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Toxicity of Coal Gasifier Solid Waste to the Aquatic Plants *Selenastrum capricornutum* and *Spirodela oligorhiza*

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Government and industry in the United States are considering the products of small coal gasifiers as supplements for oil and natural gas (USDOE 1981). These coal gasification plants produce solid and liquid wastes that are potentially hazardous to the environment. Memphis Light, Gas and Water (MLGW) is considering a coal gasification plant for Memphis, TN. This plant will consume 2800 tons of coal per day and produce significant quantities of gasifier agglomerates and wastewater sludge as solid waste products. Since these solid wastes are to be stored on land adjacent to the plant, the relative environmental hazard of the waste is important. Disposal of solid waste in landfills has caused many environmental problems due to failures in the integrity of the landfill. This has caused leakage of stored material from the dump into the surrounding environment contaminating both surface and ground water resources. The relative toxicity of the potential leachate from stored coal gasification solid waste is necessary to predict the environmental impact in the event of leakage from the landfill.

Few studies of the environmental effects of coal gasification plants have been reported (Page 1978; Thomas et al. 1978); the Industrial Fuel Gas (IFG) design to be used by MLGW has not been assessed (USDOE 1981). The Foster-Wheeler/Stoic design was studied by Cushman et al. (1982) and relatively little toxicity was found in distilled water leachates from bottom ash when tested with *Daphnia magna*, *Selenastrum capricornutum*, and *Microcystis aeruginosa*. This process is different from the IFG process; they operate under different pressure and temperature regimes and thus produce different qualities of solid wastes.

Classical assessment of aquatic toxicity has focused on fish and invertebrates primarily due to their economic importance. However, increased awareness of the role of aquatic vegetation as primary producers in aquatic systems has stimulated their use in aquatic hazard evaluations. Toxicity bioassays using algae (Miller et al. 1978) and floating aquatic vascular plants (Walbridge 1977) have been developed. This paper presents the results of solid waste leaching tests using a procedure which was designed to mimic landfilling of solid waste. Results are reported for leachate analysis of the ash agglomerate and the relative toxicity of this leachate to *Selenastrum capricornutum* (a unicellular green alga) and *Spirodela oligorhiza* (a floating aquatic vascular plant).

MATERIALS AND METHODS

Ash agglomerate, generated at the Institute of Gas Technology pilot plant in Chicago, Illinois, was obtained from MLGW. Samples were subjected to the Extraction Procedure (EP) of the U.S. Environmental Protection Agency (USEPA 1980). One hundred grams of sample were passed through a 9.5 mm sieve and added to 16 times its weight of distilled water. The pH was adjusted to below 5.0 with 0.5 N acetic acid and the sample was mixed for 24 hr at room temperature. The pH was adjusted to 5.0 and distilled water was added according to the following equation:

$$V = 20(W) - 16(W) - A$$

Where V is the amount of distilled water to be added, W is the weight of solids charged to the extraction vessel, and A is the amount of 0.5 N acetic acid added. Liquid was separated from the solids by passing it through a 0.45 μm membrane filter.

Total alkalinity, total hardness, pH, total dissolved solids, chemical oxygen demand, total organic carbon, phenols, and total chromium were determined in accordance with standard methods (USEPA 1979, APHA/AWWA/WPCF 1975).

Leachate toxicity to *Selenastrum* was determined using growth optimized static bioassays (Klaine and Ward 1983). The algal stock cultures were originally obtained from the National Eutrophication Research Laboratory, USEPA, Corvallis, OR. Erlenmeyer flasks (250 ml) were shaken (100 RPM) in a Controlled Encironment Incubator Shaker (New Brunswick Scientific Co.), aerated with 0.5% (v/v) enriched air, illuminated with fluorescent tubes (120 $\mu E\ m^{-2}\ s^{-1}$), and held at constant temperature (24 ± 2^{o}C). Axenic cultures were grown in a modified basal nutrient medium originally developed for the Algal Assay Bottle Test (Miller et al. 1978). Modifications include a tenfold increase in nitrate nitrogen concentration and buffering at pH 7.1 with a 0.03 M phosphate buffer. The medium was routinely autoclaved for 15 min at 15 psi and 121^{o}C. Algal cells were counted every 12 hours and the exponential growth rate determined by measuring the slope of the straight-line portion of the semilog plot of cell number versus time.

Leachate toxicity to *Spirodela* was determined using axenic cultures obtained from Dr. D. L. Sutton, University of Florida, Ft. Lauderdale, FL. One-third strength Hutner's medium (Hutner 1953), pH 6.5, was autoclaved in 100 mm diameter storage jars (Corning Glass), and three or four fronds were added to begin the bioassay. All tests were performed in a Controlled Environment Incubator Shaker (120 $\mu E\ m^{-2}\ s^{-1}$ and $24 \pm 2^{o}C$). Fronds were counted daily and the exponential growth rate determined from the straight-line portion of the semilog plot of frond number versus time.

RESULTS AND DISCUSSION

No toxic substance was apparent from the chemical analysis of the EP leachate (Table 1). All values are below Resource Conservation and Recovery Act (RCRA) standards (USEPA 1980). Values for total organic carbon and chemical oxygen demand indicate that a large amount of organics may leach from the ash agglomerate. These organics may exert chronic effects on aquatic organisms, but had little acute effects on the two organisms tested.

Table 1. Chemical analysis of EP leachate

pH	4.8	
Total dissolved solids	190.0	mg L^{-1}
Total alkalinity	45.0	mg L^{-1}
Total hardness	31.0	mg L^{-1}
Chemical oxygen demand	251.0	mg L^{-1}
Total organic carbon	95.0	mg L^{-1}
Phenols	0.018	mg L^{-1}
Total chromium	0.006	mg L^{-1}

Toxicity bioassays with Selenastrum indicate a computed EC_{50} (effective concentration of leachate required to reduce growth rate 50%) of 55% leachate (v/v). The threshold of toxic response was 20% leachate (Figure 1). The EC_{50} for Spirodela was 76% leachate (v/v) and the threshold was 20% leachate (Figure 2). The USEPA assumes at least a ten-fold dilution of the leachate in the environment (Epler et al. 1980). Neither organism responded to 10% of the leachate in the bioassays. These results indicate that the growth response of the organisms tested is quantitatively related to leachate concentration; and that the IFG gasifier solid wastes would not be hazardous as classified by RCRA guidelines.

The EC_{50} values indicate that Selenastrum is more sensitive to the leachate than Spirodela. Since the alga is distributed throughout the water column and the duckweed only inhabits the water surface, the alga maintains a more constant exposure to the toxicant. Uptake processes in the vascular plant may be quite different from the alga resulting in less toxicant being absorbed by the duckweed. Additional studies are needed to delineate additional differences between these two test species.

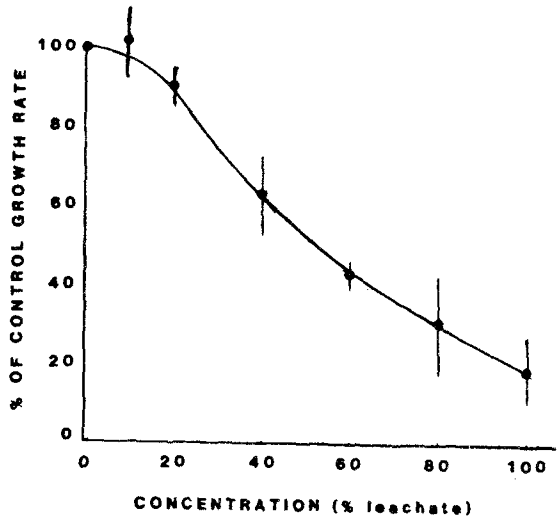

Figure 1. Effects of Ash Agglomerate EP Leachate on Selenastrum capricornutum. Error bars represent 95% confidence interval, n=3.

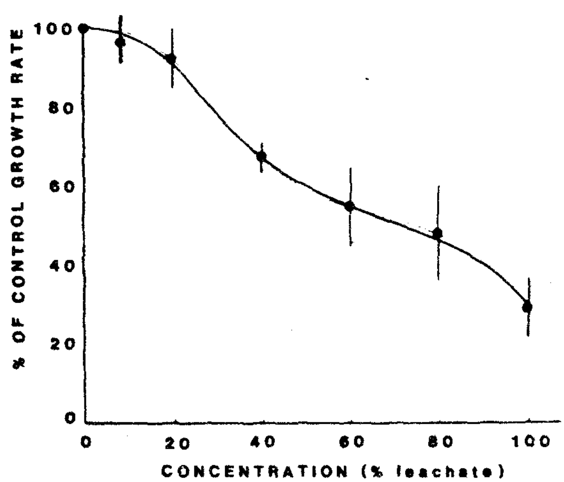

Figure 2. Effects of Ash Agglomerate EP leachate on Spirodela oligorhiza. Error bars represent 95% confidence interval, n=3.

If the integrity of a landfill was compromised, leachate would impact a receiving stream as a pollutant. The high levels of organics in this leachate may present a chronic effect on aquatic organisms, especially if these organics are bioconcentrated or bioaccumulated. It is also possible that these organics may affect drinking water quality downstream. Data are needed to determine the chronic effects of these types of wastes on both plants and animals.

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