

Dose – Response Relationship of Organisms in Soil with Heavily Weathered Hydrocarbons and Changes in Fertility Parameters

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ABSTRACT

The response of different types of organisms in soil containing highly weathered hydrocarbons was investigated. Heavily weathered oil was only slightly toxic to earthworms and bacteria; only above 50,000 mg/Kg TPH was a response observed in earthworms (*Eisenia foetida*, ~5 % mortality), and concentrations of ~30,000 mg/Kg were only slightly toxic to bacteria (Microtox). None-the-less, at even low concentrations, these kinds of hydrocarbons reduced vegetative growth, apparently by modifying soil fertility parameters. In soil contaminated with very weathered heavy oil range hydrocarbons, native marshy vegetation (*Cyperus laxus* Lam.) showed a reduction of 10 % in height at ~2,300 mg/Kg ($r^2=0.976$). Likewise, in soil contaminated with mid-range hydrocarbons which had been co-produced with and weathered in the presence of sulfur, ~2,600 mg/Kg showed a reduction in above ground biomass production in pasture (*Brachiaria humidicola*) of 10 % ($r^2=0.982$). These observations were correlated with a reduction in the field capacity of the soil ($r^2=0.964$) which showed a linear relationship with TPH concentration ($r^2=0.993$). These finding suggests that the principal mechanisms by which hydrocarbons affect soil organisms is qualitatively different with fresh hydrocarbons and very weathered hydrocarbons, and that toxicity and field capacity are more appropriate parameters to use as soil remediation criteria.

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INTRODUCTION

Historically, many petroleum producing regions employed waste disposal and treatment methods which were inadequate to avoid severe impacts to soil. This is the case in the Gulf of Mexico region, especially in Tabasco and southern Veracruz area (1). With respect to determining appropriate clean-up criteria for sites with chronic contamination resulting in the last century, it is important to evaluate the impacts to soil organisms (2). It has been shown that the kinds of heavily weathered hydrocarbons present in old sites are very difficult to degrade (3), but have relatively low toxicity (4). In the present study the differential response of earthworms, bacteria, and plants to the presence of heavily weathered hydrocarbons in the soil were compared. Also, the relationship between plant development and impacts to soil physical-chemical properties was evaluated.

METHODOLOGY

In the first set of experiments, sediments were collected from a marshy area in which several grasses and *Cyperus* spp. were present as clusters in a heavily contaminated marshy area behind a refinery which was constructed nearly 100 years ago. The hydrocarbons contamination was due to chronic discharges over several decades (roughly eight) during which the hydrocarbons were weathered in a humid tropical environment. Oily material and sediments were collected as well as *Cyperus laxus* (Lam) plants. Contaminated soil was mixed with clean soil, peat and tezotle to obtain soil with a range of hydrocarbon concentrations. The soil prepared in this way was then used in dose response experiments with earthworms (*Eisenia foetida*), bacteria (Microtox bioassay) (5) and with the predominant native marsh plant, *Cyperus laxus*. In these experiments mortality, bioluminescence and biomass production were observed, respectively.

In the second set of experiments, sediments were collected from a beach area in an artificial reservoir previously used to contain waste water from a sulfur mine. This area had been contaminated with acid waste water which also contained hydrocarbons derived from the salt domes that were exploited for sulfur (the hydrocarbons were not recovered and were considered waste products by the mine operators). This area had been treated to neutralize the acidity but was still very contaminated with very viscous hydrocarbons which had been co-weathered in the presence of hydrocarbons for 10 – 20 years in a humid tropical environment. The sediment collected was very poor in non-petroleum organic matter and had a very high content of bentonite clay. This material was then mixed with red clay subsoil to obtain a range of hydrocarbon concentrations. The soil was placed in treatment cells of 0.4 m x 0.4 m x 0.2 m deep and planted with a tropical forage grass (*Brachiaria humidicola*) and aerial biomass was measured periodically by making cuttings and drying the material. This soil was also evaluated for field capacity according to ref. (6) and hydrocarbon concentrations by EPA method 418.1 (7).

RESULTS

Results of the earthworm bioassay are shown in figure 1. As observed in this figure, a typical dose-response curve produced which showed that even at very high concentrations of these heavily weathered hydrocarbons, there was relatively little adverse effect to these organisms. At concentrations up to 5 % TPH very little effect was observed. However, the

affect to the native marsh plant from this area was much greater (see figure 2). Also, a typical dose-response curve was observed with a high correlation ($r^2=0.976$), but which showed a 10 % reduction in plant height at a hydrocarbon concentration of only about 2,300 ppm (0.23 %).

In the second set of experiments, a typical dose-response curve was also produced in humidicola grass ($r^2=0.982$), and also showing a 10 % reduction in biomass at a similar concentration (~2,600 ppm, 0.26 %), (see figure 3). These observations were correlated with a reduction in the field capacity of the soil ($r^2=0.964$) (see figure 4) which showed a linear relationship with TPH concentration ($r^2=0.993$) (figure 5). However, in the microtox bioassay in this study, at concentrations of roughly 3 % TPH the toxicity in the Mictotox bioassay was only slight, especially in comparison to the natural toxicity observed in mineral soils in the region (8).

CONCLUSIONS

The very weathered hydrocarbons investigated in this study showed relatively low toxicity to both bacteria and earthworms. Both of these organisms have high surface area in contact with the contaminated media and therefore would be expected to be relatively sensitive, especially earthworms which have both external and internal membranes exposed to soil surfaces. However, in the 3 – 5 % range of hydrocarbon concentration either no adverse affect was observed, or it was very slight in comparison to the response to uncontaminated regional soils. Conversely, at very low concentrations, two vegetative species, a forage grass, and a native marshy species, showed reduced growth at concentrations as low as 0.23 – 0.26 % TPH, more than ten times less. It is to be expected that these kinds of organisms, with more resistant outer layers of cells would be less affected by potentially toxic substances. None-the-less, the opposite was observed. At the same time, a very strong inverse correlation between field capacity and TPH concentration was observed which was also strongly correlated to a reduction in vegetative biomass production.

These observations suggest that heavily weathered hydrocarbons are indeed of low toxicity as observed by other investigators (4) but that this kind of hydrocarbon adversely affects plant growth by altering physical-chemical parameters important for soil fertility. With this in mind it may be more prudent to concentrate on the restoration of these parameters in the soil, rather than on the reduction in total hydrocarbon concentration in remediation programs involving heavily weathered hydrocarbons.

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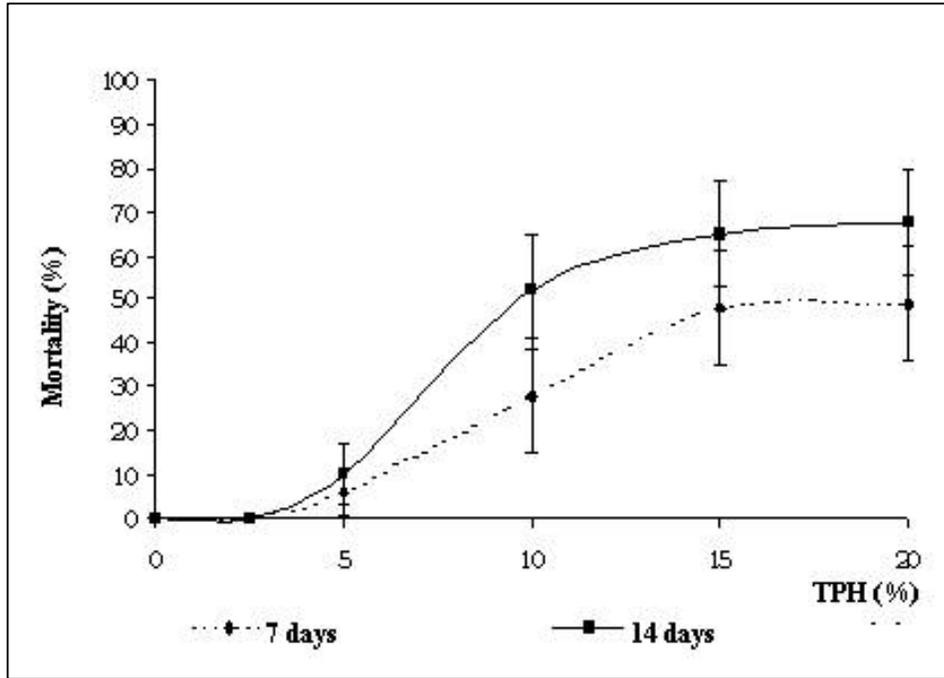


Figure 1. Mortality of *Eisenia foetida* L. at 7 and 14 days exposure to different hydrocarbon concentrations.

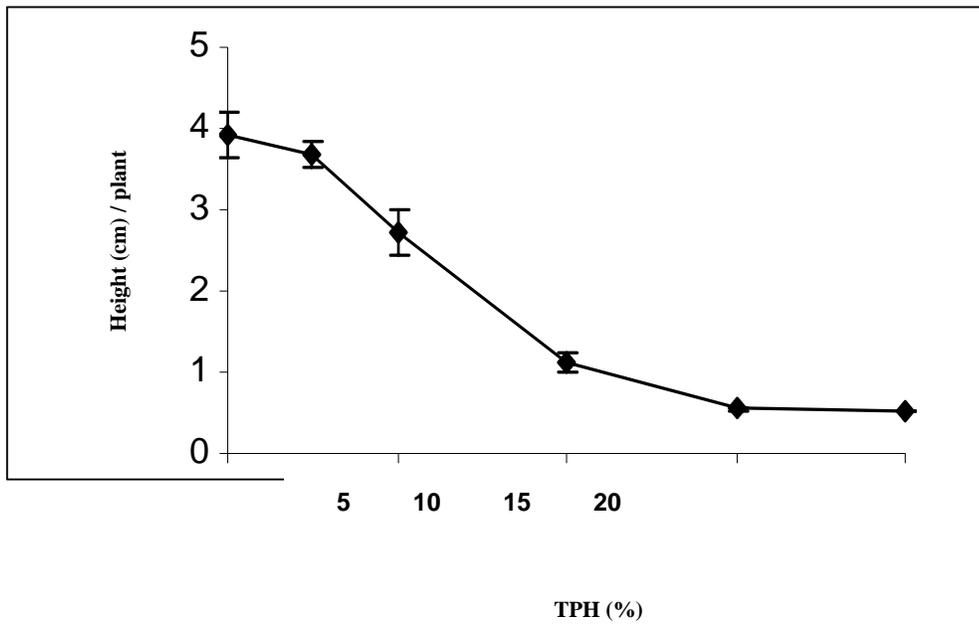


Figure 2. Plant height at different hydrocarbon concentrations.

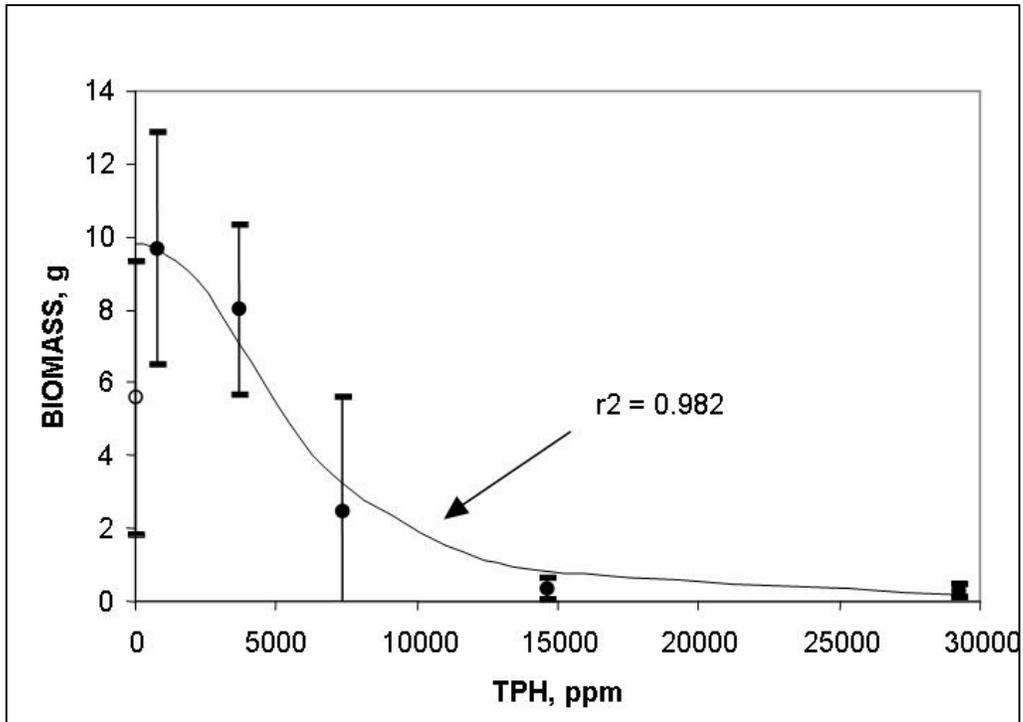


Figure 3. Dose-response relationship of humidicola grass in sediments with heavily weathered hydrocarbons.

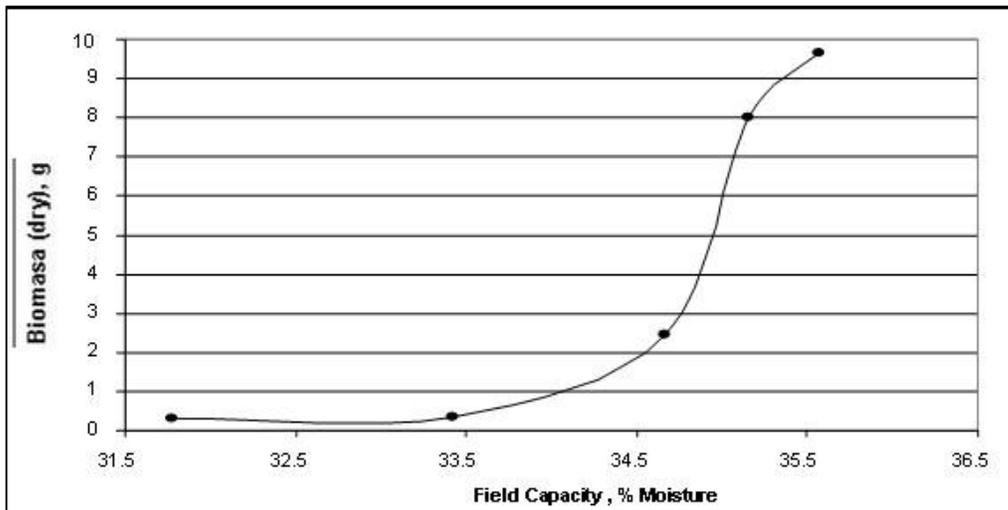


Figure 4. Biomass production in relation to field capacity in sediments with heavily weathered hydrocarbons.

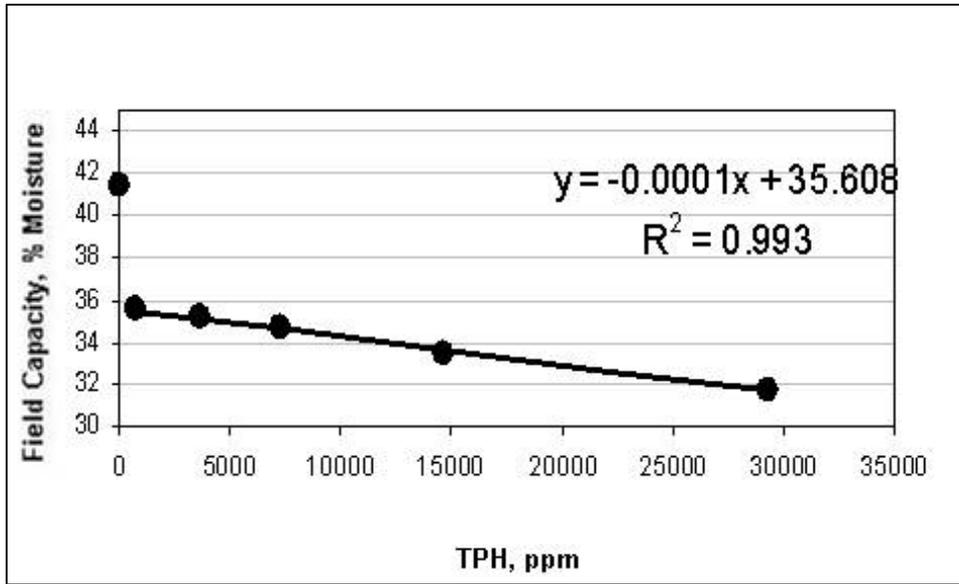


Figure 5. Relationship between field capacity and hydrocarbon concentration.