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Hanson, K.G.

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Microbial Response to Amendment of an Eroded Brown Loamy Sand with an Oily Waste Sludge

K. G. Hanson¹, V. O. Biederbeck¹, F. Selles¹, D. C. James¹ and T. A. Fonstad²
¹Semiarid Prairie Agricultural Research Centre, Agriculture and Agri-Food Canada, Swift Current, SK and ²Agricultural and Bioresource Engineering, University of Saskatchewan, Saskatoon, SK

Introduction

Disposal of oil production wastes became a major environmental issue for heavy oil development in western Canada as replacement of conventional oil recovery methods by thermally “enhanced oil recovery” (EOR) techniques not only coaxed more oil from the reservoirs, but also produced greater volumes of waste sludge (Biederbeck et al. 1993). In the Canadian prairie region there are 3.1 million hectares of sandy soils (> 50% sand) that are highly erosive, low in organic matter, water holding capacity, cation exchange capacity and fertility (Biederbeck et al. 1997). These soils may benefit from application of oil production wastes.

Measurement of microbial populations and activities can provide useful information regarding the rates of hydrocarbon biodegradation in soil and their eventual bioconversion into stable, and soil-improving humus although they are not direct measures of biodegradation (Bossert and Kossen, 1997).

Our field study was conducted to:

- (i) determine the impact of a salt-free heavy oil sludge on crop production and on soil and water quality of a marginal, erodible soil;
- (ii) to generate benchmark data needed by regulatory agencies and the petroleum industry to develop guidelines and protocols that will facilitate and control the future use of hydrocarbon wastes as a resource for the protection and improvement of erosion-prone, sandy cropland.

This portion of the study examines soil microbial populations and changes in soil aggregation.

Materials and Methods

On November 5, 1997, the field study was initiated on a Hatton loamy sand near Richmond, SK (Table 1) with the application of 3 rates of waste oil sludge (0, 1 & 2% initial oil content of soil (w/w)) (Table 2) and the first one-third of 2 N & P fertilizer rates (none and best management) into the top 10 cm of soil. The best management fertilizer application was based on the amount of oil added and the C:N:P ratio of stable soil organic matter so as to optimize the microbial conversion of oil to humus. For the 1% oil treatment (w/w), 235 kg N/ha and 80.2 kg P₂O₅/ha were applied initially and that fertilization was doubled for the 2% oil addition. All treatments were replicated four times on a total of 96 plots (2m x 12m). The remaining two-thirds of the fertilizer were applied on April 7th and 15th, 1998. Only 48 plots were seeded in spring 1998: 24 to Calibre oats and 24 to Kyle

durum on April 15th. Due to poor emergence, probably from moisture stress, all plots had to be re-seeded on May 27, 1998.

Table 1. Physical and chemical properties of Hatton loamy sand at field site near Richmond, SK (Ben Kambeitz farm). Values are mean of 16 samples across the site, collected July 15, 1997.

(a) PHYSICAL						
Depth (cm)	Texture	Water Content(%)		pH	BD(g/cc)	Ec (dS/m)
		PWP (15.0 bar)	FC (0.3 bar)			
0 - 10	Loamy Sand	3.06	5.53	7.47	1.37	0.25

(b) CHEMICAL						
Depth (cm)	Total C (%)	Organic C (%)	Total N (%)	N03-N (ppm)	SO4-S (ppm)	PO4-P (ppm)
0 - 10	0.68	0.41	0.04	1.26	2.16	22.06

Soil samples were taken within 24 hours of oily waste incorporation, and again 3 weeks later, then in Spring and Fall 1998. Samples were stored at SPARC at 0 C until they were mixed and sieved at room temperature (warming was required to ensure complete mixing).

Table 2. Characteristics of the Consumers' Co-operative Refinery Ltd. Heavy Oil Upgrader waste sludge from Regina, SK.

(a) MAJOR CONSTITUENTS		
WATER: 61%	HYDROCARBONS: 31%	SOLIDS (Clay): 8%

(b) MINOR CONSTITUENTS			
Na: 280 ppm	Cl: 280 ppm	Total volatiles: 420 ppm	
Total PAHs: 5000 ppm	N: 70 ppm	P: 20 ppm	S: 6000 ppm

Different soil microbial populations were enumerated by dilution plating onto various media: bacteria and actinomycetes on soil extract agar, procaryotic oil degraders on Oil agar (Atlas 1995), and filamentous fungi and yeasts on rose bengal streptomycin agar. All agar plates were incubated at 21°C SE and Oil agar for 14 days and RBS agar for 6 days. For *in vitro* respiration (carbon mineralization) measurements 50 g of soil were incubated at field capacity in Biometer flasks during 30 days at 21°C.

Results and Discussion

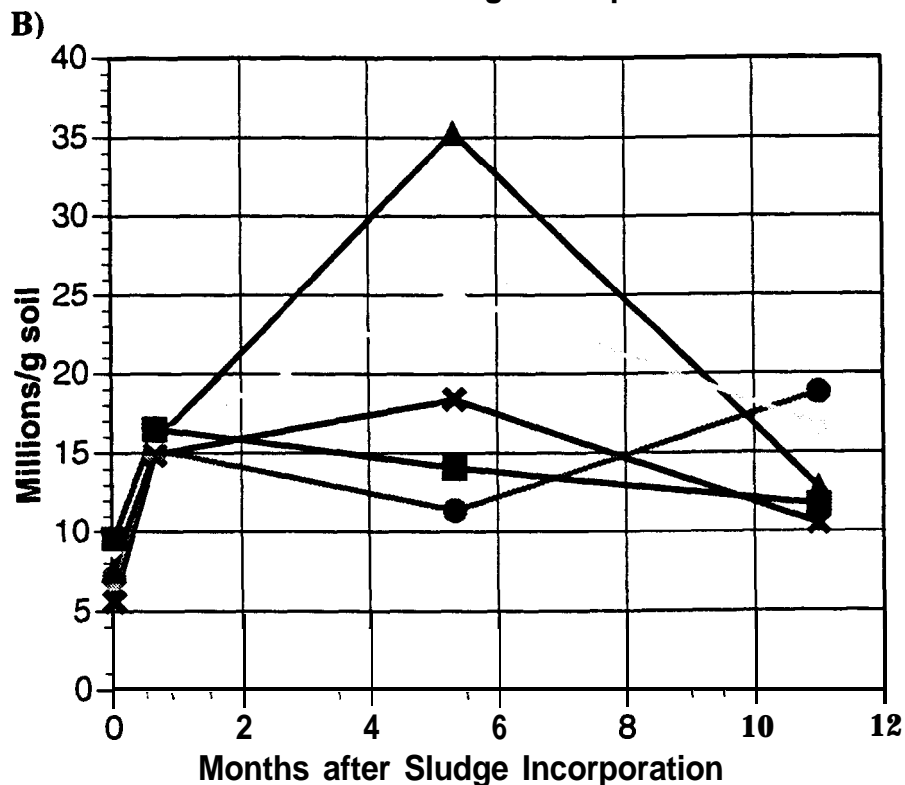
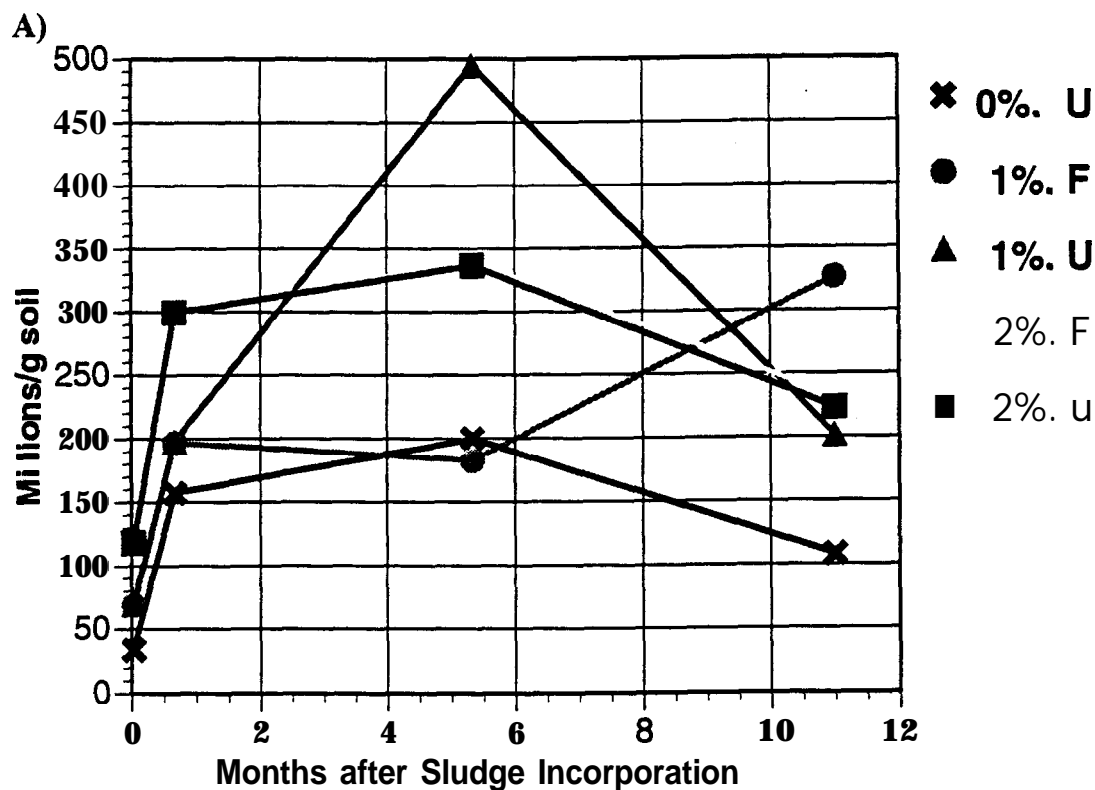


Figure 1. Effect of oily waste sludge from the CCRL Upgrader on A) bacteria and B) actinomycete populations in the top 10 cm of the loamy sand near Richmond, SK.

Contrary to literature reports (Riser-Roberts 1995), initial microbial populations in oil treated soils were higher than was expected (Figures 1 and 3). Warming and agitation of the soil in the laboratory to effect complete mixing of the incorporated organics, prior to cold storage and analyses at SPARC, could be responsible for this observation. Bacterial populations (Figure 1 A) for all treatments peaked after about 5 months except for the 1% oil and fertilized treatment. This was earlier than observed by Biederbeck et al. (1994) where populations peaked at about 12 months. Actinomycetes (Figure 1 B) followed a similar trend. Interestingly, the percentage of oil degraders (Figure 2), selectively counted on

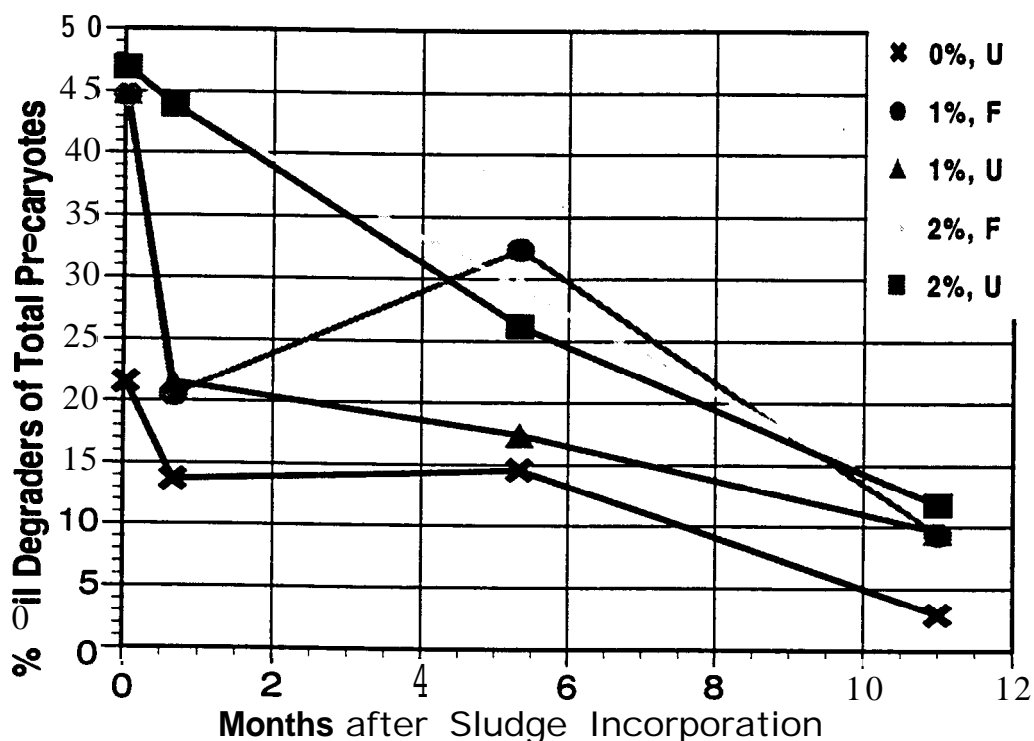


Figure 2. Effect of oily waste sludge from the CCRL Upgrader on the percentage of oil degraders in the top 10 cm of the loamy sand near Richmond, SK.

Oil agar, dropped for all treatments over the eleven months with the majority of treatments peaking at the initial sampling. Filamentous fungal and yeast populations (Figure 3 A and B) are still increasing after eleven months which is believed to be a good indicator of an improved and more balanced microbial ecology. C-mineralization (Figure 4) shows dramatic decreases between initial sampling and Spring 1998 but only for those oiled treatments that were fertilized. This reduction coincides with some declines in microbial populations and especially low crop emergence (data not shown). However, it may well be that adequate fertilization improves the efficiency of the bioconversion process from oily waste to humus by greatly reducing microbial respiration or venting of the added organic C thus resulting in less atmospheric pollution and greater C sequestration by this sandy soil. Similar drops in respiration rates have been reported elsewhere after addition of nitrogen fertilizer to C-rich soils (Soderstrom et al. 1983) but the reasons for these microbial responses to N fertilization are yet to be fully elucidated.

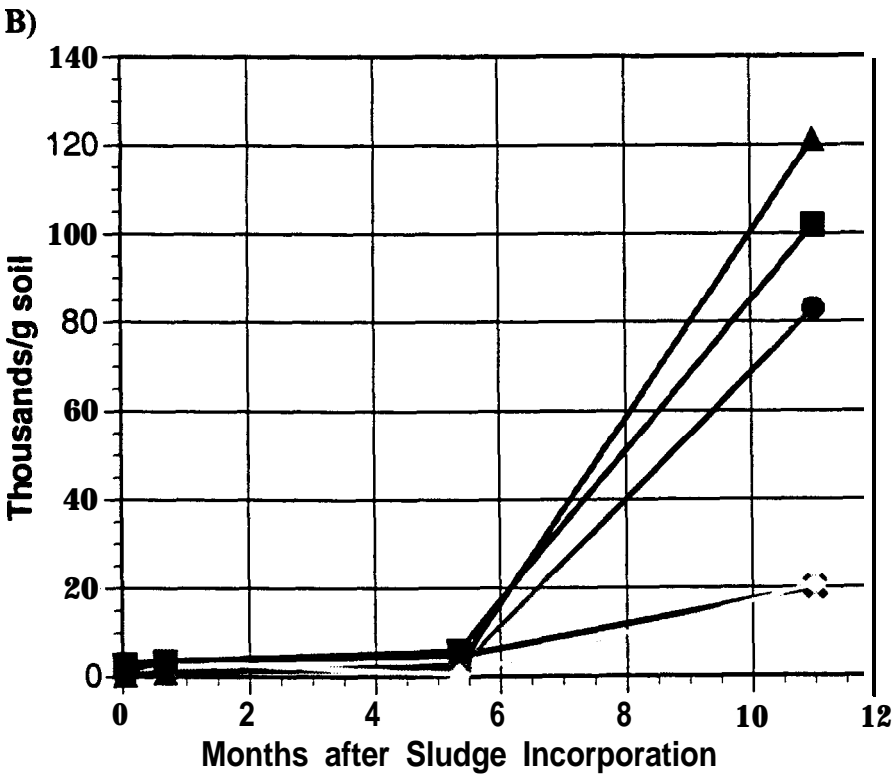
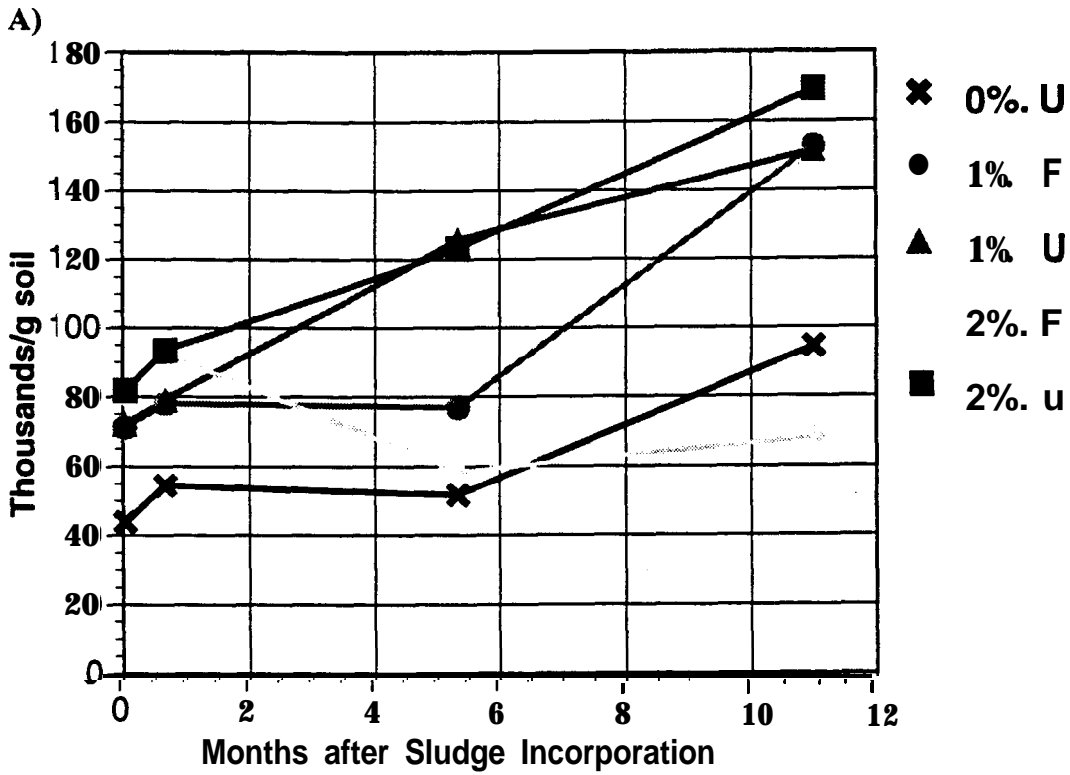


Figure 3. Effect of oily waste sludge from the CCRL Upgrader on A) filamentous fungi and B) yeast populations in the top 10 cm of the loamy sand near Richmond, SK.

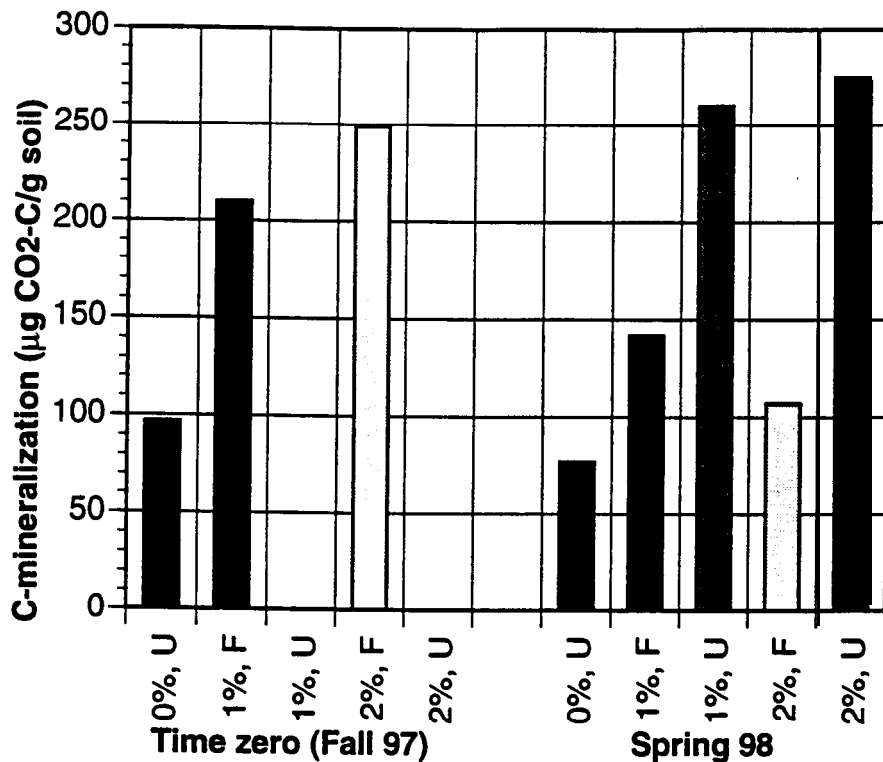


Figure 4. Effect of oily waste sludge soil incorporation on carbon mineralization during 30 days of incubation. Note the oiled, unfertilized treatments were not measured at time zero.

By spring 1998, the wind erodible soil fraction was decreased by 9% when 1% oil (w/w) was applied and by 13% when 2% oil was applied. Water stable aggregates increased by 58% and 65%, when waste oil was applied at 1 and 2% (w/w), respectively.

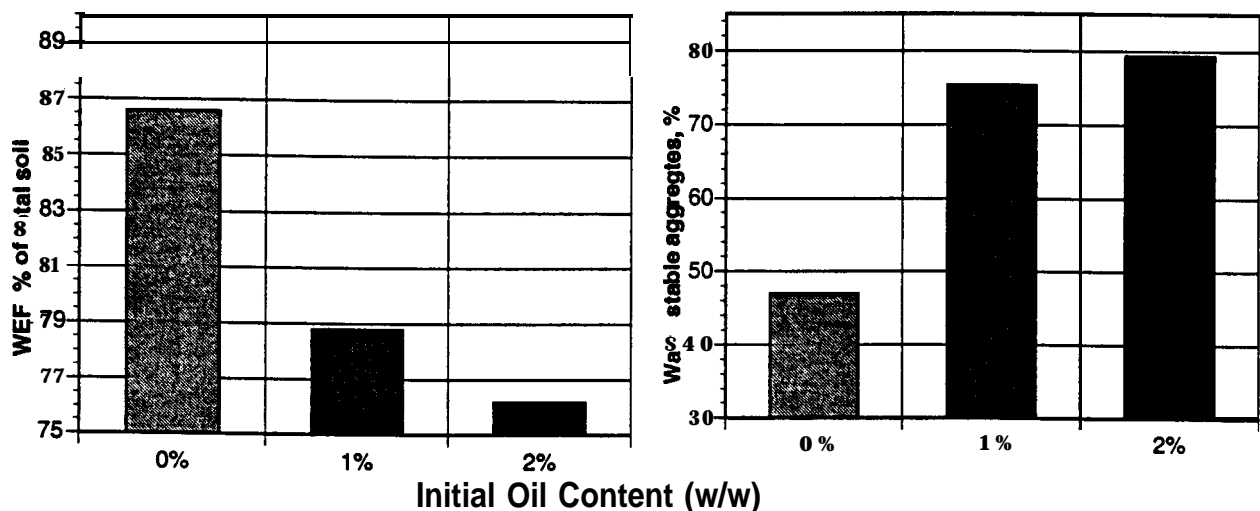


Figure 5. Differences in wind erodible fraction (%) and water stable aggregates (%) five months after oily waste sludge application to the loamy sand near Richmond, SK.

Conclusions

- 1) Soil incorporation of oily waste sludge boosted most microbial populations when compared to the unoiled control treatment.
- 2) Fertilization markedly reduced microbial populations and respiration, particularly at the 2% level of oil addition.
- 3) Incorporation of oily waste greatly reduced the erodibility of this very sandy soil.

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Acknowledgements

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