DIFFERENTIATION OF PHYSICAL FROM CHEMICAL TOXICITY IN SOLID WASTE FISH BIOASSAYS

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Abstract. This study showed that particulate (i.e., physical) toxicity was responsible for rainbow trout deaths in bioassays with two separate solid wastes. This conclusion was based on: (1) fish necropsies which indicated physical damage to gills but no evidence of chemical damage to liver or kidney, (2) chemical analyses which indicated that levels of Priority Pollutants and other target compounds were too low to cause the observed toxicity, (3) structural and chemical analyses of the waste particles which showed that these consisted of inert materials, and (4) the use of centrifugation techniques to remove most of the suspended particulate material in bioassay tanks resulting in an elimination of most of the toxicity. The particles associated with the lethal effects were approximately 5 to 10 μm in size. Regulatory testing of solid wastes must distinguish physical and chemical toxicity since disposal options can vary depending on the mode of toxicity. For instance, chemical toxicity raises concern regarding leaching through soils into groundwater, whereas if physical particles are responsible for toxicity, such leaching is not of concern.

1. Introduction

Increasing environmental awareness has led to increasing regulatory control, particularly with regard to the disposal of solid wastes. To date, in the United States, only Washington State includes an aquatic toxicity test as part of its regulatory procedures for classifying solid wastes stored on land. The Washington State Department of Ecology (WDOE, 1981) Static Acute Toxicity Test is adapted from ASTM (1980) and is intended as a range-finding test to determine the acute toxicity of materials following the requirements of the Washington State Hazardous Waste Regulations. This test involves a total of seven test chambers with 10 fish in diluent water added to each chamber. One chamber acts as a control, three chambers contain a 1000 mg L⁻¹ concentration of the waste, and three chambers contain a 100 mg L⁻¹ concentration of the waste. If, after 96 hr, more than 10 out of 30 fish die in the 100 mg L⁻¹ chambers, the waste is classified as Extremely Hazardous. If more than 11 out of 30 fish die in the 1000 mg L⁻¹ chambers, the waste is classified as Dangerous. Lower levels of mortalities result in an Unclassified designation.

In Washington State, multimillion dollar disposal decisions are based on the results of these simple bioassay tests, and it is expected that similar aquatic bioassays will be
more widely used in future for the regulation of waste disposal (Dowd, 1984). Accordingly, it is imperative that these tests provide a realistic basis for classification, in particular that physical and chemical toxicity be distinguished. Wastes that are chemically toxic require far more rigorous (and expensive) disposal than wastes that are physically toxic. For instance, chemical toxicity raises concern regarding leaching through soils into groundwater, whereas if physical particles are responsible for toxicity, such leaching is not of concern.

This study originated after a series of WDOE (1981) solid waste bioassays with material from an aluminum smelter produced conflicting results (sometimes fish died, sometimes they did not), and chemical analyses of the waste material, and of the leachate water, indicated that this material did not contain any chemical contaminants at high enough levels to account for the observed lethali ties. Although physical toxicity was not initially suspected, preliminary necropsies of fish gills (conducted in an attempt to determine the mechanism of toxicity) indicated that this was a possible cause of the observed mortality. Subsequent studies were aimed at determining the exact cause of mortality, and reasons why these materials were not consistently lethal to the fish.

Physical toxicity, in the form of grain size effects, has been identified in marine sediment bioassays with infaunal amphipods (Swartz et al., 1985), but the mechanism of toxicity has not been examined. Physical toxicity has been recognized by the U.S. Environmental Protection Agency (1972, 1976) as a separate regulatory problem from chemical toxicity but only in terms of water quality criteria, not in terms of solid waste toxicity testing.

In the present paper, we show that particulate, physical toxicity accounts for mortalities in WDOE (1981) fish bioassays with particular solid wastes, describe the apparent mode of action of this physical toxicity, and describe a procedure that reduces physical toxicity as a factor in these bioassays.

2. Materials and Methods

Testing was conducted using two separate solid wastes produced by the Intalco Aluminum plant in Ferndale: a dust and a sludge. All bioassays were conducted following WDOE (1981) protocols, using rainbow trout (Salmo gairdnerii) and clean glass aquaria. Fish were held and acclimated for a minimum of 14 d and a maximum of 30 d prior to testing and were fed ad libitum until 24 h prior to testing when feeding was discontinued. All testing adhered to APHA (1985) criteria and was conducted at pH 6.0 to 6.2, 12 ± 1 °C, dissolved oxygen levels greater than 9.0 mg L⁻¹, 45 mg L⁻¹ CaCO₃ hardness, and fish loading densities of 0.25 to 0.50 g L⁻¹.

The dust had been previously submitted to nine separate WDOE (1981) bioassays with mixed results (in some cases all the fish died, in some none died). The sludge had been previously submitted to two separate WDOE (1981) bioassays and had proved lethal in both cases. However, in none of these previous bioassays had chemical analyses indicated a source of this toxicity (chemical levels detected were consistent with more detailed analytical results reported herein, cf. Table I).