 years, several biodegradable plastics have been introduced into the market. These products are composed of starch-base products (e.g., corn) combined with resins. Since sunlight is required for the degradation of these products, they will not degrade in landfills and can only be used for composting purposes. While these products are useful for the collection of yard waste, their use will not help to abate the quantity of plastics placed in landfills each year. In order to produce plastics that will degrade in a landfill setting, another approach must be taken.

Microtech Research, Inc. has developed an alternative method of creating biodegradable plastics. This method involves a proprietary combination of organic and inorganic chemical materials which have been mixed in a very precise formulation and compounded into a reactor-grade master batch pellet. When this pellet is compounded with any polyethylene or polypropylene resin, the resulting plastic is biodegradable. The biodegradation of ECM-treated plastic occurs through aerobic (oxygen dependant) and anaerobic (dependent on the absence of oxygen) pathways. Microorganisms consume the plastic, assimilating the material for cellular processes and producing a mixture of metabolic products (principally methane, carbon dioxide, and water). Plastics synthesized using the

ECM process may be useable in the manufacture of bags, agricultural film, landscape netting, diaper liners, and numerous other products.

The viability of ECM-treated plastic as an environmentally safe, biodegradable product was evaluated by conducting standard tests on ECM pellets and plastic film created using the ECM process. Biodegradation tests were conducted to determine the susceptibility of the products to biodegradation. In addition, chemical analyses and standard plant and animal toxicity tests were conducted on the end product of the biodegradation process to determine the safety of the product. The results of these tests are discussed below.

2.0 BIODEGRADATION TESTS

Laboratory testing is a common method used to determine the susceptibility of compounds to biodegradation. Testing methods have been developed and standardized by several organizations including the American Society of Testing Materials (ASTM), Organization for Economic Cooperation and Development (OECD), and European Standards Organization (CEN). The method employed by the various tests involves adding a small amount of test compound (in this case, ECM pellets or plastic film) to a large amount of a material called inoculum (a highly active substance used to grow microorganisms). The test is run at the same time using a reference compound that is known to be biodegradable, also added to inoculum. Biodegradation can be evaluated by measuring the amount of methane and carbon dioxide produced. Using this result, the percentage of sample that has biodegraded is calculated as the percentage of solid carbon of the sample that has been converted to gaseous, mineral carbon. If the results from the test and reference materials are similar, the test material has biodegradable properties.

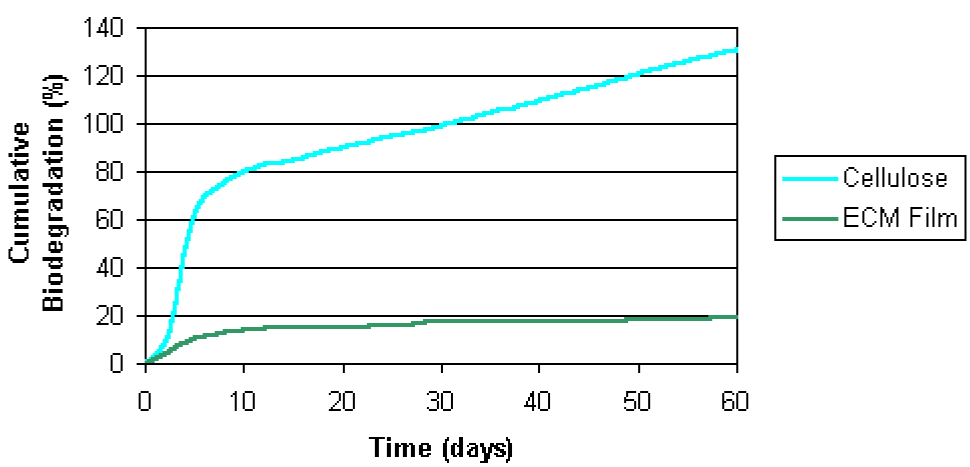
2.1 Short-Term Aerobic Biodegradation (Composting)

Refuse that is composted degrades under aerobic conditions. The susceptibility of ECM-treated plastic to biodegradation under aerobic conditions was evaluated using the controlled composting biodegradation test (ASTM method D.5338.92). This test is conducted under optimum oxygen, temperature, and moisture conditions, simulating an intensive aerobic composting process. The test was conducted on plastic films (the base compound from which plastic bags are manufactured) composed of 50% ECM and 50% resin. Cellulose (the main constituent of plant tissues and fiber) was used as the reference material.

The test or reference compound was added to an inoculum consisting of mature compost. Mixtures were placed in test vessels and intensively composted for 60 days. At the end of the test, the carbon dioxide production rate and the cumulative carbon dioxide production were measured. The percentage of biodegradation was calculated using this information.

The cellulose degraded quickly (Figure 1), especially within the first 10 days of the test. By the end of the test, essentially all the cellulose had degraded. The 50% ECM film did not degrade as completely or as quickly as the cellulose. At the end of the test, 19% of the film had degraded. Cellulose is a completely biogenic material that degrades quickly. Since the composition of the 50% ECM film is half resin (a material that does not degrade on its own), biodegradation of this material should take much longer than degradation of biological materials. Plastics that contain a lower percentage of ECM (e.g., 5% ECM film) will degrade more slowly than the 50% ECM film. The results of the aerobic degradation tests indicate that, in time, plastics produced using ECM pellets will biodegrade in aerobic conditions.

Figure 1. Aerobic Biodegradation of 50% ECM Film and Cellulose



2.2 Long-Term Aerobic Biodegradation

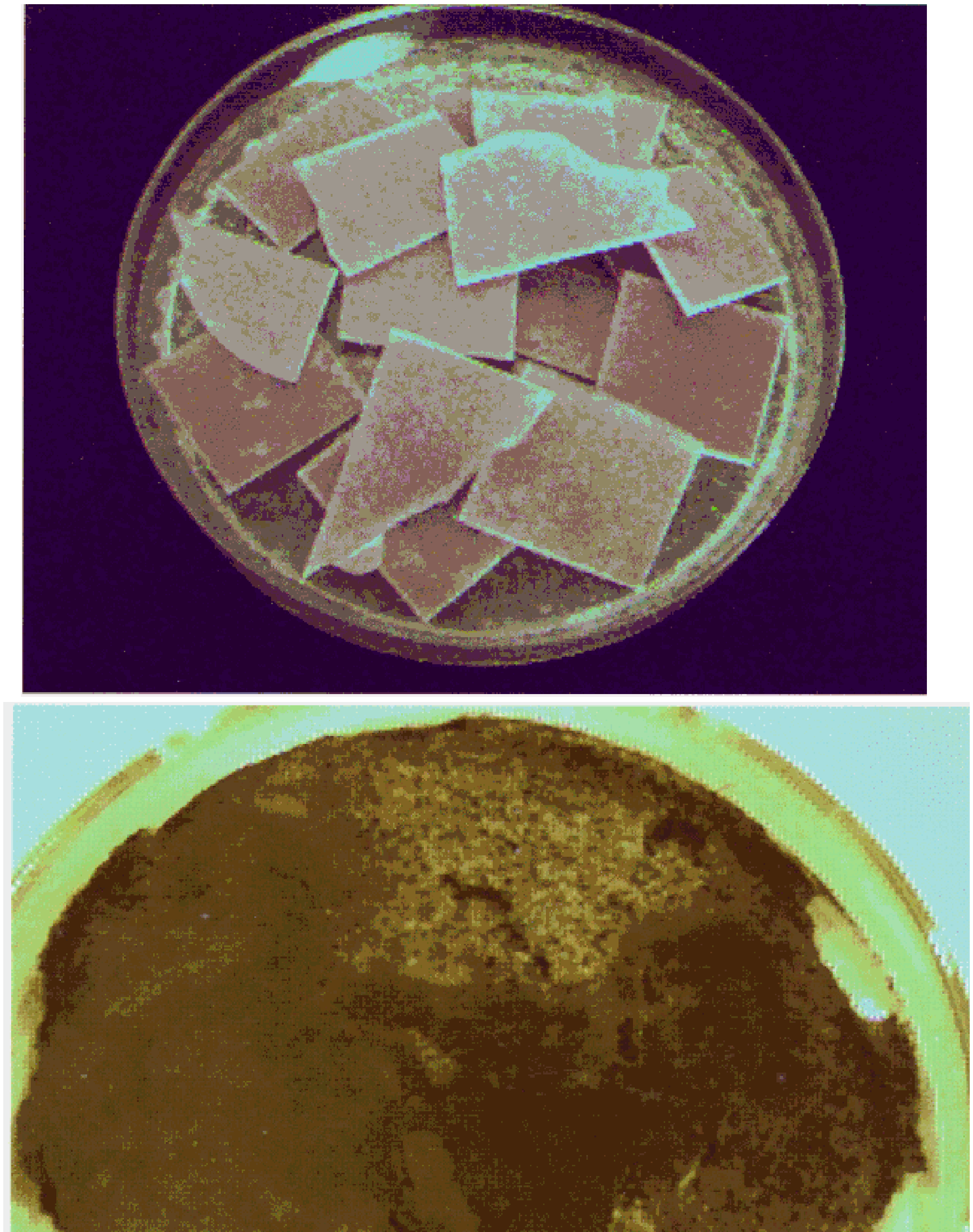
The long-term susceptibility of ECM pellets and films to biodegradation under aerobic conditions was evaluated using tests for determining resistance of plastics to fungi (ASTM G.21) and bacteria (ASTM G.22). These tests measure the degradation of plastics due to fungi and bacteria – they are usually used to prove the resistance of plastics to these organisms but can be used to prove susceptibility.

ECM pellets and 5% ECM film were placed onto petri dishes (small, flat containers) coated with a growth medium called agar, which were then placed into an incubator. No microorganisms were introduced to the test material other than the opportunistic microorganisms introduced through non-sterile handling and from the room air. Petri dishes were periodically removed and test materials were observed for signs of microbial growth and sample appearance (disintegration of test material The test duration was 22 months.

During the test, the plastics displayed evidence of attack by microorganisms. All of the petri dishes began to show microbial growth between day 5 and day 9 of the test. After 11 months of incubation, the film samples showed heavy cracking and separation and the ECM pellets showed significant reduction in size and disintegration of the pellet form. After 19 months of incubation, the microbial growth appeared to diminish. At this time, the film and ECM pellet samples were no longer distinguishable as discrete pieces and were easily crushed. Photographs of 5% ECM film at the beginning and end of this test are presented in Figure 2.

The results of the aerobic tests indicate that both ECM pellets and ECM film will eventually biodegrade in an aerobic environment. The process of aerobic degradation for these substances takes time. Within 2 years, ECM pellets or film disposed of in a compost situation should be completely degraded. Since it is generally recommended that materials used in composting degrade within 90 days, it would appear that ECM treated plastics are not ideally suited for composting.

Figure 2. 5% ECM Film, Day 1 and Day 672
(Laboratory Video, Microtech Research)



LLDPE cast film strips totally degraded

**Tests conducted from 1/6/97 through 11/9/98 –
672 days exposure time**

2.3 Anaerobic Biodegradation

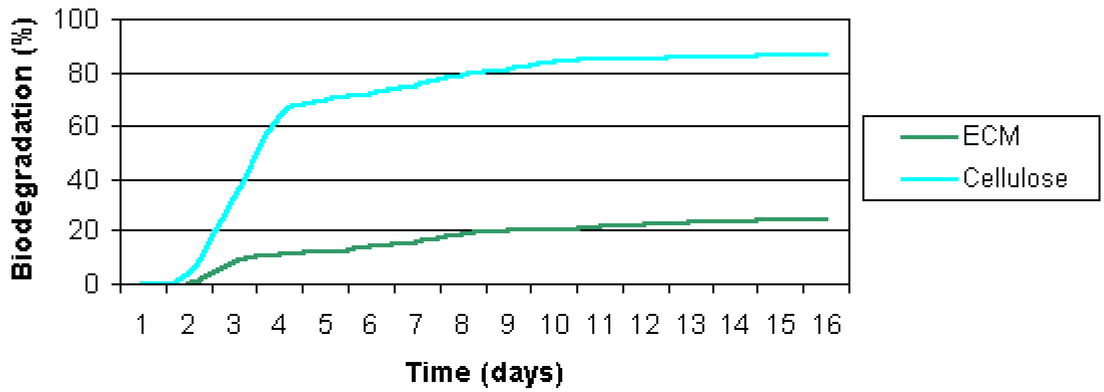
Refuse (including plastics) disposed of in landfills eventually becomes buried and cut off from any supply of oxygen. For an item to biodegrade in a landfill, it must be susceptible to breakdown by anaerobic microorganisms. The biodegradation of products in a landfill can be determined through a test involving high-rate dry anaerobic batch fermentation (ASTM D.5511-94). The optimal conditions of this fermentation method are stationary (no mixing) and dry conditions similar to those found in landfills. In order to evaluate the biodegradability of the product in landfills, this test was conducted using the ECM pellet as the test material and cellulose as the reference material.

The test began by adding a small amount of test or reference material to an inoculum consisting of a concentrated medium of the same bacteria found in landfills. Test vessels were then filled with the mixtures, closed airtight, and placed in an incubator for 15 days. At the end of the test, the amount of methane and carbon dioxide produced per gram of test substance was calculated. This information was used to calculate the percentage of biodegradation (percentage of solid carbon that has been converted into biogases) for both cellulose and ECM pellets.

As in the aerobic tests, biodegradation of cellulose started at a high rate (Figure 3). After 5 days, more than 70% of the original sample had biodegraded. At the end of the 15-day test, 87% of the sample had degraded. The ECM pellets biodegraded at a moderate rate; after 15 days, 24% of the sample had biodegraded. Since these values account for carbon released in respiration but not carbon assimilated by the microorganisms, the degree of degradation of both the pellets and cellulose may be underestimated.

The results of this test indicate that ECM pellets do biodegrade under anaerobic conditions, although at a slower rate than cellulose. If disposed of in landfills, the ECM pellets should completely break down. ECM-treated plastics should also break down in anaerobic conditions, although at a slower rate than the 100% ECM pellets.

Figure 3. Anaerobic Degradation of ECM Pellets and Cellulose



3.0 CHEMICAL ANALYSES OF END PRODUCTS

The final degradation product of ECM pellets or film may contain residues of the original material such as metabolites, undegraded components and inorganic components. Chemical analyses of the degradation product were conducted to evaluate whether these residues are environmentally safe. Samples of the final product from the 22-month aerobic biodegradation test, including both the degraded pellets and degraded film, were subjected to three standard EPA analyses: total extractable metals, volatile organic compounds (VOCs), and Toxicity Characteristic Leaching Procedure (TCLP) – a procedure designed to determine the mobility of chemicals present in liquid and solid wastes.

The total extractable metals analysis measured cadmium and lead. These two metals are used in the production of plastics and are often present in the final product. Cadmium was not detected in the degraded film or pellets. :Lead was detected in both the degraded film (0.7 mg/kg) and pellets (4.6 mg/kg). The average concentration of lead present in United States soil is 16 mg/kg, more than two times higher than the detected concentrations. Since the levels of lead present in the final degradation products of ECM pellets are lower than the levels present in U.S. soil, they will not have an impact on soil-dwelling organisms.

A total of 33 VOCs were analyzed in the degradation products of the film and pellets. Twenty-nine of the chemicals were not detected in either sample. All four of the detected chemicals (acetone, 2-methylene chloride, and styrene) were present in low levels. Detected concentrations of all four chemicals were lower than the U.S. EPA Region 5's Ecological Data Quality Level (EDQL) benchmarks. The U.S. EPA uses EDQLs to identify chemicals that could possibly pose a risk to exposed wildlife. Since none of the detected chemicals exceed the EDQL, the end product does not contain harmful levels of any of the tested VOCs.

TCLP analyses were conducted for eight metals and 13 semi-volatile organic compounds (SVOCs). The results of the TCLP indicate whether any of the analyzed chemicals are likely to migrate from their disposal area into surrounding soil. Lead was the only chemical detected. The concentration of lead detected in the TCLP analysis (1.5 mg/L) was lower than the U.S. EPA's regulatory level for lead using TCLP (5 mg/L). Solid wastes with concentrations above the regulatory level are considered to “exhibit the characteristic of toxicity.” All of the chemical analyses indicate that chemicals in the final degradation product of ECM pellets are not present in concentrations that would be harmful to exposed organisms.

4.0 TOXICITY TESTS

Although the results of the chemical analyses of the end products indicated that none of the tested chemicals were present at harmful concentrations, it would not be possible to analyze every potentially toxic chemical that might be present in the degraded products. For this reason, the possible toxicity of the degradation product was further assessed using toxicity tests. Laboratory toxicity tests are commonly used to determine whether or not a substance is harmful to the organisms that may come into contact with it. Test organisms are exposed to a known quantity of the test substance in the medium (e.g., soil, water) occupied by the organisms. At the end of the test, the survival or growth of the organisms are measured.

ECM-treated plastics may be disposed of in landfills or may be composted. While compounds in landfills are generally not exposed to organisms, composted plastics are exposed to plants, soil-dwelling animals (*e.g.*, earthworms), and aquatic organisms. These plants and animals will also be exposed to the degradation products of improperly disposed plastics (*i.e.*, litter). Four toxicity tests were conducted on ECM pellets – two with plant species and two with animal species. The medium used in these tests was a mixture of soil and compost (or, in one case, a solution of water and compost). The test compost was produced by composting ECM pellets in a 10% concentration with municipal solid waste for 3 months. For each toxicity test, a reference was run with control compost (compost without ECM pellets). At the end of the exposure period, the survival or growth of the organisms exposed to the test compost was compared to that of organisms exposed to the control compost.

4.1 Plant Growth

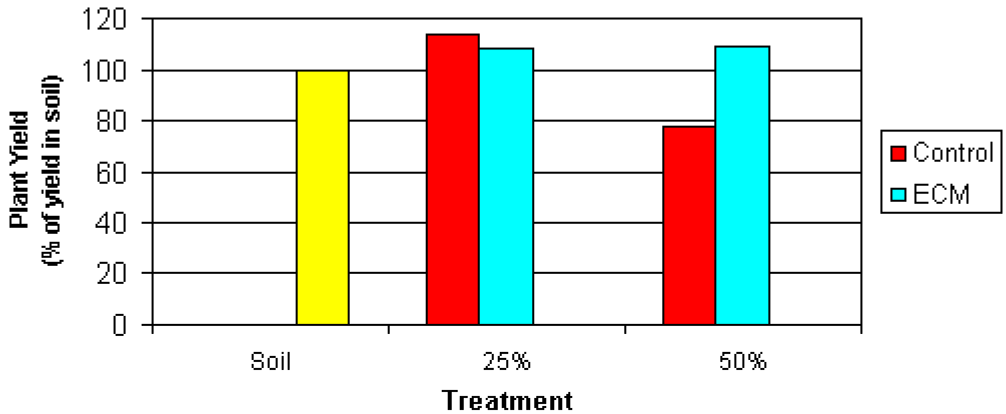
The possible effect of ECM compost on flowering plants was evaluated using two toxicity tests. Angiosperms, or flowering plants, are the most diverse and widespread class of plants and are divided into two classes: monocots (plants with one embryonic seed leaf) and dicots (plants with two embryonic seed leaves). Representatives from both of these classes were used in toxicity tests – summer barley was used to represent monocots, and cress was used to represent dicots.

4.1.1 Summer Barley Test

A European test (RAL GZ 251) was used to determine the tolerance of summer barley to compost. Summer barley is a species of cereal grass. The summer barley test involves the germination and growth of this plant in mixtures of standard soil and compost. After approximately 10-12 days of exposure, the plants were dried and weighed to obtain the dry weight. If there is no significant difference between results obtained from the test (ECM) compost and those obtained from the control compost, the ECM residuals are considered to be non-toxic.

The mixtures of soil and compost tested were 25/75 and 50/50 ratios of compost/soil. The five soil mixtures tested were ECM25, ECM50, Control25, Control50, and untreated soil (numbers associated with the ECM and control mixtures indicate the percentage of compost in the mixture). The results (presented as a percentage of results obtained using soil) are presented in Figure 4.

Figure 4. Results of Summer Barley Test (dry weight)

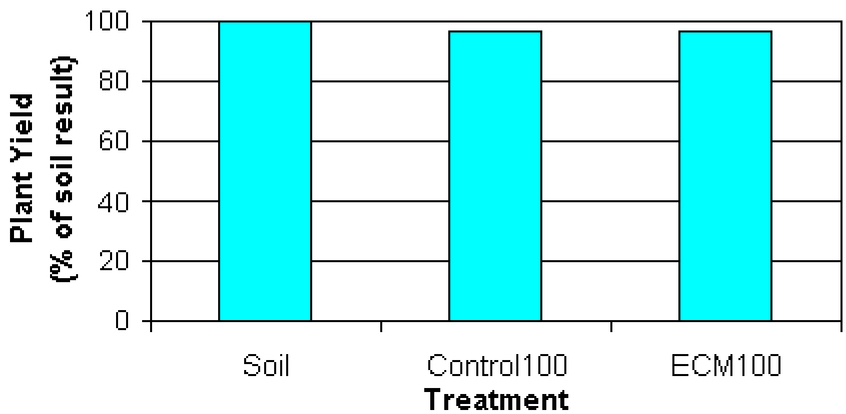


The barley grown in the ECM test compost performed well compared to that grown in soil or the control compost. There was no significant difference between the yield obtained on the control compost and the yield from the ECM test compost. In fact, barley grown in the ECM50 compost produced a greater yield than that grown in the Control50 compost. These results indicate that the end product of the biodegradation of ECM pellets is not toxic to monocotyledonous plants.

4.1.2 Cress Test

Cress is a dicotyledonous; leafy plant. The cress test is a European test (RAL GZ 251) that involves the germination and growth of cress seeds on 100% compost. After 7 days of exposure, the dry weight is obtained. Cress tests were conducted with three substances –ECM compost (ECM 100), control compost (Control 100), and soil. The results (expressed as a percentage of the soil results) are presented in Figure 5.

Figure 5. Results of Cress Test (dry weight)



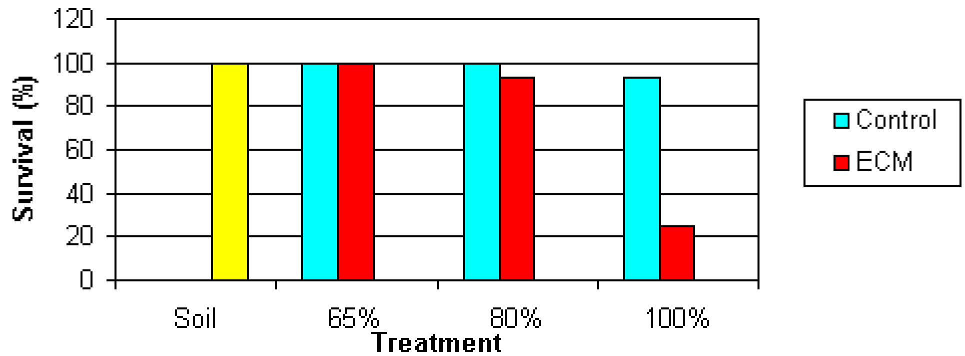
At the end of the test, all emerged plants had a healthy appearance. On a dry weight basis, the yield was about the same for all three treatment groups. These results indicate that the ECM compost is not toxic to dicotyledonous plants. The results of the cress and barley tests demonstrate that the final degradation product of ECM pellets is not toxic to either of the classes of flowering plants.

4.2 Earthworm Acute Toxicity Test

In order to examine the possible toxic effects of ECM pellet degradation products on soil-dwelling organisms, an earthworm acute toxicity test was conducted. In an acute toxicity test, organisms are exposed to high concentrations of a test substance for short periods of time. Since the earthworm feeds on soil, this organism is suitable for the toxicity testing of ECM compost. The toxicity test used was a European test (OECD Guidelines #207) in which earthworms are exposed to soil and compost combined in varying ratios. After 14 days of exposure, the number of surviving worms is counted and percent survival is calculated.

Earthworms were exposed to mixtures of compost (control or ECM) and soil in ratios of 65/35, 80/20, and 100/0 of compost/soil. Earthworms were also exposed to 100% soil. The results are shown in Figure 6.

Figure 6. Results of Earthworm Test (survival)



All of the tested concentrations produced satisfactory results (between 90 and 100% survival) except for ECM100. At this concentration, only 25% of the earthworms survived the test, a result that is significantly different than the result at Control 100. The results of this test indicate that, when undiluted, ECM compost causes mortality in earthworms. When ECM compost is added to soil, acute mortality is not evident.

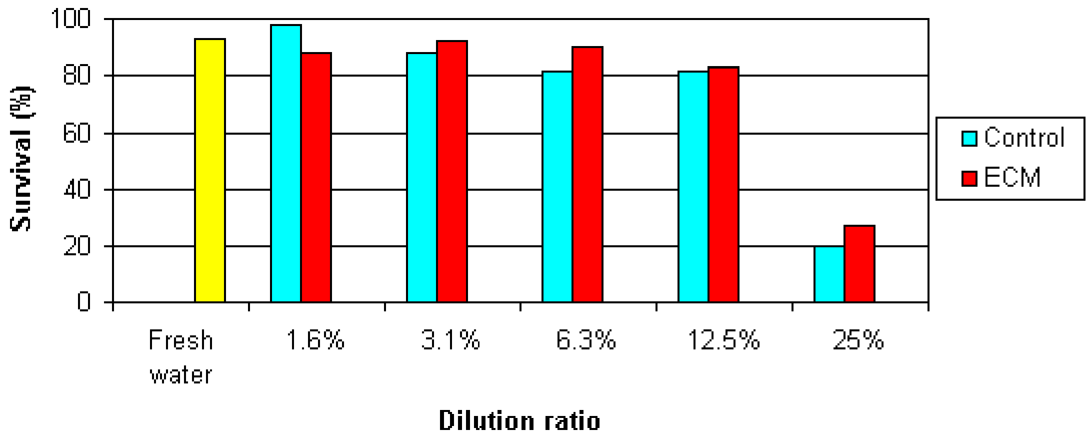
4.3 *Daphnia* Acute Toxicity Test

Substances in landfills or compost heaps can migrate to nearby bodies of water through liquids percolating in the ground (leaching) or rainfall (runoff). Through these processes, ECM degradation products may be transported into lakes, rivers, or other water bodies. Organisms inhabiting these water bodies would be exposed to any toxic residues that may be in the degraded plastic. For this reason, an acute toxicity test was conducted with an aquatic animal, the small freshwater crustacean *Daphnia.*

In order to expose *Daphnia* to the ECM compost, several solutions of "compost tea" were prepared by diluting compost with water in a range of dilutions. *Daphnia* were placed in containers filled with the solutions and exposed for 24 hours. After exposure, the number of surviving organisms was counted and percent survival calculated.

Control and ECM compost were diluted with water to produce solutions of 1.6%, 3.1%, 6.3%, 12.5%, and 25% compost in water. A control test was also run in which organisms were exposed to fresh water. Results are presented in Figure 7.

Figure 7. Results of Daphnia Test (survival)



The survival of *Daphnia* was above 80% at all dilutions except at 25%. At this concentration, there were low survival rates in both control and test solutions – only 20 to 30% of the *Daphnia* survived. The low survival rates observed at this dilution were not caused by any ECM residuals present in the test compost. Rather, the large amount of solids in the water at this dilution caused the observed mortality in both the control and ECM tests. There is no significant difference between survival observed in the control compost and that observed in the test compost at any of the dilutions. In fact, the ECM compost produced higher rates of survival in all but one dilution (1.6% compost). The results of the *Daphnia* test indicate that ECM compost is not toxic to freshwater organisms.

5.0 SUMMARY AND CONCLUSIONS

The successful production and marketing of biodegradable plastics will help alleviate the burden placed on the environment by consumers. Although many biodegradable plastics have been introduced into the marketplace, all of them must be composted and none of them biodegrade in landfills. For this reason, none of these products has gained widespread use in the United States. The technology developed by Microtech Research, Inc. allows the manufacture of plastics that biodegrade in aerobic or anaerobic conditions. Biodegradation tests indicate that products made using this technology will degrade when disposed of in landfills. Toxicity tests completed on the end product of degradation demonstrate that it should be safe under anticipated environmental exposures. Products made using ECM treated plastics (garbage bags, diaper liners, agricultural film, etc.) can be marketed as biodegradable and safe for the environment, filling an empty niche in today's market.

McLaren Hart, Inc.

www.mclaren-hart.com