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Fate of Jet Fuel JP-4 in Soil

Deborah Dean-Ross

Department of Biological Sciences, Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805-1499, USA

Jet fuels are complex mixtures of hydrocarbons that partition in the environment according to their physical properties. They may evaporate, dissolve in water, absorb onto sediment or soil or degrade by chemical or biological processes. Several studies have been conducted that address the fate of jet fuel hydrocarbons in the environment. Results of experiments using aquatic test systems indicate that for two fuels commonly used in fueling operations, JP-4 and JP-8, evaporation was the major removal process for low molecular weight hydrocarbons. For most hydrocarbons biodegradation was not a significant removal process (Spain et al., 1985; Pritchard et al., 1988: Dean-Ross et al., 1992).

In a study of the removal of JP-8 from soil (Dean-Ross et al, 1992), it was shown that higher molecular weight hydrocarbons were removed significantly faster in soil with an active microbial population then in soils treated to kill microorganisms, indicating that biodegradation could enhance the removal rate of these hydrocarbons. The present study was undertaken to obtain soil biodegradation data on JP-4 for use in contingency planning.

MATERIALS AND METHODS

For soil biodegradation tests, 25 g (dry weight equivalent) of soil collected from the campus of Chippola Community College (Chippola, FL), was placed in 150 mL milk dilution bottles. The soil was a sandy loam (76% sand, 14% silt and 10% clay) with a pH of 5.4 and an organic matter content of 5.08% (A&L Great Lakes Laboratories, Ft. Wayne, IN). Two sets of bottles were used, one set containing untreated (active) soil and the other receiving soil treated with 2% (wt) $HgCl_2$. Each bottle received 250 μL of JP-4. Twelve bottles were prepared per treatment, and triplicate bottles were analyzed at appropriate intervals. Three additional bottles containing 25 g of soil (dry weight) were incubated under identical conditions to the JP-4 bottles. These bottles were weighed weekly to calculate weight loss. The corresponding amount of water was added to the JP-4 bottles to maintain a constant moisture level. The heterotrophic bacterial population in untreated soil was estimated by the MPN method.

Table 1. Disappearance of hydrocarbons from active soil

Hydrocarbon	Concentration in extract (μg/ml) at: O time	5 day	10 day	15 day
2,3-dimethylpentane	.061	0	0	0
heptane	.277	0	0	0
methylcyclohexane	.094	0	0	0
toluene	.087	0	0	0
3-methylheptane	.136	0	0	0
octane	.197	0	0	0
ethylbenzene	.060	0	0	0
m-xylene	.067	0	0	0
o-xylene	.034	0	0	0
nonane	.118	0	0	0
iso-butylbenzene	.028	0	0	0
1,3,5-trimethylbenzene	.035	0	0	0
1,2,4-trimethylbenzene	.068	0	0	0
decane	.102	0	0	0
undecane	.108	.018	.012	.011
dodecane	.111	.056	.016	.014
tridecane	.099	.067	.022	.018
tetradecane	.057	.067	.020	.019
pentadecane	.027	.032	.017	.016
hexadecane	.015	.010	.008	0

Soil samples were extracted with 15 mL of CS_2 containing naphthalene as an internal standard. In order to exclude fine soil particles, 1 mL samples from soil were drawn from near the top of the solvent layer. Extracts were analyzed by high resolution capillary gas chromatography with flame ionization detection. The separations were performed using a fused silica capillary column, 30 m long, with an internal diameter of 0.24 mm, and coated with 1.0 um of a bonded and cross-linked stationary phase consisting of 5% phenyl-substituted polymethylsilixane (DB-5, J&W Scientific, Inc.). All sample injections were 1 μL in volume. The column temperature was held at 40° C for 4 minutes and then increased to 205° C at a rate of 3° C/minute. The injection port and detector temperatures were 300° C. Analyses were performed on a Perkin-Elmer Model 8500 Gas Chromatograph (Perkin-Elmer Co, Inc.). Twenty individual components of jet fuel JP-4 were selected for quantitation. Response factors were calculated from the peak areas of a standard solution prepared for each of the twenty hydrocarbon components.

To determine if the active set of samples was significantly lower in concentration than the sterile set, a Student's t-test was performed using the 95 percent confidence level.

Table 2. Disappearance of hydrocarbons from sterile soil

Hydrocarbon	Concentration in extract (μg/ml) at: O time	5 day	10 day	15 day
2,3-dimethylpentane	.050	0	0	0
heptane	.235	0	0	0
methylcyclohexane	.081	0	0	0
toluene	.091	0	0	0
3-methylheptane	.121	0	0	0
octane	.177	0	0	0
ethylbenzene	.057	0	0	0
m-xylene	.063	0	0	0
o-xylene	.033	0	0	0
nonane	.110	0	0	0
iso-butylbenzene	.027	0	0	0
1,3,5-trimethylbenzene	.035	0	0	0
1,2,4-trimethylbenzene	.057	0	0	0
decane	.095	0	0	0
undecane	.102	.018	.010	.006
dodecane	.104	.056	.015	.017
tridecane	.094	.070	.043	.029
tetradecane	.056	.065	.049	.029
pentadecane	.031	.038	.032	.018
hexadecane	.015	.010	.008	.005

RESULTS AND DISCUSSION

Hydrocarbons with molecular weights equivalent to decane or lower disappeared from the soil in both active and sterile treatments by the first sampling time, indicating that evaporation was the major removal process for these hydrocarbons (Tables 1 and 2). Hydrocarbons with molecular weights higher than decane were not removed as rapidly from soil as for the more volatile hydrocarbons and traces of these hydrocarbons persisted until the end of the experimental period. For undecane, dodecane and hexadecane, no significant differences were noted between the active and sterile treatments. For tridecane, tetradecane and pentadecane, however, significant differences were noted between the active and sterile treatments on day 10 for all three hydrocarbons and day 15 for tridecane and tetradecane.

Based on the above data it can be concluded that biodegradation contributed to the removal of the higher molecular weight fraction of jet fuel from soil. Three of the analyzed components disappeared faster in the active treatments than in the sterile treatments. This is in agreement with the results of a similar soil biodegradation study conducted with jet fuel JP-8 (Dean-Ross et al., 1992).

The above results suggest that for the less volatile hydrocarbons, manipulation of conditions to enhance biodegradation may increase their rate of removal from the terrestrial environment. This agrees well with literature reports on land farming of waste hydrocarbons (Bartha and Bossert, 1984) and the results of a recent study on the biodegradation of JP-4 in a contaminated aquifer (Aelion and Bradley, 1991). These authors found that biodegradation was compound specific. For example, under experimental conditions in which evaporation was not a factor, hexane disappeared more rapidly from active than from sterile treatments while branched alkanes of similar molecular weight showed no such effect. For the bulk of jet fuel finding its way to the terrestrial environment, evaporation will undoubtedly be the major removal process; however, biodegradation has the potential to lessen the environmental impact of less volatile hydrocarbons.

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