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ENVIRONMENTAL EFFECTS OF SOLAR THERMAL POWER SYSTEMS

**MINERALIZATION OF CARBON DURING MOIST INCUBATION OF
SOIL JF79 TREATED WITH ORGANIC HEAT TRANSFER AND STORAGE FLUIDS**

FEBRUARY 1981

PREPARED FOR

U.S. DEPARTMENT OF ENERGY

Contract No. DE-AM03-76-SF00012

**LABORATORY OF BIOMEDICAL AND ENVIRONMENTAL SCIENCES
UNIVERSITY OF CALIFORNIA, LOS ANGELES**

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Printed in the United States of America
Available from
National Technical Information Service
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Springfield, VA 22161

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MINERALIZATION OF CARBON DURING MOIST INCUBATION OF SOIL JF79
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January 1981

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U.S. DEPARTMENT OF ENERGY

Contract No. DE-AM03-76-SF00012
between the U.S. DOE and
the University of California

Laboratory of Biomedical and Environmental Sciences
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ABSTRACT

Biodegradability of four heat transfer/storage fluids (ethylene glycol, Therminol 66, Caloria HT43, and Dow Corning Fluid No. 200) were examined. The degradation was monitored by periodically measuring the mineralization of carbon in moist fluid-contaminated soils incubated at 28^o and 37^oC for 8 weeks. Ethylene glycol mineralized relatively readily. The other three fluids did not show measurable amount of carbon mineralization during the experimental period. This implies potential long term environmental effects of mismanaged or accidental releases of these fluids into natural environment.

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INTRODUCTION

A variety of fluids may be used for heat transfer and for heat storage in solar thermal power systems. These fluids may be organic or eutectic salts. The organic fluids are usually hydrocarbon or silicone oils. These fluids possess attractive thermal qualities, but vary in toxicity, flammability and biodegradability (Searcy 1978; Kahane 1980). One of the concerns in the use of these materials is their possible release into natural environment through spills, leaks in operational equipment, accidents, or improper disposals. This paper is concerned with the biodegradability of several organic heat transfer/storage fluids that may be used or are in use in demonstration solar thermal power systems.

MATERIALS & METHODS

The soil used for this study was Soil JF79, which was collected in the northern Mojave Desert area of the Nevada Test Site where our plots for assessing the plant toxicity of heat transfer/storage fluids are set up. The soil is nonsaline, calcareous one with montmorillonite as the predominant clay mineral. The < 2-mm size fraction of the soil was used for experimentation. Its chemical properties were as follows: pH (1:1 H₂O suspension) 8.29; organic carbon 0.11 percent; cation exchange capacity 16.16 me/100g; exchangeable cations Ca 11.78, Mg 1.70, K 2.39, and Na 0.09 me/100g; lime as

CaCO₃ 0.45 percent; free iron oxides 1.40 percent; and electrical conductivity of the saturation extract 0.31 mmhos/cm.

The heat transfer/storage fluids applied to the soil in this study were ethylene glycol, Therminol 66, Caloria HT 43, and Dow Corning No. 200. These were fresh materials as supplied by the manufacturers. The physico-chemical properties of these materials have been compiled by Searcy (1978) and Kahane et al. (1980). These materials were applied to the soil at the rate of 1,000 ppm on the basis of weight of oven-dry soil. The N, when applied, was done so at the rate of 5,000 ppm as NH₄NO₃. This is equivalent to 5 tons per acre (0.405 hectare).

The mineralization of carbon was measured by the method described by Cornfield (1961). Ten grams air-dried, 2-mm-sieved soil was mixed with a heat transfer/storage fluid (0.1 percent by weight) and placed in 25 x 150 mm Pyrex test tube. Water was then added from a pipette to bring the soil water content to 1-bar percentage. A 1-dram vial (15 x 45 mm) containing 0.2 g barium peroxide was placed next on the moist soil in the test tube. After this, one ml of distilled water was added to the vial and the test tube closed with rubber stopper. For each treatment, two controls were set up. A control (untreated soil) for measuring CO₂ released from native soil organic matter, and a control (barium peroxide-water mixture) to serve as blank for CO₂ contained in the barium peroxide initially and in the air of the test tube. The test tubes were placed in incubators in racks at an angle of 20° from the horizontal to increase the CO₂ absorbing surface area of the alkaline solution in the vials. The test tubes with their contents were incubated in triplicate for various lengths of time (3, 7, 14, 21, 28, 35, 42, 49, and 56 days). One set of tubes was incubated at 28°C and the other set at 37°C.

The vials in the test tubes were gently shaken for few seconds each day in an upright position, in order to break the "scum" of barium carbonate, which formed on the surface of the alkaline solution. In the present experiments, the rates of mineralization of organic materials were such that only one charge of barium peroxide was sufficient for the experimental period of 56 days. The carbonate content of the vials was determined in Collins-Scheibler Apparatus by reaction with 2N HCl. The apparatus that was fabricated by our shops section is shown in figure 1. The description and operational details of it have been given by Collins (1906).

RESULTS AND DISCUSSION

The mineralization of carbon in soil treated with ethylene glycol and NH_4NO_3 during incubation at 28° and 37°C is shown in Figure 2. As indicated by the slow, but increasing release of CO_2 during the 56-day incubation period, the native organic matter in the control soil underwent some degree of mineralization. The cumulative amount of C released as CO_2 increased from 0.26×10^{-2} percent of soil mass in 3 days to about 0.95×10^{-2} percent in 56 days with 28°C incubation. With 37°C incubation, the cumulative C released from 0.37×10^{-2} percent (3 days) to about 1.59×10^{-2} percent (56 days), indicating that the C release was higher at the higher temperature. The addition of NH_4NO_3 to the control soil did not appreciably change the release of C as CO_2 . The addition of ethylene glycol, on the other hand, greatly increased the release of C. Thus, ethylene glycol appeared to be quite readily mineralized. However, when NH_4NO_3 was added to the soil treated with ethylene glycol, the release of C was markedly reduced. This effect probably was due to the immobilization of C in the microbial cells by the formation of C-N compounds.

Figure 3 shows the mineralization of C in soil treated with Therminol 66 and NH_4NO_3 during incubation at 28° and 37°C. The control soil again showed an increase of cumulative release of C as CO_2 with incubation at both temperatures. In general, the application of NH_4NO_3 or Therminol 66 did not change appreciably the release of C relative to that by the control soil. The application of NH_4NO_3 to the soil treated with Therminol 66 had no effect on the release of C. Thus, during the experimental period of 8 weeks, no apparent mineralization of C in Therminol 66 appeared to have taken place.

Figures 4 and 5 show the mineralization of C in soil treated with Caloria HT43 and Dow 200, respectively. As before, the control soil showed an increase of cumulative release of C as CO_2 with time, and the application of NH_4NO_3 had no apparent effect. The application of Caloria HT43 or Dow 200 also did not have any apparent effect on the release of C. Thus, as with Therminol 66, there was no apparent mineralization of C in Caloria HT43 or Dow 200 during the experimental period.

The release of C as CO_2 was generally higher at 37°C than at 28°C. This effect was due to the release of C from both soil organic matter and ethylene glycol, when the latter was applied (Fig. 1). When Therminol 66, Caloria HT43, or Dow 200 was applied, the release of C as CO_2 was primarily from soil organic matter, since these heat transfer/storage materials were not appreciably mineralized.

The ready biodegradability of ethylene glycol compared to the other three fluids examined suggests that relatively low molecular weight organic substances are more readily biodegradable than the high molecular weight ones. This has implication in that if the high molecular weight

Therminol 66, Caloria HT43, and Dow 200 had been used in heat transfer/storage systems and had gone through many heating and cooling cycles, they may have shown some degree of biodegradation. This might occur because during prolonged use, the fluids would very likely become appreciably degraded into lower molecular weight substances. Another implication is indicated by the behavior of Therminol 66, Caloria HT43, and Dow 200. Their apparent nonbiodegradability implies potential long-term environmental effects of mismanaged or accidental releases of these fluids into natural environment.

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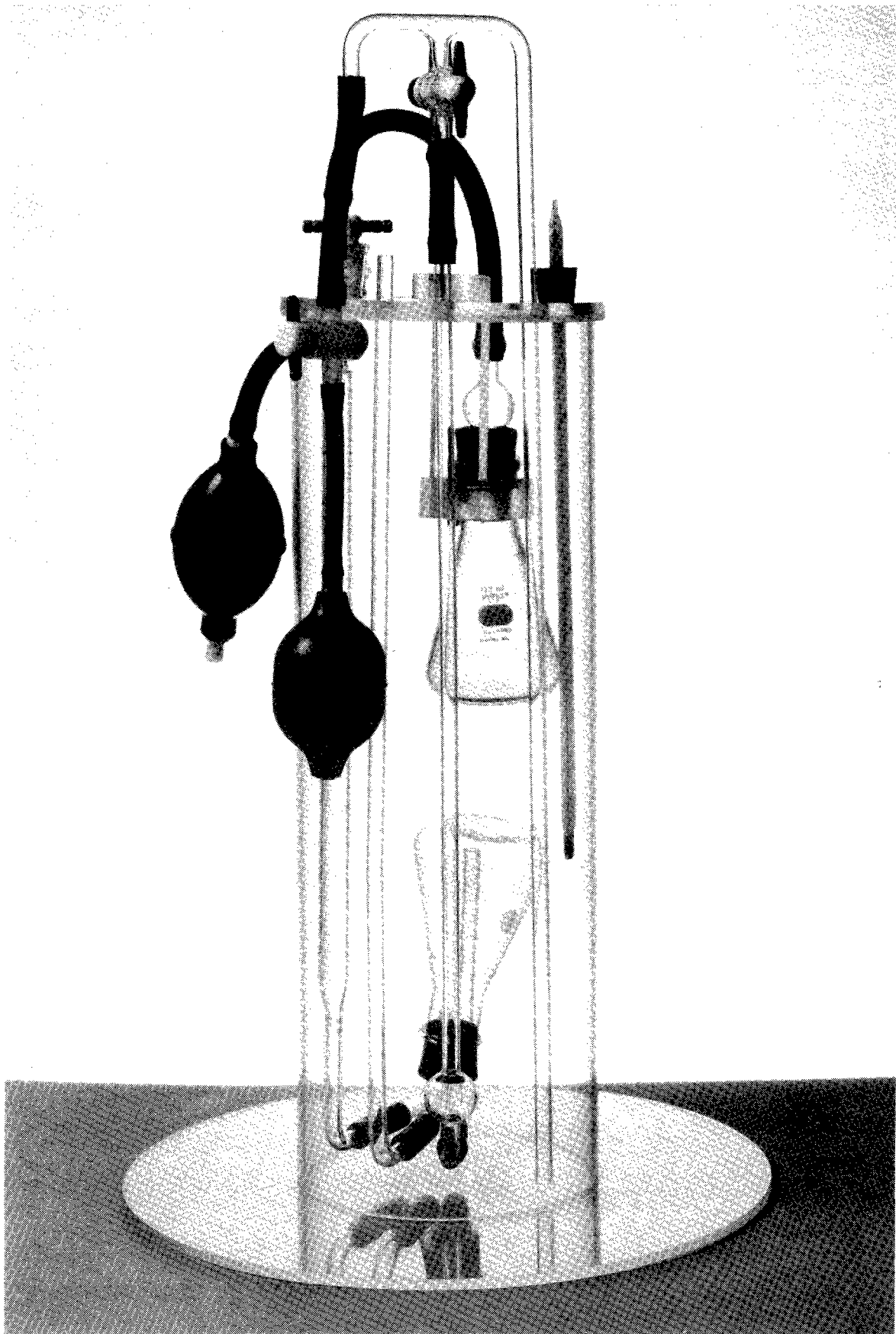


Fig. 1. Collins-Scheibler calcimeter for measuring CO_2 released from carbonates.

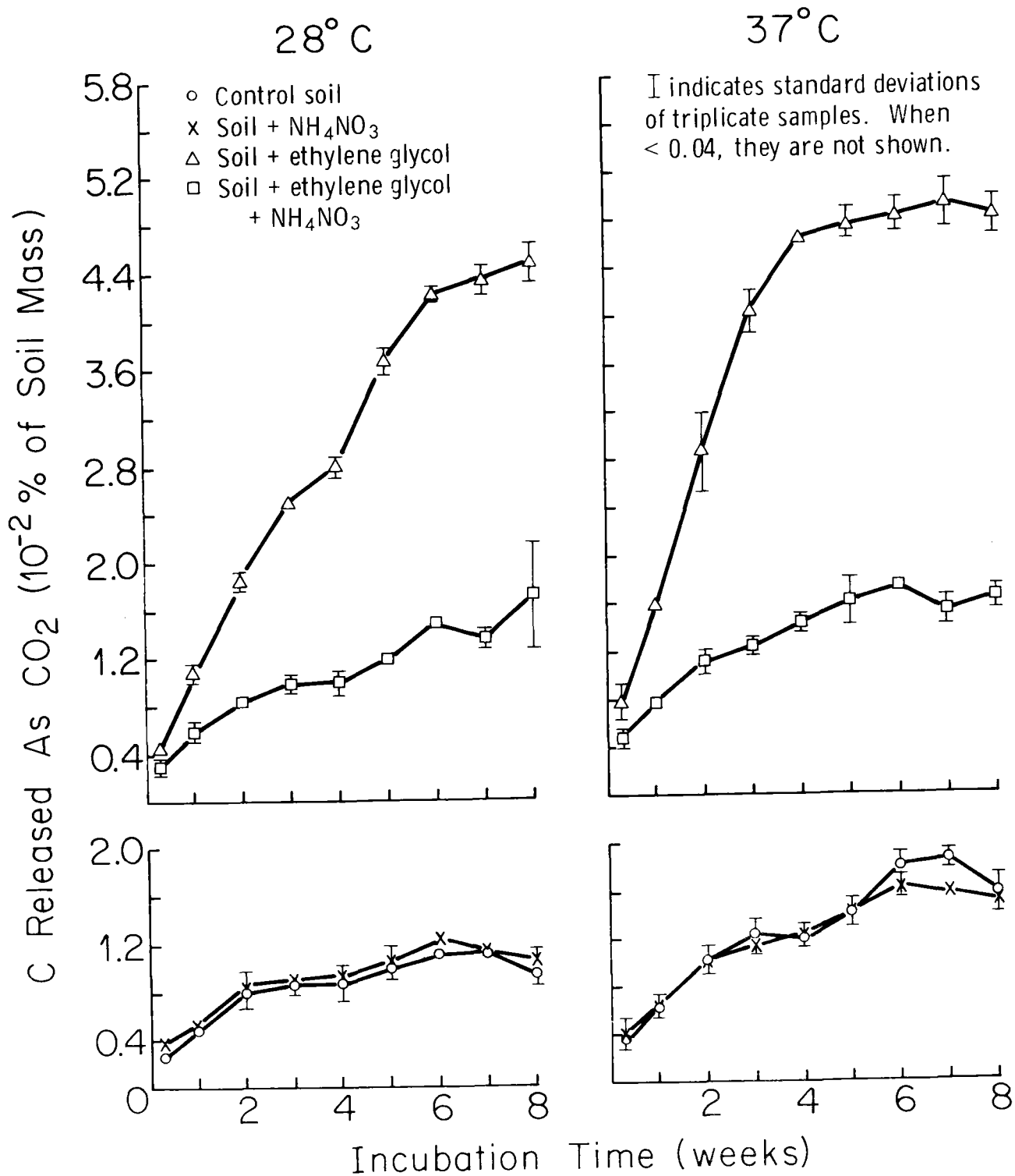


Fig. 2. Mineralization of carbon in soil treated with ethylene glycol and NH₄NO₃ during incubation at 28° and 37° for 8 weeks.

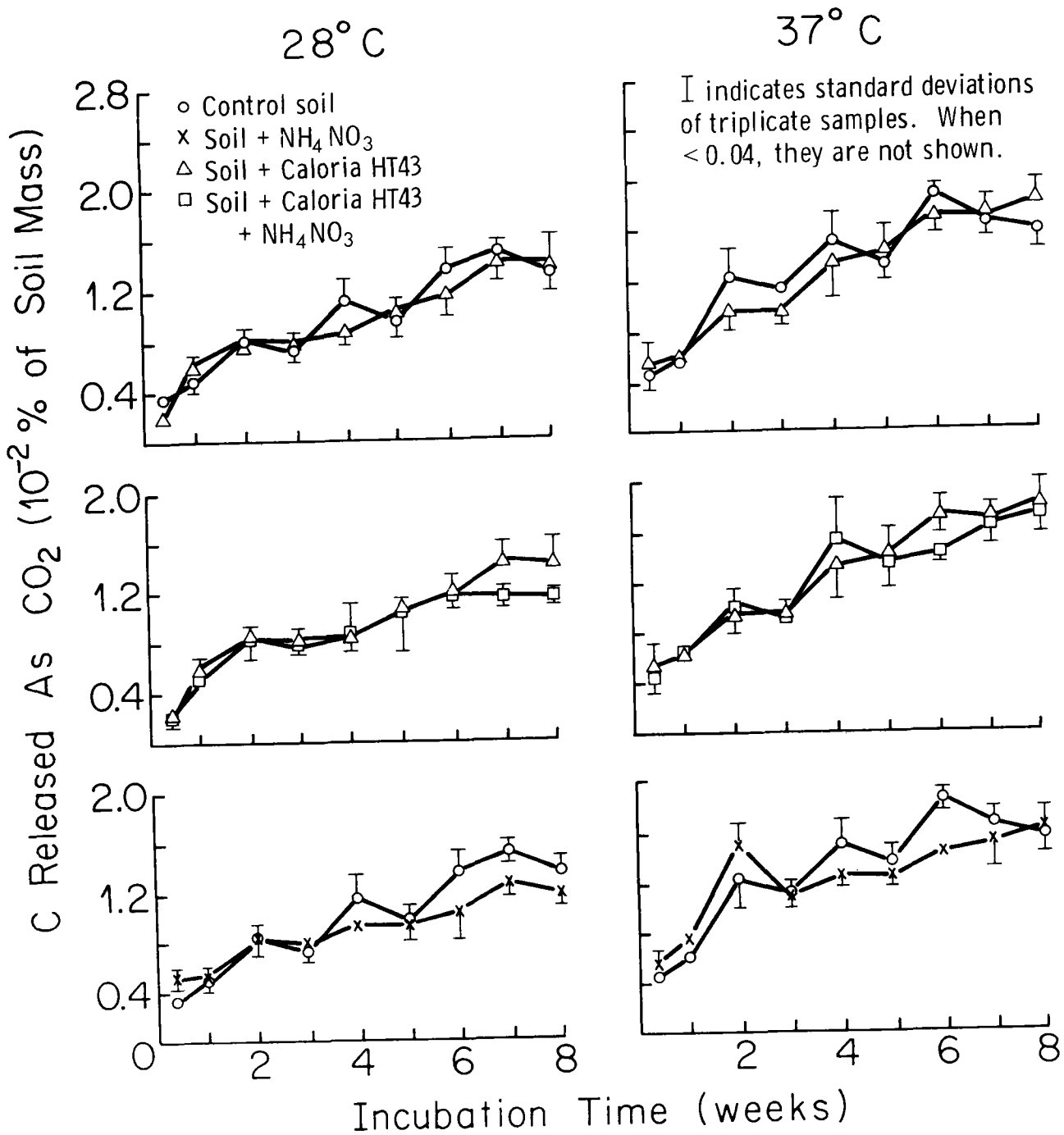


Fig. 4. Mineralization of carbon in soil treated with Caloria HT43 and NH₄NO₃ during incubation at 28^o and 37^oC for 8 weeks.

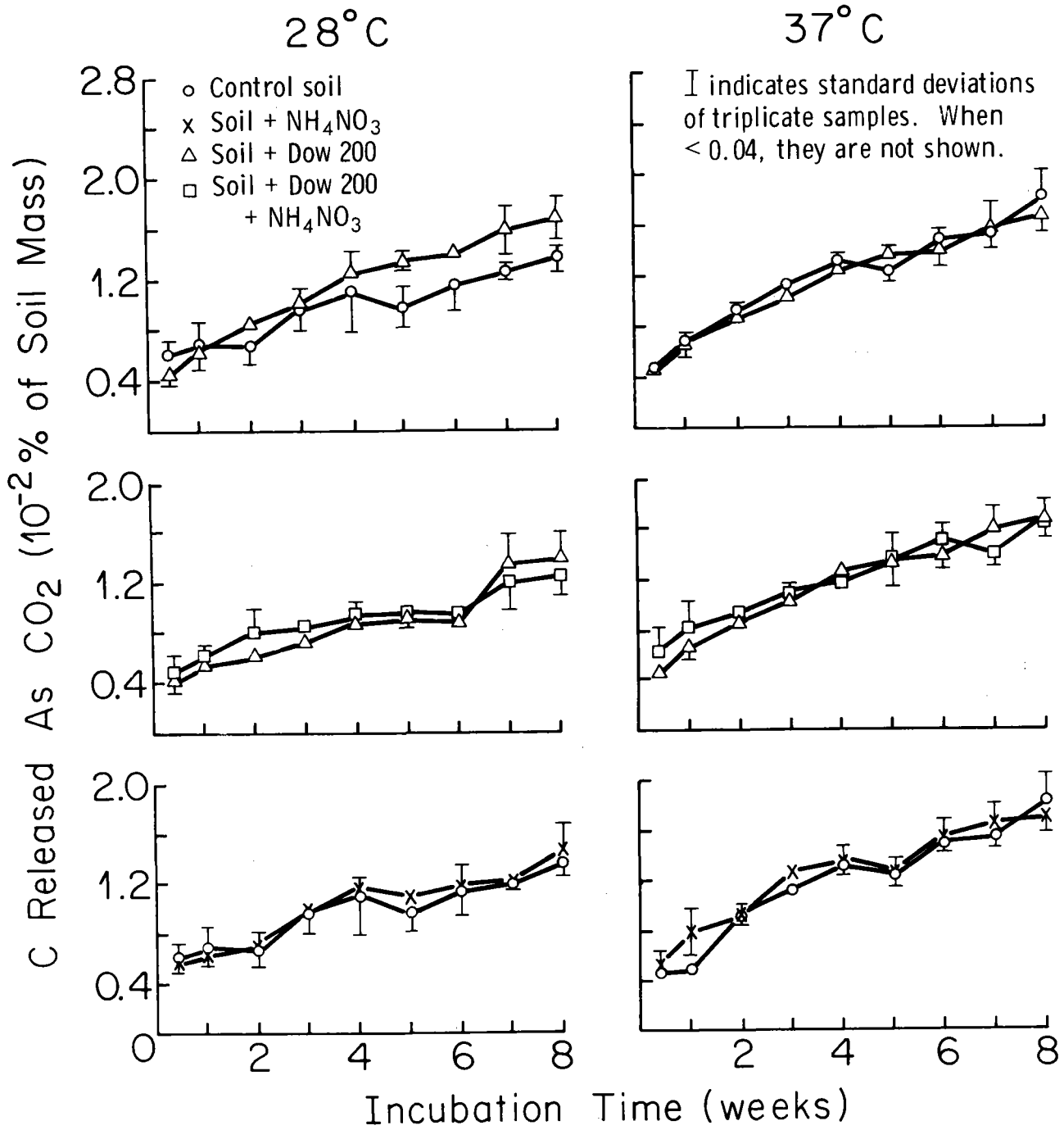


Fig. 5. Mineralization of carbon in soil treated with Dow 200 and NH₄NO₃ during incubation at 28^o and 37^oC for 8 weeks.

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