Mycoremediation of Household Hazardous Waste through *Pleurotus ostreatus*

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Abstract: Currently, there is no reliable method to completely dispose of household hazardous waste. This study aims to examine the potential of using Oyster Fungi (*Pleurotus ostreatus)* as a method of biodegrading hazardous waste, specifically, alkaline batteries. Expired and leaking batteries were placed in sawdust along with fungal spawn. As the spawn grew, the pH was monitored to determine whether the hazardous component–potassium hydroxide–was indeed degraded. A control sample–batteries and sawdust without fungi–was used as a comparative tool. The fungi were then allowed to grow for five weeks. Results found that the pH of the sawdust mixture decreased after five weeks by a significant amount in all three samples of the fungal mixture. The control mixture exhibited a comparatively small decrease in pH. The alkalinity of the batteries was significantly weakened after five weeks of exposure to the fungal spawn (p value=.0004). This study displays a method of accelerating the degradation of household hazardous waste. In five weeks, the fungi were able to significantly reduce the pH of the hazardous component. When exposed to the mycelia, the rate of reduction of pH was drastically increased relative to the rate without the fungi. Further research is necessary to determine the long term potency of such a method. This study examined the effectiveness of mycelia in the biodegradation of alkaline batteries.

Introduction and Background:

The proliferation of household electronic devices has demanded the production of cheap and convenient power sources. These portable power sources came to be known as batteries, and the most common household battery today is the Alkaline AA battery, or an electrochemical cell. In 2011, AA batteries alone accounted for 80% of the sales of manufactured batteries in the United States (Olivetti, Gregory, and Kirchain, 2011). The majority of these cells, however, are non-rechargeable, and after the capability to produce current diminishes, the battery becomes useless in the household. The majority of environmental harms a battery poses materialize in the next step, disposal of the battery. Many of these batteries end up in landfills, as people dispose them with their household waste. The harsh climate landfills are subject to may induce a crack or breach in the protective coating of a battery, creating a leak. There are several toxic components of the leachate, the material that may leak out of the battery. The two most dangerous are Potassium Hydroxide (KOH) and potential Zinc fumes. Potassium hydroxide is a very corrosive substance, and is described as acutely toxic to humans and animals alike. When inhaled or ingested, it can cause serious damage to the respiratory and digestive tracts (Potassium Hydroxide MSDS). In addition, batteries produced before 1996 contain trace amounts of mercury (Battery Recycling, 2012). In spite of these prevalent dangers, many states have allowed for disposal of these batteries with domestic waste, sending them to landfills. The state of California, along with several others, has mandated that all batteries be disposed of through specific programs, ultimately sending them to hazardous waste sites. There still remains a substantial amount of AA batteries in landfills, however. An increased duration of residence in landfills will potentially leak these hazardous toxins—allowing them to seep into the ground, and possibly infiltrate groundwater. One pragmatic solution is bioremediation of these contaminants.

This study will examine the viability of using *Pleurotus ostreatus*, or the oyster fungi, as a tool to biodegrade the leachate from leaking alkaline batteries. The development of fungi to biodegrade toxins is relatively new, and the amount of topic literature pales in comparison to other methods of bioremediation. The Oyster fungus, though, has been shown to biodegrade hazardous synthetic dyes utilized extensively by the textile industry (Bhatt, 2003). *Pleurotus ostreatus* is able to biodegrade these toxins because of enzymes from the mycelia, such as ligninases (Koshy, 2012).

The primary objective is to research the ability of those enzymes to biodegrade the toxins from leaking alkaline batteries. Secondary objectives include examining the rate of biodegradation and uniqueness of such degradation.

Materials and Methods

To test the bioremediation capabilities of the fungi, six plastic containers were sterilized using hydrogen peroxide, and then filled with sawdust. Three of the containers were inoculated with fungal spawn. The other three containers were left without fungal spawn, as the control. Leaking AA alkaline batteries were placed in all six containers, and the mixtures were thoroughly stirred. The leaks, primarily caused by age, were approximately equal on both sides. For this experiment, the batteries were broken open to accentuate the leak, releasing the majority of potassium hydroxide within the battery. While handling the batteries, several safety regulations were adhered to: both latex and rubber gloves were worn, as well as a gas mask, and safety goggles, to prevent any contact with the potassium hydroxide, a caustic agent. All six containers were watered on a biweekly basis. To measure the change in toxicity, the pH of the sawdust-water mixture was monitored. The main contaminant from an alkaline battery leak is potassium hydroxide, a base. A change in pH, more specifically a reduction, would indicate severe dilution, or transformation into another compound. A pH probe was used, and the pH was measured nearest to the battery, as to prevent any distortion of the pH due to the sawdust. Five data points for each container were collected, one per week. Once the data collection was finished, the contents of all six containers were disposed of in the Santa Clara County household hazardous waste disposal site. Following the data collection and disposal of the sawdust-water mixture, tests to determine that the findings of the project were statistically significant were performed. The study examined three trials, so the matching statistical test, a 2 sample T test, was used to verify that the data collected was statistically significant.

Data

Week	pH of Trial 1	Average pH of Control
Week 1	10.2	10.1
Week 2	9.9	10
Week 3	9.5	9.9
Week 4	9.1	9.9
Week 5	8.6	9.8

Week	pH of Trial 2	Average pH of Control
Week 1	10.4	10.1
Week 2	10.2	10
Week 3	9.8	9.9
Week 4	9.3	9.9
Week 5	8.7	9.8

Week	pH of Trial 3	Average pH of Control
Week 1	9.9	10.1
Week 2	9.8	10
Week 3	9.6	9.9
Week 4	9.1	9.9
Week 5	8.6	9.8

Each trial mixture had its own plastic container, as to ensure uniqueness. The study took the average pH of all the control containers, and input it in the third column.

Results and Discussion

Over the course of five weeks, a general trend was observed in all three containers: the pH of the mixtures consistently fell, from approximately 10 to below 9. The results were shown to be statistically significant as well. The pH of the control also exhibited a decrease, but this was shown to be statistically insignificant. *Pleurotus ostreatus* was able to biotransform the potassium hydroxide, as the reduction of the pH indicated the presence of a different compound. External research has also shown that potassium hydroxide biodegradation significantly reduces the toxicity of the mixture (Potassium Hydroxide MSDS). The 2 sample T tests yielded a p value of .004. In comparison to the alpha level of .01, the p value was much less, affirming the statistical significance of the results. The reduction in pH of the mixture signaled the biotransformation of potassium hydroxide into a less toxic substance, demonstrating that *Pleurotus ostreatus* does indeed have the capability to biodegrade the hazardous waste present in household batteries.

The long term viability of such a project needs to be researched further in order to cement fungal bioremediation as an effective tool to break down hazardous waste. Many fungal bioremediation studies have only examined the capabilities of fungi to degrade one specific pollutant. In many polluted and contaminated regions, however, there are a multitude of different types of pollutants from different chemical families. Another avenue of research could be examining the ability to simultaneously biodegrade multiple toxins or pollutants. This avenue would crystallize the scientific view of bioremediation pathways, demonstrating whether or not the fungi are able to adapt its enzymes to the surrounding substances. In addition, the ability of the fungi to biodegrade pollutants under harsh environmental stress, and not under ideal, controlled conditions is important to examine if this technology were to ever become a tool to remediate contaminated, outdoor areas.

This study can further the use of fungal bioremediation as a technology used in hazardous waste cleanup. The implications of the study indicate the possibility of fungal bioremediation in landfills and polluted sites, but until the avenues of research previously indicated are thoroughly explored, the pragmatism of such a tool is unknown.

Tables and Figures

Figure 1-Trial 1

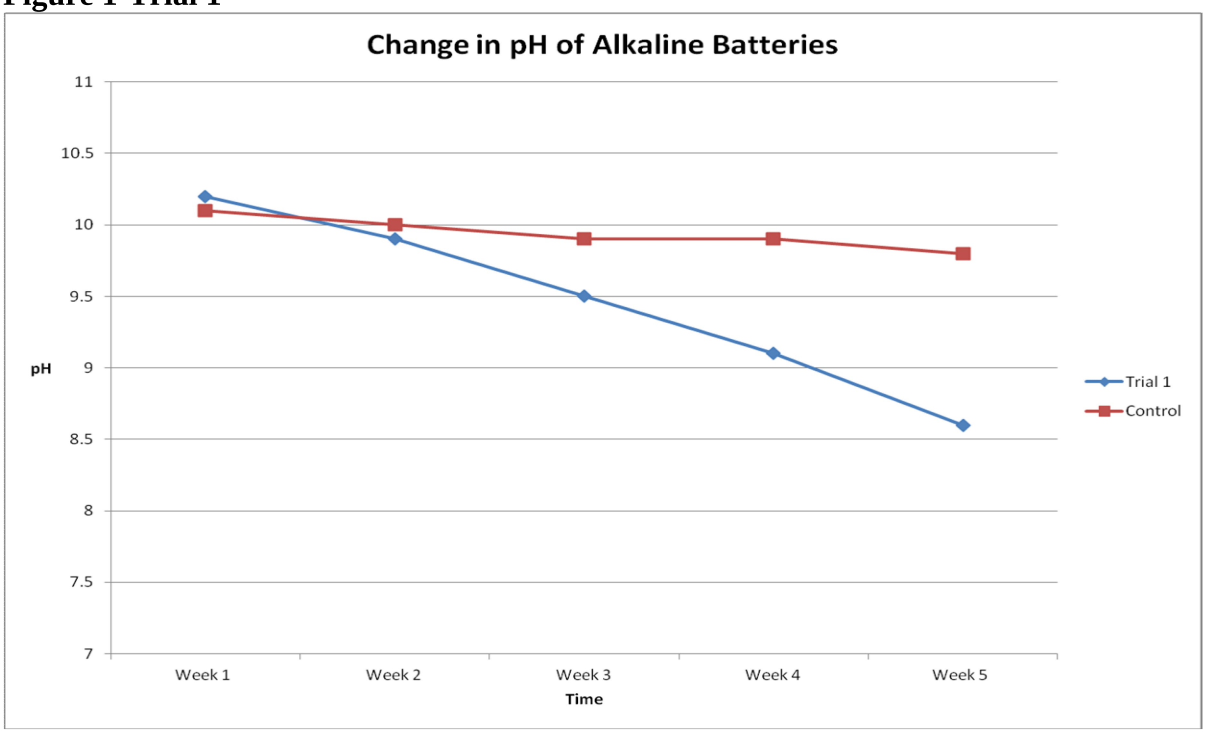


Figure 2-Trial 2

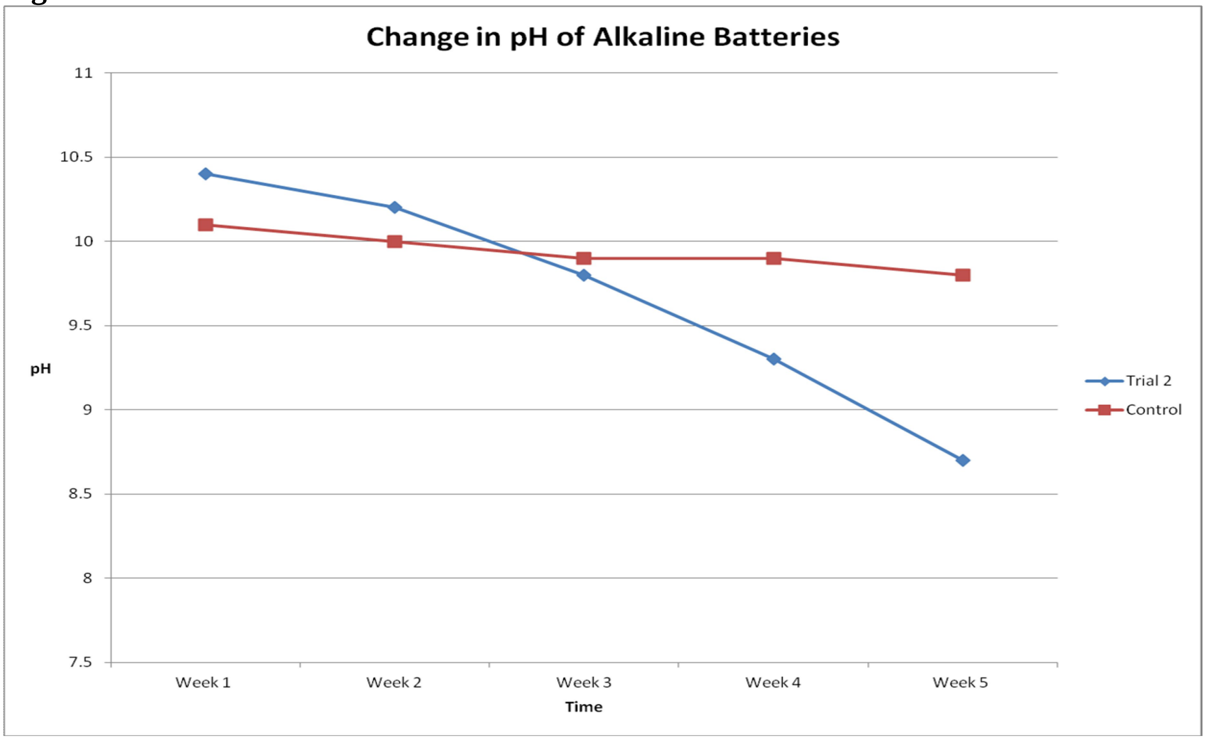
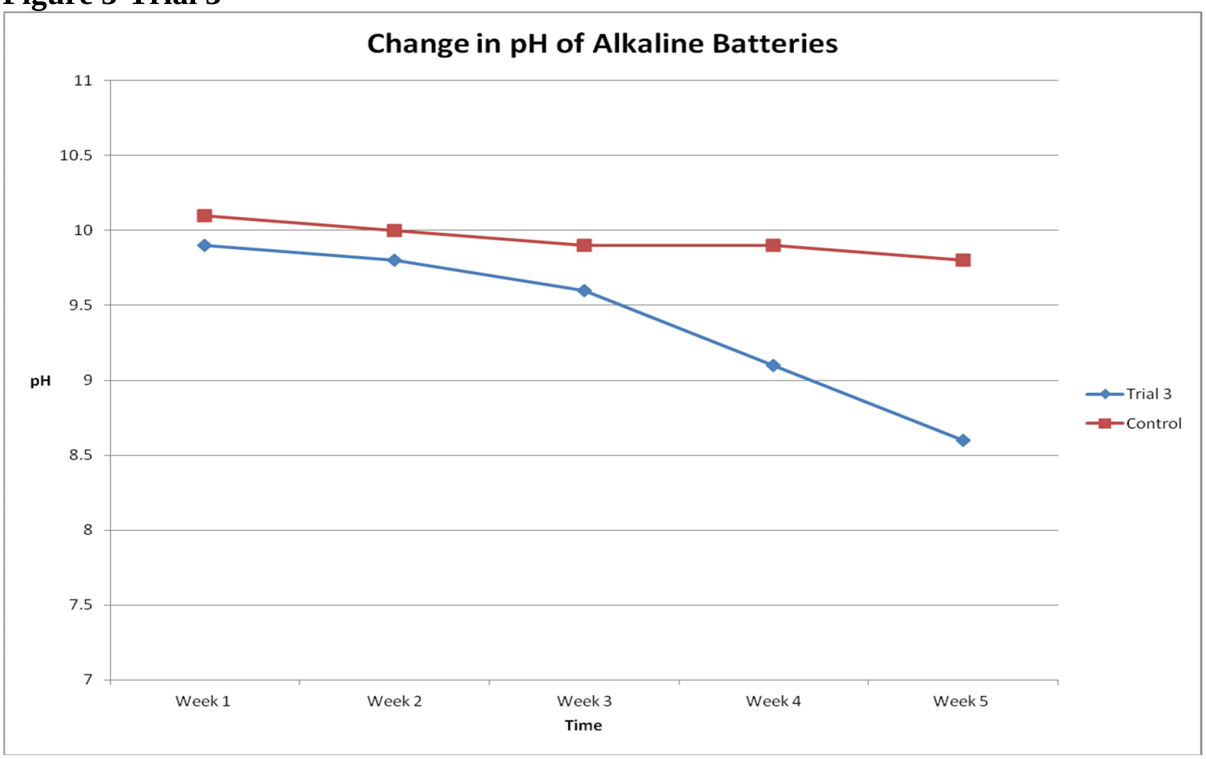


Figure 3-Trial 3

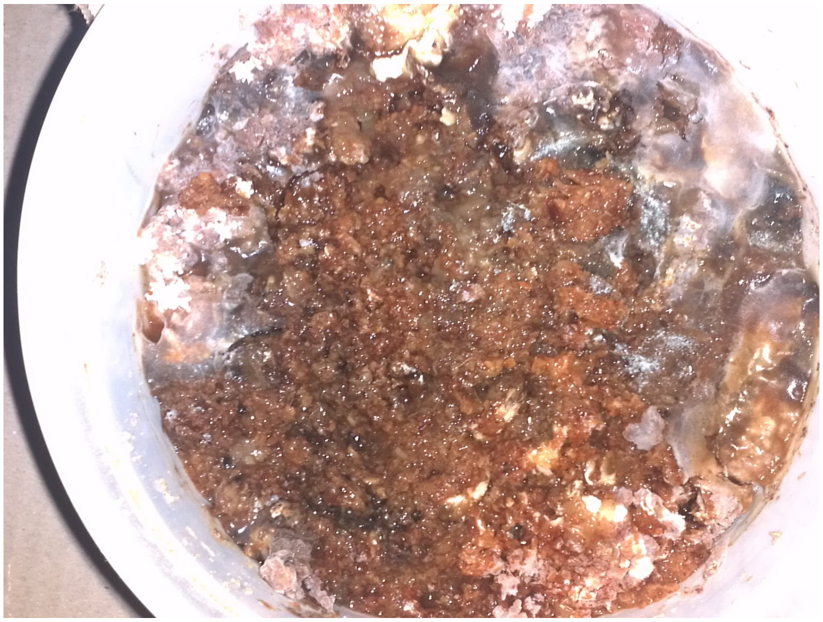


Figures 1, 2 and 3 are graphical representations of the data collected over the period of five weeks. The red, or the control, is the average pH of all three control containers, and is reflective of the data present in the data tables. In addition, the blue lines all represent the pH of the containers with *Pleurotus ostreatus*, and visibly demonstrate a decrease in pH.

Figure 4

This is a picture of a fungal trial approximately 2 weeks into the experiment. There is significant fungal growth to the side of the container, and there is a slower fungal growth on the other side as well. The significant fungal growth from the second week to the termination of the project can be observed from the picture below.

Figure 5



This is a picture of a separate fungal trial at the end the experiment. There is visible mycelial growth towards the edges of the container, and the growth is slowly moving to consume the center as well.

Acknowledgements

Many thanks to Ms. Amanda Alonzo, who provided me with assistance, advice, and guidance throughout the duration of the project. Mr. Paul Stamets and Ms. Katie Brownson of Fungi Perfecti also assisted me immensely by providing information and advice about Pleurotus. Lastly, the author would like to thank Ms. Sowmya Chander and Mr. Ramesh Calamur for editing this paper, and assisting me with the logistical issues of the project.

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