Ecology:

Effects of Bauxite on Marine Invertebrate Populations in Discovery Bay, Jamaica

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Abstract: *Bauxite mining is an economically important industry in Jamaica. Though bauxite dust, containing heavy metals like aluminum, iron, manganese, lead, and zinc, is often present in ecosystems in the vicinity of Jamaican mining facilities, the influence of bauxite contamination on marine near-shore ecosystems in Jamaica has not been evaluated. Here, we assess (1) whether abundance of infaunal invertebrates differs among sites that may have different bauxite contamination levels, and (2) whether bauxite is likely to drive these differences. We sampled the infaunal invertebrate communities of three sites at different distances from the Kaiser Jamaica Bauxite Company in Discovery Bay, Jamaica, and found that the abundance of infaunal invertebrates was lowest at the highest contamination site and highest at the lowest contamination site. We also experimentally exposed mysid and brine shrimp to processed bauxite and sediments from the three sites. Results from these experiments suggest that bauxite may increase mortality of mysid shrimp and, hence, drive the differences in infaunal abundance observed in the field. In addition to increasing invertebrate mortality, bauxite may have sub-lethal effects. The influence of this contaminant on the behavior, growth, reproduction, and other physiological processes of marine organisms deserves further study because of its potentially harmful effects on benthic marine communities.*

Introduction

Waste from the processing of aluminum oxide (i.e. bauxite tailings, or "red sludge," and dust contaminated with aluminum, iron, lead, manganese and zinc) is often present in ecosystems in the vicinity of bauxite mining facilities (1). Exposure to bauxite reduces the abundance of freshwater macroinvertebrates (2,3,4), reduces the viability of sea urchin embryos (5), and may otherwise negatively affect marine invertebrate communities.

Bauxite dust from Kaiser Jamaica Bauxite Company is deposited in the Columbus Park area of Discovery Bay, Jamaica (adjacent to the Kaiser loading wharf), by wind and spillage during transfer of bauxite to ships for transport (6). We hypothesized that the deposition of bauxite dust at Discovery Bay would have negative impacts on infaunal assemblages. We assumed that bauxite contamination would decrease with increasing distance from the Kaiser plant; therefore, we predicted that there would be greater infaunal colonization of bristle brushes submerged at a site (i.e. West Back Reef) one km away from the Kaiser Jamaica bauxite loading wharf than at Columbus Park, reflecting greater infaunal abundance at the distant site relative to Columbus Park. Similarly, we expected that infaunal colonization would be greater at a site six km from the loading wharf (i.e. Pear Tree Bottom) than at either Columbus Park or West Back Reef.

We also hypothesized that marine invertebrates experimentally exposed to bauxite and bauxite-contaminated sediments would have lower survivorship than those exposed to uncontaminated sediments. We expected that mysids exposed to bauxite would have the highest mortality, followed by those exposed to sediment from Columbus Park, West Back Reef and Pear Tree Bottom. We also predicted that brine shrimp eggs exposed to these treatments would show similar patterns in hatching rate.

Methods

We selected three sampling sites: Columbus Park (CP), West Back Reef (WBR), and Pear Tree Bottom (PTB). CP, our contaminated site, was approximately 500 m from the Kaiser Jamaica loading wharf; WBR, our intermediate contamination site, was one km northwest of the wharf; and PTB, our uncontaminated site, was six km east of the wharf. On 3 March 2005, we laid a 10 m transect parallel to the shore on fine-grained sediment and at a depth of approximately one m at each site. At five randomly-selected points along the transect, we inverted a plastic container over the sediment, pressed the lip of the container five cm into the sediment, and scooped that sediment into the container (approximately 1.5 L of sediment), homogenizing the five samples within each site. We also collected seawater from above the sediment at each site. Because sediment grain size can influence infaunal communities (7), we wanted to ensure that mean grain size was similar

Image courtesy of the US Geological Survey between sediment treatments. We therefore sieved the homogenized sediment mixtures with coarse mesh to remove large sediment fragments and decrease the differences in average grain size among treatments. All seawater collected was strained with a 153 µm mesh to remove zooplankton. Bauxite was collected from outside the Kaiser Jamaica Bauxite Company.

We created five treatments for our mysid and brine shrimp experiments: uncontaminated (PTB sediment and PTB water), intermediate contamination (WBR sediment and WBR water), contaminated (CP sediment and CP water), bauxite (pure bauxite and PTB water), and a control (PTB water and no sediment). In the mysid experiment, we filled ten plastic containers (approximately 2 Ls each), excluding the control, with a 1.5 cm layer (approximately 250 mL) of the appropriate sediment and a 3.5 cm layer (approximately 1 L) of the appropriate seawater. The control was filled with a 5 cm layer of PTB seawater. There were two containers per treatment and five treatments. We used pipets to add 30 mysid shrimp (genus *Mysidium,* collected from WBR on 5 March 2005) to each container at 11:00 h on 5 March 2005. For 108 h, two independent observers counted the number of surviving mysids every 12 h. The two counts were averaged for each time step. We also made observations of mysid behavior. We used one-way ANOVAs to compare mysid survivorship among treatments at 12 h, 36 h, 60 h, and 96 h.

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In the brine shrimp experiment, we added a 1.5 cm layer (approximately 38 mL) of the appropriate sediment and 3.5 cm layer (approximately 1 L) of the appropriate seawater to each of five Nalgene bottles. Each container was continuously aerated with a bubbler and received lamplight for the duration of the experiment. We added approximately 3 mL of dry brine shrimp cysts (genus *Artemia*) to 10 mL of water, and added 2 mL of this mixture to each treatment on 5 March 2005. We counted the number of unhatched eggs, dead individuals, and live individuals in a 2 mL subsample 48 hours after the addition of the cysts. A second replicate of these treatments began on 8 March 2005 and ran for 48 h. We calculated the proportion of live hatchlings in the total number of live hatchlings + eggs + dead hatchlings, and the proportion of dead hatchlings in the total number of live hatchlings + dead hatchlings. We used one-way ANOVAs to compare the means of these proportions among treatments.

For the invertebrate colonization experiment, we attached bristle brushes to bricks with cable ties and wire. Four bricks were placed at two m intervals along the transects used for collecting sediment at each site (i.e., CP, WBR, PTB) on 4 March 2005. Bristle brush colonization is a reasonable proxy for abundance of infaunal invertebrates (8). After 72 h, we retrieved the bristle brushes from each site and immediately rinsed them in saltwater and freshwater to completely defaunate them. We preserved infauna in 10% formalin and counted and identified all specimens to order. Total abundance and individual taxa abundances as a proportion of total abundance were compared between the three sites with one-way ANOVAs.

Results

At 12 h, mysid survivorship differed significantly among the five treatments (One-way ANOVA, $F = 7.55$, $df = 4,5$, $p = 0.02$). More mysids had died in the bauxite treatment than in the PTB and control treatments (Tukey's HSD post-hoc test, $\alpha = 0.05$; Fig. 1). Mysid survivorship in the CP and WBR treatments did not differ significantly from other treatments. At 36 h, 60 h, and 96 h, there was no significant difference in mysid survivorship among treatments ($F < 1.84$, $df = 4,5$, $p > 0.26$). We observed a lower activity level and less swarming in the bauxite treatment relative to other treatments.

We found no difference in the proportion of live hatchlings in the total sample (i.e., [# live hatchlings]/[# live hatchlings + # eggs + # dead hatchlings]) among the treatments in the brine shrimp experiment ($F = 1.72$, $df = 4,5$, $p = 0.28$). There was also no difference in the proportion of dead hatchlings in the number of animals that had hatched (i.e., [# dead hatchlings]/[# live hatchlings + # dead hatchlings]) among the treatments ($F = 0.27$, $df = 4,4$, $p = 0.88$).

Abundance of infaunal invertebrates sampled from bristle brushes differed significantly among the three sampled sites ($F = 11.81$, $df = 2,9$, $p = 0.003$). Abundances at PTB and WBR were greater than abundance at CP (Tukey's HSD post-hoc test, $\alpha = 0.05$; Fig. 2).

The proportions of copepods, amphipods, isopods, decapods, ostracods, and polychaetes were similar among the three sites ($F < 2.11$, $df = 2,9$, $p > 0.18$). The proportion of gastropods was marginally higher at PTB than at CP or WBR ($F = 4.01$, $df = 2,9$, $p = 0.06$). However, a Tukey's HSD post-hoc test found no significant difference in gastropod abundance among the sites. The proportion of foramaniferans was greater at PTB than at CP or WBR ($F = 15.22$, $df = 2,9$, $p = 0.001$).

Discussion

Our results suggest that bauxite contamination may negatively influence marine invertebrate communities in Discovery Bay, Jamaica. Though results from our brine shrimp experiment did not support our hypothesis, data on mysid survivorship suggest that bauxite may increase the likelihood of death in exposed individuals. At 12 h, there were more surviving individuals in the control and low contamination treatment (i.e., PTB) than in the bauxite treatment. As expected, survivorship for individuals in the high contamination treatment (i.e., CP) was greater than that for individuals in the bauxite treatment and less than that for individuals in the intermediate and low contamination treatments; however, these relationships were not significant.

At 36 h, 60 h, and 96 h, there were no significant differences in mysid survivorship among treatments. However, trends conformed to our predictions. The low and intermediate contamination sites (i.e., PTB and WBR) had higher survivorship than the high contamination site (i.e., CP), and the high contamination site had higher survivorship than the bauxite treatment. Given the low number of replicates (2) within each treatment, it is reasonable to conjecture that increasing replication might increase the likelihood of detecting significant differences among the treatments at the various time steps.

Surprisingly, survivorship at 36, 60, and 96 h of individuals in the control treatment was comparable to survivorship of individuals in the high contamination and bauxite treatments. The control treatment lacked sediment, and consequently may have also lacked food. This may explain the high rate of death in the control treatment relative to that in some of the other treatments, all of which contained sediment. The bauxite treatment contained only bauxite collected from the Kaiser Jamaica bauxite processing facility, and therefore, probably also lacked food. Survivorship of individuals in the bauxite treatment was lower than that for individuals in the control treatment, though this relationship was not significant. This indicates that there may be an effect of bauxite (i.e., toxicity), other than lack of food, which caused greater mortality in this treatment. This is further supported by the significant difference in mortality between the bauxite and control treatments at the 12 h time step. The results of the mysid experiment provide some support for our prediction that survivorship depends on the level of bauxite contamination in a treatment, and suggests that bauxite may negatively affect marine invertebrates.

Data from our study of invertebrate colonization rates at the three sites agree with our predictions, and the results of our mysid experiment. We found fewer invertebrates in brushes collected from the high contamination site, CP, than in those from the intermediate and low contamination sites, WBR and PTB. There were more invertebrates in brushes collected at the low than intermediate contamination site, although this difference was not significant. Because bristle brush colonization is a reasonable proxy for infaunal abundance (9), these results suggest that the abundance of infaunal invertebrates in the field may decrease with increasing exposure to bauxite. We found no significant differences in the proportion of each taxon among the three sites, except a greater abundance of foramaniferans at PTB than at WBR or CP. No research of which we are aware suggests that foramaniferans are especially sensitive to environmental contaminants, and we therefore conclude that the observed difference is probably due to other site-specific factors. While bauxite may reduce the abundance of infauna, there is little evidence for an effect of bauxite on infaunal community composition.

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The results of this study indicate that (1) bauxite is potentially detrimental to marine invertebrates, and (2) levels of bauxite contamination in Discovery Bay may be high enough to negatively influence invertebrate communities. Mortality, however, is not likely to be the only effect of bauxite contamination. Our observations of mysid behavior suggest that individuals exposed to bauxite are less active and less likely to exhibit swarming behavior. These effects could have important implications for populations of mysids and other marine invertebrates exposed to bauxite in the field. The effects of bauxite on behavior, growth, reproduction and other physiological processes in marine invertebrates deserve further study.

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