Adam, G., and Duncan, H.J. (1999) Effect of diesel fuel on growth of selected plant species. Environmental Geochemistry and Health, 21(4), pp. 353-357.

# Effect of diesel fuel on growth of selected plant species

**G. Adam and H. Duncan**

*Department of Agricultural, Food and Environmental Chemistry,Joseph Black Building, University of Glasgow, GLASGOW G12 8QQ, Scotland.*

*Received 11 June 1999; accepted 23 September 1999*

*Environmental Geochemistry and Health* 21: 353–357, 1999.

**Abstract**

Diesel oil is a complex mixture of hydrocarbons with an average carbon number of C8-C26. The majority of components consist of alkanes, both straight chained and branched and aromatic compounds including mono-, di- and polyaromatic hydrocarbons. Regardless of this complexity, diesel oil can be readily degraded by a number of soil microorganisms making it a likely candidate for bioremediation. The concept of using plants to enhance bioremediation, termed phytoremediation, is a relatively new area of scientific interest. It is particularly applicable to diesel oil contamination as diesel oil generally contaminates the top few metres of soil (surface soil) and contamination is not uniform throughout the site. By encouraging plants to grown on diesel oil contaminated soil, conditions are improved for the microbial degradation of the contaminant. During this study, establishing plants on diesel oil contaminated soil proved difficult. Diesel oil is phytotoxic to plants at relatively low concentrations. At concentrations below this phytotoxic level, the development of plants grown in diesel oil contaminated soil differs greatly from plants grown in uncontaminated soil. Tolerance of plants to diesel oil and ability to germinate in diesel oil contaminated soil varied greatly between plant species as well as within plant species. The broadest differences in germination were seen within the grasses with certain species thriving in low levels of contamination (e.g. Creeping bent) while others were intolerant of diesel oil contamination (e.g. Rough meadow grass). The herbs, legumes and commercial crops screened appeared to be largely unaffected by low levels of diesel oil contamination (25g diesel $kg^{-1}$). At the higher level of contamination (50g diesel $kg^{-1}$), half of the twenty two plant species screened failed reach a germination rate equal to 50% of the control rate. Two species of grass failed to germinate at all at this contamination level. Plant species that successfully germinated and grew were studied further to determine the effect of diesel oil contamination on the later stages of plant development. This work investigates the effect of diesel oil on plant growth and development.

**Keywords** : phytoremediation, petroleum hydrocarbons, PAHs, plant performance.

## 1. Introduction

Phytoremediation, or the use of green plants and their associated microbiota to remediate environmental contaminants, has recently become an area of intense study (Cunningham *et al*., 1996). Plants have been shown to encourage organic contaminant reduction principally by providing an optimal environment for microbial proliferation in the root zone (rhizosphere) (Kruger *et al*., 1997). These degradative processes are influenced not only by rhizosphere microorganisms, but also by unique properties of the host plant (Walton *et al*., 1994). This often leads to enhanced breakdown of organic contaminants in soils that are vegetated, compared to non vegetated soils. If plants can be successfully established on polluted soils, then the plant - microbial interaction in the rhizosphere may provide an economical method for enhancing microbial degradation of complex organic contaminants. Diesel oil is one such contaminant that should, in theory, be remediated by a mixed community of microorganisms under these conditions. In practice however, there are many problems associated with establishing a beneficial plant cover on diesel oil contaminated soil.

Diesel oil is a complex mixture of petroleum hydrocarbons containing everything from volatile, low molecular weight alkanes which are potentially phytotoxic, to naphthalenes which may interfere with normal plant development. In addition, polycyclic aromatic hydrocarbons (PAHs) found in diesel spills are of particular concern as they are relatively persistent in the soil environment. Of the medium distillate fuel oils used in terrestrial situations, diesel oil has the highest content of PAHs and total aromatics (Wang *et al*., 1990) which makes it increasingly more difficult to remediate. Within the framework of a larger study on diesel oil phytoremediation, attention was given to the effect of diesel oil on plant performance. This included the effect of diesel oil on seed germination, the spatial distribution of plant roots grown in diesel oil contaminated soil and changes in plant root morphology observed in the presence of diesel. Examples are given for a variety of different plant species including grasses, herbs, legumes and commercial crops.

## 2. Germination and Seed Emergence

Twenty two plant species including grasses, herbs, legumes and commercial crops were screened for their ability to germinate in diesel oil contaminated soil. At relatively low levels of diesel oil, delayed seed emergence and reduced germination rates were observed for a variety of plant species (Table 1).

*Table 1* Germination rates (%)[a] of plant species exposed to varying concentrations of diesel oil, measured 14 days after planting at 20ºC.

| Plant species | | Germination Rate (%) Diesel concentration (g/kg) | | |
|---|---|---|---|---|
| Common name | Latin name | 0 | 25 | 50 |
| Grasses | | | | |
| Cocksfoot | *Dactylis glomerata* | 53 | 20 | 0 |
| Creeping Bent [b] | *Agrostis stolonifera* | 30 | 38 | 5 |
| Highland Bent [b] | *Agrostis castellana* | 85 | 50 | 46 |
| Black Grass | *Alopecurus myosuroides* | 60 | 30 | 3 |
| Sweet Vernal Grass [b] | *Anthoxanthum odoratum* | 90 | 60 | 15 |
| Rough Meadow Grass [b] | *Poa trivialis* | 55 | 10 | 0 |
| Westerwold's Ryegrass | *Lolium multiflorum* | 78 | 64 | 50 |
| Sheep's Fescue | *Festuca ovina* | 58 | 38 | 24 |
| Strong Creeping Red Fescue | *Festuca rubra ssp. rubra* | 82 | 88 | 40 |
| Chewing's fescue | *Festuca rubra ssp. commutata* | 48 | 50 | 20 |
| Annual Canary Grass | *Phalaris canariensis* | 72 | 60 | 10 |
| Herbs and legumes | | | | |
| Black Medick | *Medicago lupulina* | 20 | 20 | 24 |
| Fodder Burnet | *Sanguisorba minor ssp muricata* | 18 | 16 | 2 |
| Common Vetch | *Vicia sativa* | 64 | 60 | 42 |
| Red Clover | *Trifolium pratense* | 56 | 56 | 40 |
| White Clover | *Trifolium album* | 68 | 36 | 12 |
| Little Yellow Trefoil | *Trifolium dubium* | 40 | 36 | 18 |
| Lucerne | *Medicago sativa* | 74 | 84 | 66 |
| Commercial crops | | | | |
| Oil Seed Rape cv. Rocket | *Brassica napus var. olifera* | 100 | 100 | 95 |
| Oil Seed Rape cv. Martina | *Brassica napus var. olifera* | 100 | 100 | 95 |
| Flax cv. Viking | *Linum usitatissimum* | 74 | 66 | 38 |
| Flax cv. Elise | *Linum usitatissimum* | 94 | 96 | 98 |

[a] 100% germination rate equals every seed planted germinating and producing a sizeable shoot (> 2mm).

[b] These seed species were planted at a sow rate of 100 per replicate. The remaining species were planted 25 seeds per replicate

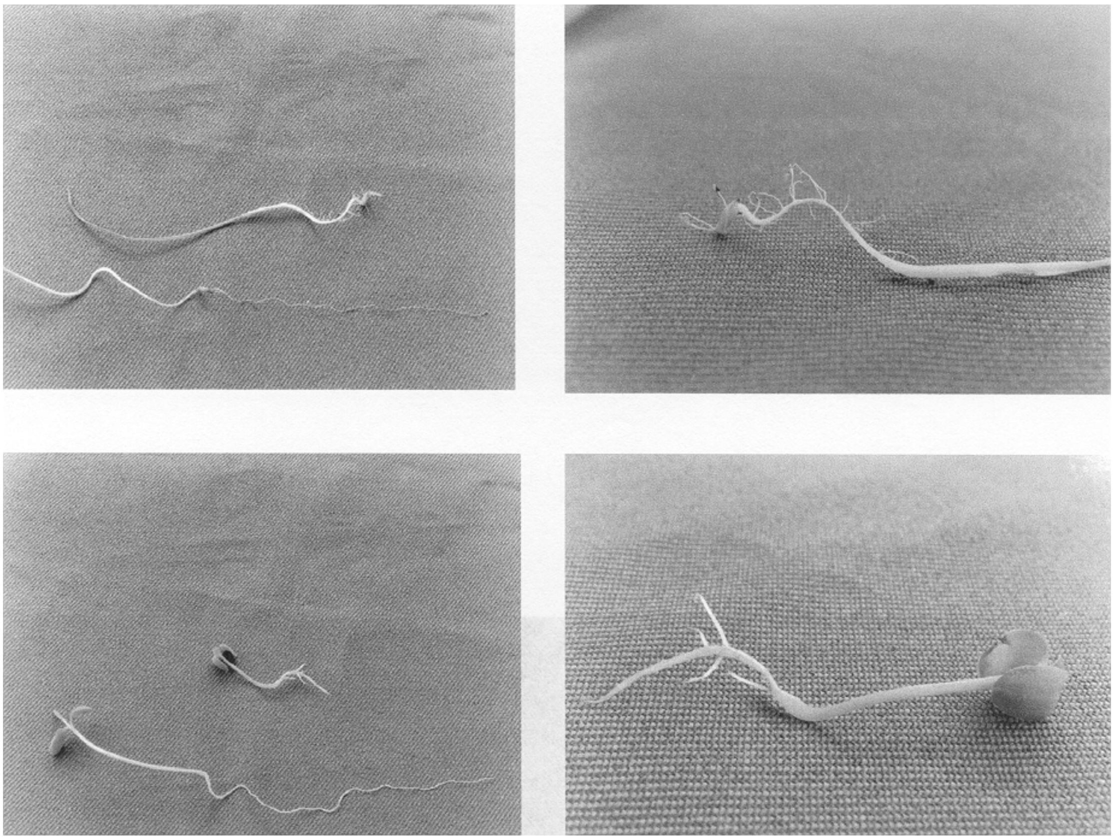
## 3. Plant Performance

The overall heights of plants grown in diesel oil contaminated soil were stunted compared to control plants grown in uncontaminated soil. This effect cannot be attributed directly to delayed seed emergence as some plant species germinated as successfully as the controls, yet their development was impaired by the presence of diesel. For example, the oil seed rape cultivar Martina germinated well in the presence of diesel (Table 1) but the production of top growth was noticeably reduced to 17.8% and 16.6% of the control top growth in 25g diesel/kg soil and 50g diesel/kg soil treatments respectively. The same pattern was observed for root biomass with reductions falling to 21% and 20% of the control biomass for the two treatments (unpublished work).

## 4. Root Morphology

Plants grown in diesel oil contaminated soil exhibit formation of adventitious roots (root structures which arise in unusual positions) as illustrated in Figure 1. Photographs (a) and (b) show the formation of adventitious roots on the stem of a Canary grass seedling where no such structures are found on the control seedling. Photographs (c) and (d) show increased lateral roots present on a Flax seedling grown in contaminated soil as opposed to the control seedling.

(a) (b)



(c) (d)

*Figure 1* Effect of diesel on root formation of two week old seedlings.

(a) Annual canary grass - seedlings grown in contaminated (top) and uncontaminated (bottom) soils ; (b) Annual canary grass - enlargement of seedling grown in contaminated soil ; (c) Flax - seedlings grown in contaminated (top) and uncontaminated (bottom) soil and (d) Flax - enlargement of seedling grown in contaminated soil.

## 5. Spatial Distribution of Roots

An experimental system was set up which enabled the pattern of root development of selected plant species to be followed in a model soil system contaminated with diesel oil. Initial observations indicate plant roots avoid diesel oil contaminated areas completely if they have uncontaminated soil to grow into. If there is no available uncontaminated soil, roots will grow through contaminated regions until they find an area of uncontaminated soil. However, at lower contamination levels (up to 10g diesel/kg soil) roots will enter the contaminated area after an acclimation period. This observation is also seen with concentrated patches of diesel oil. Once the majority of the surrounding uncontaminated soil has been utilised, the roots begin to move into the contaminated patch. This suggests that degradation of diesel oil may be enhanced by the action of rhizosphere microorganisms.

## 6. Further work

Work is continuing on the effects of diesel on plant development with attention being given to attributing these effects to a specific fraction or fractions of diesel oil.

## References


Cunningham, S. D., Anderson, T. A., Schwab, A. P. and Hsu, F. C. 1996. Phytoremediation of soils contaminated with organic pollutants. *Advances in Agronomy*. **56** : 55 – 113.

Kruger, E. L., Anderson, T. A. and Coats, J. R. 1997. Phytoremediation of contaminated water and soil. In Kruger, E. L., Anderson, T. A. and Coats, J. R. (eds.), *Phytoremediation of soil and water contaminants.* ACS Symposium Series **664**. American Chemical Society, Washington, D. C. pp 2 – 17.

Walton, B. T., Guthrie, E. A. and Hoylman, A. M. 1994. *Toxicant degradation in the rhizosphere*. In Anderson, T. A. and Coats, J. R. (eds.), *Bioremediation through rhizosphere technology*. ACS Symposium Series **563**. American Chemical Society, Washington, D. C. pp 11 – 26.

Wang, X., Yu, X., and Bartha, R. 1990. Effect of bioremediation on PAH residues in soil. *Environmental Science and Technology*. **24** : 1086 – 1089.