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International Journal of Microbiology and Current Research

Research Article

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Metal Leachate from Alkaline Battery Litters: A threat to Aquatic Organisms

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Article Info

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Received: March 26, 2019
Accepted: April 1, 2019
Published: April 8, 2019

Citation: Grover S, Sibi G. Metal Leachate from Alkaline Battery Litters: A threat to Aquatic Organisms. *Int J Microbiol Curr Res.* 2019; 1(1): 26-28.
doi: 10.18689/ijmr-1000105

Published by Madridge Publishers

Abstract

Disposal of spent alkaline batteries into the environment is a major concern as the metal leachate enters into aquatic environments. Microalgae are widely used in metal toxicity assay since they are sensitive organisms with a high capacity of bioaccumulation due to their high surface of contact. In this study, zinc and manganese were recovered from spent batteries through acid treatment and the leachate was tested on *Chlorella vulgaris* for adverse effects. Three acids namely, sulphuric, phosphoric and hydrochloric acid were used as leaching solution to recover the metals from alkaline batteries. Microalgal cells were exposed to the metal leachate and the adverse effects by means of morphological changes were observed. All the tested metal leachates have produced detrimental changes within three minutes of exposure. The results revealed the possible toxicity of metal leachate from battery litters into the environment and its detrimental effect on microalgae.

Keywords: Zinc; Manganese; Batter litter; Metal leachate; *Chlorella vulgaris*.

Introduction

Alkaline batteries that contain zinc and manganese dioxide due to their easy use and low cost are widely used. The chemically active components are high purity zinc powder for the anode, electrolytically produced manganese dioxide for the cathode and concentrated potassium hydroxide solution for the electrolyte. The management of spent batteries has been an issue of environmental concern. Batteries represent a large volume of toxic and hazardous materials [1]. Urban battery litter contains mainly AA and AAA size batteries accounted for more than 90% of the total [2]. Pollution caused by the alkaline batteries was less than that of zinc carbon because the former contain less lead (Pb) and cadmium (Cd) than the latter [3]. The zinc anode of dry cells contains low percentages of Cd and Pb for improvement in strength and ductility. Among the battery types used for various purposes, majority are single use batteries that find their way to landfills or incinerators.

The designs, manufacture, recycle and disposal of batteries all necessitates some form of hazardous waste management [1]. Basically battery is disposed by four methods: composting, incineration, land filling and recycling. Land filling was the most frequently used; and recycling was the most preferred by industry and environmentalists [4]. With any battery disposal method, the potential exists to release heavy metals into the environment through landfill leachate or incineration stack gases. The disposal of batteries into the environment leads to leaching of heavy metals from landfills into ground water, or volatilize into the atmosphere during combustion at open dumpsites [5].

Microalgae are widely used in metal toxicity assay since they are sensitive organisms with a high capacity of bioaccumulation due to their high surface of contact [6]. In this study, *Chlorella vulgaris* was used as model organism to evaluate the detrimental effect of zinc and manganese recovered from spent alkaline batteries through acid treatment. The cell morphology of microalgae exposed at various time intervals to metal solution from battery powder was considered as a parameter of metal toxicity.

Materials and Methods

Organism and growth conditions

Monoalgal, axenic culture of *Chlorella vulgaris* was used in this study. The algae were grown in Bold's basal media with continuous illumination (white fluorescent light, 132 mmol photons m^{-2} sec^{-1}).

Battery dismantling and leaching process

Spent alkaline batteries of AA size were manually dismantled using a hammer mill. The other components of battery such as plastic films, ferrous scraps and paper pieces were scrapped. The black powder obtained containing zinc and manganese was used for the experiments.

Leaching

0.1 g of the dry black powder obtained was transferred to beakers containing 10 ml of leaching solution (Sulphuric acid, hydrochloric acid, phosphoric acid). A magnetic mixer with heating system was used to provide good contact between the powder and leaching solution. After the leaching period, the mixture was filtered and the filtrate was used for the experiments.

Effect of battery leachate on microalgae

The effect of zinc and manganese obtained from spent battery (leachate) was evaluated on the morphological changes of *C. vulgaris*. 0.1 ml of microalgal culture was added with 0.9 ml of leaching solution and the mixture was allowed to stand for 5 minutes. 2-3 drops of the treated microalgal cells were taken at every minute and observed under a microscope for morphological changes. Acid alone was used as control.

Results

The batteries used in this work were a common brand, AA size spent batteries. Acidic and alkaline solutions were tried to dissolve the battery powder along with distilled water. Among the solutions tested, acidic solution involving H_2SO_4 was dissolving the battery powder completely resulted in a black solution. Concentrated sulphuric acid, hydrochloric acid and phosphoric acid were used to recover zinc and manganese from the spent batteries. The recovery of both Zn and Mn from batteries treated with H_2SO_4 can be written according to following equations.

$$ZnO+H_2SO_4 \longrightarrow ZnSO_4+H_2O$$

$$Mn_2O_3+H_2SO_4 \longrightarrow MnSO_4+MnO_2+H_2O$$

The effect of zinc and manganese recovered from battery powder through acid treatment was evaluated by microalgal exposure time. The detrimental effect of heavy metals from spent batteries was higher with increasing time of exposure to *C. vulgaris* (Figures 1-3). Among the acids tested, hydrochloric acid had more impact on the morphological changes than the sulphuric and phosphoric acid. The microalgal cells were treated with battery leachate prepared by various acid treatments and observed under a microscope for morphological changes for a period of three minutes. Above this period, most of the cells were disappeared thus indicating the lethal effect of battery leachate. In general, all the three acids were produced detrimental effect on *C. vulgaris* revealing the metal toxicity from spent batteries.

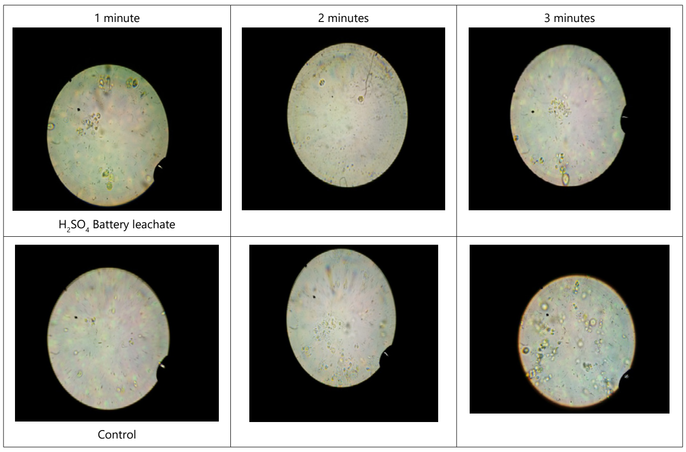

Figure 1. Cells of *C. vulgaris* exposed to battery leachate from H_2SO_4 treatment.

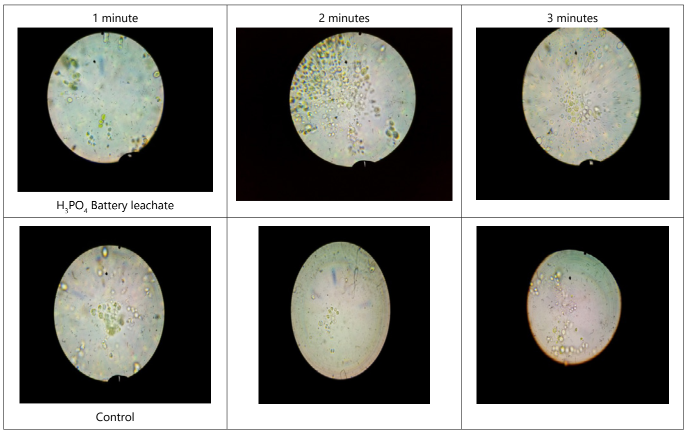

Figure 2. Cells of *C. vulgaris* exposed to battery leachate from H_3PO_4 treatment.

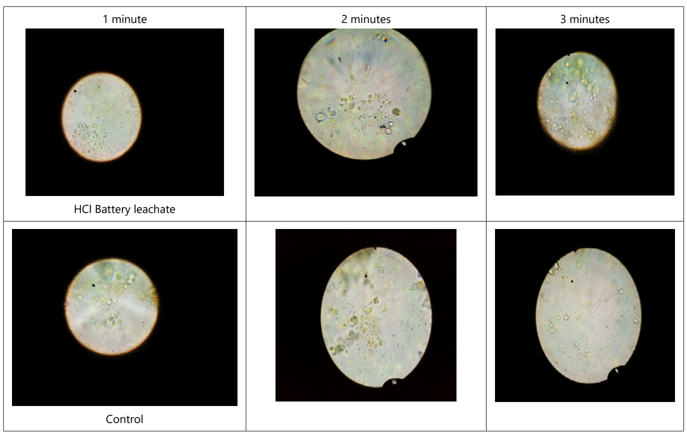

Figure 3. Cells of *C. vulgaris* exposed to battery leachate from HCl treatment.

Discussion

The features of batteries make them an efficient power source. The consumption of batteries has increased because of the versatility, reduced cost and its requirements by the electronic devices. H_2SO_4 was used to recover the metals from alkaline batteries [7,8]. In this study, the experiments were carried on using diluted sulfuric acid in the range of 0.1 N, 0.3 N and 0.5 N as the leaching stage with these concentrations of sulfuric acid is commonly used to dissolve ZnO [9]. Spent battery electrode powder, containing Mn and Zn was treated via reductive leaching by H_2SO_4 and 0.5 mol/L of H_2SO_4 was found optimal reductive leaching condition [10].

Metal ions can enter the cells if the cell wall is disrupted by natural or artificial force [11] and compartmentalized into different sub cellular organelles. In this study, the acidic pH could have caused the cell wall damage in microalgae that facilitates the entry of zinc and manganese. Zinc is an essential trace element for aquatic organisms and humans however high concentrations of zinc may cause adverse effects to the organisms [12-15]. Zinc toxicity to the microalgae *Scendesmus obliquus* was reported by Li et al. [16] with LC50/EC50 value ranged between 0.057–0.217 mg/l. The effect of zinc and manganese on the microalgae *Pavlova viridis* was studied by Li et al. [17,18] and the increase in antioxident enzyme activity indicated the oxidative stress caused by the metals. For zinc, growth inhibition may not be related to the intracellular metal concentration, but to extracellular zinc [19]. The possible mode of toxic action of zinc is related to the cell membrane, where it may disrupt the uptake of calcium which is necessary for the Ca-ATPase activity in cell division [20]. Manganese toxicity to terrestrial plants and humans has been reported [21,22]. Based on the previous studies, it was reported that both zinc and manganese has adverse effects on aquatic organisms. The disposal of spent batteries into the environment leads to leaching of toxic metals into terrestrial and aquatic habitats. From this study, the detrimental effect of battery leachate on *C. vulgaris* has proven that alkaline battery waste are of major concern in affecting the microalgae and other aquatic organisms.

Conclusion

This study investigated the toxicity of metals recovered from spent battery on the microalgae, *Chlorella vulgaris*. Sulphuric acid, phosphoric acid and hydrochloric acid were used as leaching solutions to recover zinc and manganese from alkaline batteries. The microalgal cells were treated with battery leachate and within 3 minutes of exposure, the cells were killed and were confirmed by the discoloration and changes in the morphological characteristics. The results revealed the toxicity of metal leachate from battery litters into the environment and its detrimental effect on microalgae.

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