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MASTER

MINERAL CYCLING IN SOIL AND LITTER ARTHROPOD FOOD CHAINS

Progress Report

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ABSTRACT

Recent progress and current status are reported for research concerned with mineral element dynamics in soil arthropod food chains. Research is performed within the larger context of terrestrial decomposition systems, in which soil arthropods may act as regulators of nutrient dynamics during decomposition. Research is measuring rates of nutrient accumulation and excretion by using radioactive tracer techniques with radioactive analogs of nutrients. Experimental measurement of radioactive tracer excretion and nutrient element pools are reported for soil microarthropods, using new methods of counting and microprobe elemental analysis. Research on arthropod-fungal relations is utilizing high-efficiency extraction followed by dissection of 13 x 13 cm soil blocks. A two-component excretion model is reported for Cobalt-60 in earthworms (*Eisenia foetida*), demonstrating that no assimilation of cobalt occurs from the mineral soil fraction but is entirely from organic matter. Collection of data sets on soil arthropod communities and abundances is completed.

INTRODUCTION

This Annual Report describes current status of research projects investigating the dynamics of soil and litter arthropod food chains. The central focus of the research is on the measurement of elemental flows along soil arthropod food chains, with emphasis on mineral element or nutrient flows. Research is oriented towards the broader context of the regulation of terrestrial decomposition by arthropods. Decomposition is a generalized ecosystem process which governs nutrient regeneration in terrestrial ecosystems, thereby limiting primary production and governing rates of mineral cycling within ecosystems. It has been demonstrated that soil fauna, including soil arthropods, perform a regulatory function in the decomposition process. Research reported here is concerned with quantifying the movement of materials, particularly mineral nutrients, along food chains in soil systems. The interactions between activities of soil fauna, accumulation and release of nutrients by soil microbes, nutrient release from decomposing organic matter, and nutrient mobilization for plant uptake are being investigated in laboratory and field studies.

The general process of decomposition of organic matter releases nutrients for assimilation by roots. Decomposing organic matter is a major nutrient reservoir in many terrestrial ecosystems. That nutrient mobilization in soil systems results from a complex interaction is now emerging. Biological processes such as root exudation, mycorrhizal activities, microbial immobilization, microbial nitrogen fixation and faunal feeding interact to regulate nutrient availability for uptake by vegetation. It is becoming generally accepted that soil arthropods can regulate nutrient release during decomposition, although the exact mechanisms are not yet clear (Crossley 1977). Use of pesticides to exclude soil arthropods has been shown to decrease rates of nutrient release from decomposing leaf litter (Crossley and Witkamp 1964, Witkamp and Crossley 1966, Lee 1974, Croom and Ragsdale 1976) or woody litter (Abbott 1980). More recently, field and laboratory research has demonstrated that arthropod activities may stimulate fungal growth to the extent that some elements (especially P) exhibit enhanced retention during decomposition (Douce and Crossley MS, Seastedt and Crossley 1980, Whittaker et al. 1979). Current research is attempting to demonstrate interactions between soil arthropods and mycorrhizal fungi. These fungi are symbionts with plant roots and have been shown to be of major importance in plant nutrition (Marx et al. 1970). Plants whose roots possess mycorrhizal fungi perform markedly better in nutrient-poor soils. If soil fauna feed upon the mycorrhizal fungi, they may be influencing the uptake of nutrients by plants. It is not clear whether such feeding might reduce nutrient uptake by plants due to destruction of mycorrhizae, enhance uptake due to stimulation of mycorrhizal growth, or simply be a consequence of Ca metabolic pathways in fungal hyphae and soil microarthropods (Cromack et al. 1977).

The need for understanding of soil processes and their regulation is becoming critical because of anthropogenic influences on soil systems.

These external influences may modify rates of decomposition or leaching, or alter the organic matter regime in soils. Anthropogenic influences range from generalized atomspheric or regional ones such as acid precipitation to localized processes. Planned releases of various types of waste materials into soil systems is increasing (Porter 1978). To some, soil disposal is viewed as the only alternative remaining for various types of waste. One viewpoint holds that soil systems constitute a varied set of enzymes capable of decomposing a wide variety of residues. Proper use of soil systems for waste disposal will require a broader understanding of the manner in which they operate, and the consequences of such disposal to other systems (for example, aquatic systems draining the soils or accumulating their exports). The research reported here is thereby contributing to the basic understanding of the decomposition process, and is providing information which will be useful in evaluating technological impacts on soil systems.

Results are reported under two subprojects. The first is concerned with laboratory and field studies of nutrient relations between arthropods in food chains and with their fungal food base and the substrate associated with it. The second subproject is concerned with research on granitic outcrop areas. The latter subproject is still in a synthesis phase. Three manuscripts have been prepared and are in local review. The major activity during this reporting period has occurred under the first subproject, where most of the research effort is in the process of data collection as of this writing.

We regard the open literature as our major reporting medium. Table 1 lists publications, reports in press, and manuscripts prepared during the current period. Table 2 lists reprints of publications and manuscripts submitted as technical reports, which accompany this Annual Report. Brief descriptions will be given for these research efforts, since the detailed reports are available in the accompanying documents. Table 3 lists presentations based entirely or in part upon work performed under this Contract.

Table 1. Publications, Theses and Manuscripts Prepared During the Current Contract Period.

Published

Seastedt, T. R., Aruna Kothari and D. A. Crossley, Jr. 1980. A simplified gelatine embedding technique for sectioning litter and soil samples. Pedobiol. 20:55-59.

In Press

Abbott, David T. and D. A. Crossley, Jr. 1980. Improved methods for measuring radioactive tracer accumulation and excretion by microarthropods, with applications for a mite species, *Tyrophagus longior* (Acarina, Acaridae). Ann. Ent. Soc. Amer.

Blumberg, A. Y. and D. A. Crossley, Jr. 1980. Comparison of soil surface arthropod populations in conventional tillage, no-tillage and old field systems. Env. Ent.

Seastedt, T. R., Louis Mameli and Krista Gridley. 1980. Arthropod use of invertebrate carrion. Amer. Midl. Nat.

Stinner, Benjamin R. and D. A. Crossley, Jr. 1980. Comparison of mineral element cycling under till and no-till practices: An experimental approach to agroecosystems analysis. Proc. Int. Cong. Soil Zoology.

Yates, Leslie R. and D. A. Crossley, Jr. 1980. Cesium-134 and strontium-85 turnover rates in the centipede *Scolopocryptops nigridia* McNeill. Pedobiol.

Manuscripts in Local Review
(Not submitted for publication as yet).

Haines, B. L., J. V. Nabholz and S. DuBois. Rainfall element content and acidity from 4/30/76 to 2/17/78, Athens, Georgia.

Nabholz, J. Vincent, D. A. Crossley, Jr. and G. Ronnie Best. An inexpensive weir and proportional nutrient sampler for miniature watershed ecosystems.

Nabholz, J. Vincent and D. A. Crossley, Jr. The nutrient budgets of rock outcrop ecosystems and their response to selected perturbations.

Table 1 (continued)

Theses Completed
(Partially supported under this contract)

Blumberg, A. Y. 1979. Comparison of soil surface arthropod populations in conventional tillage, no-tillage and old field systems. MS Thesis, University of Georgia. 96 p.

Weems, D. C. 1980. The effects of no-till farming on the abundance and diversity of soil microarthropods. MS Thesis, University of Georgia. 89 p.

TABLE 2. Reprints of Publications and Technical Reports Accompanying this Annual Report.

Reprints

Seastedt, T. R., Aruna Kothari and D. A. Crossley, Jr. 1980. A simplified gelatine embedding technique for sectioning litter and soil samples. Pedobiologia 20: 55-59.

Technical Reports

Number	Title
DOE/EV/00641-38	Improved methods for measuring radioactive tracer accumulation and excretion by microarthropods, with applications for a mite species, *Tyrophagus longior* (Acarina, Acaridae).
DOE/EV/00641-39	Arthropod use of invertebrate carrion
DOE/EV/00641-40	Comparison of mineral element cycling under till and no-till practices: An experimental approach to agroecosystem analysis.
DOE/EV/00641-41	Comparison of soil surface arthropod populations in conventional tillage, no-tillage and old field systems.
DOE/EV/00641-42	Rainfall element content and acidity from 4/30/76 to 2/17/78, Athens, Georgia.

TABLE 3. Papers Presented Based in Part on Research Funded Under This Contract.

Blumberg, A. Y. Comparison of pitfall catches of arthropods in no-tillage, conventional tillage and old field systems. Southeastern Branch Meeting, Entomological Society of America, Biloxi, Mississippi, January 28-30, 1980. (Winner of Award, Student Contest).

Blumberg, A. Y. and D. A. Crossley, Jr. Soil arthropods in no-tillage and conventional tillage systems. Poster Session, Annual Meeting, Ecological Society of America, Tucson, Ariz. August 3-8, 1980.

Crossley, D. A. Jr. Regulation of nutrient cycling in forests by arthropods. Invited seminar, Michigan State University, March 10, 1980.

Seastedt, T. R., C. M. Tate and D. A. Crossley, Jr. Decomposition rates and nutrient contents of arthropod remains in forest litter. Annual Meeting, Ecological Society of America, Tucson, Arizona, August 3-8, 1980.

Subproject (1): Nutrient element accumulation and turnover in soil arthropod food chains.

The elemental contents (or concentrations) in soil arthropods result from a balance between intakes and losses. Research conducted under this subproject has included measurement of elemental pools in arthropods and their foods (Gist and Crossley 1975, Crossley 1977), rates of elemental turnover by various elements of the soil fauna, and model development and evaluation (Webster and Crossley 1978) to estimate rates of elemental flow. Also, we have investigated phenomena in influencing food chain dynamics, such as coprophagy (Webb 1977) and migration (Best et al. 1978). An important part of the research has been the application of radioisotope techniques to measure nutrient dynamics (Abbott and Crossley 1980, Yates and Crossley 1980).

Research can be conveniently subdivided between microarthropods (principally mites and collembolans) and macroarthropods (millipedes and others), since different techniques are required for the two groups. Elemental contents for macroarthropods can be measured with conventional methods (flame photometry, atomic absorption spectrophotometry, plasma emission spectrometry). Turnover rates can be measured with radioisotopes, using well-established whole-body counting techniques (Yates and Crossley 1980, for example). For microarthropods, special techniques are necessary because of the small size of the organisms. Electron microprobe techniques have been utilized for elemental analysis of microarthropods (Todd et al. 1978). For radioisotope studies, special handling techniques have been devised (Abbott and Crossley 1980). Recently we have begun to develop information on microarthropod-fungal relations, using elemental analysis, radioisotope techniques, and microscopic examination of field-collected soil samples (Seastedt, Kothari and Crossley 1980).

Results of the research conducted under this subproject are routinely reported in open-literature publication. In the following paragraphs we summarize the current status of projects, and briefly summarize recent progress. Where possible reference is made to recent publication, manuscripts prepared to technical reports. Research under this subproject is active at the moment; most projects are not ready for detailed reporting.

Radioisotope Turnover by Microarthropods

D. A. Crossley, Jr. and D. T. Abbott

Summary of progress: A manuscript was accepted for publication which describes the techniques currently being used (DOE/EV/00641-38, Improved Methods for Measuring Radioactive Tracer Accumulation and Excretion by Microarthropods, with Applications for a Mite Species, *Tyrophagus longior* (Acarina, Acaridae)). Radioisotope retention measurements of ^{85}Sr and ^{51}Cr in *Tyrophagus longior* were fit to 1 and 2 component models. The half-time for the rapid component of both radioisotopes was about 10 hours, with assimilation of ^{85}Sr being about 62%. The identification of ^{51}Cr turnover as the rate of gut clearance, as with macroarthropods such as millepedes and crickets, is still tentative for the microarthropod Tyrophagus. An inexpensive disposable culture chamber for measuring radioisotope retention for microarthropods was described along with details of methodology. An ongoing research project is using these techniques for measuring ^{32}P turnover by collembolans (Sinella curviseta).

Microarthropod - Fungal Relations

D. A. Crossley, Jr., Francis Farrar, Louise Lanier, and T. R. Seastedt

Summary of progress: The nutrient and mineral element relations between microarthropods, fungi and decomposing substrates have been investigated using several approaches. Direct examination of intact soil samples has been utilized and the results reported in a recent publication (Seastedt, Kothari and Crossley 1980). This general approach -- direct examination of soil for mite-fungal associations -- is currently being pursued in a field sampling project. We have developed a sample extraction procedure which will extract microarthropods from a 13 x 13 cm sample (2 cm thick) into a collecting grid of 20 x 20 cells. The collection thus yields information on the precise location of microarthropods in the sample block. Dissection of the sample block then provides locations of organic debris, fungal growths and roots with which the microarthropods were associated. This method is proving highly workable and is yielding excellent results on both horizontal and vertical associations. (A complete analysis should be available for the next Annual Report). The method compliments the gelatine embedding technique. The embedding technique provides more detailed information on associations, but the extraction technique provides quantification.

Nutrient concentrations in microarthropods have been measured using electron microprobe techniques (Cromack et al. 1977). We are continuing these analyses using developmental stages of various mites and collembolan species and their food substrates. Research has been temporarily suspended due to failure of the EDAX analyzer in the University of Georgia's Electron Microscopy Laboratory (the unit is being repaired). In the meantime, we have made arrangements for analyses to be performed by Dr. Clayton Gist, Oak Ridge Associated Universities. Dr. Gist has access to a similar instrument there.

A major new research project has been initiated to measure the possible enhancement of fungal nutrient retention by feeding activities of microarthropods. Some recent research (Seastedt and Crossley 1980, Douce and Crossley MS) has suggested that stimulation of fungal nutrient retention due to microarthropod activities may be more significant than the comminution effect reported by Crossley and Witkamp (1964) and Witkamp and Crossley (1966). In the latter case, leaf litter tagged with cesium-134 was found to lose tracer at a much slower rate when arthropods enhanced nutrient retention. Phosphorus loss was accelerated by microarthropods, but other nutrients increased in concentration when litter contained microarthropods. Precipitation and throughfall nutrient inputs into litter appear to be responsible for the increased concentrations. Microarthropods stimulate fungal populations which then retain more of the nutrients received in throughfall. Litter without microarthropods lacks this retentive property, possibly because fungal hyphae become senescent without grazing pressure. (Phosphorus concentrations are low in throughfall; thus, its behavior differs from that of other nutrients examined: Ca, K, Mg). We are investigating the effects of microarthropods on nutrient dynamics of forest litter in a field experiment. Plywood shelters have been constructed to prevent throughfall from reaching a set of litterbags placed on the forest floor. We then are able to add nutrients at known concentrations in simulated rainfall, to replicates with and without soil arthropods. Thus we can test whether the presence of soil fauna will enhance or depress nutrient retention by leaf litter. Originally, we had intended to incorporate radioactive ^{85}Sr into the experiment (see last year's Proposal), but have delayed that addition because of equipment failure. Litterbags have been routinely collected in this experiment, their contents dried, ground and prepared for elemental analysis. However, results are not ready for reporting at this time. We plan to initiate an experiment using ^{85}Sr this autumn, at about the time of leaf drop.

Radioisotope Turnover by Macroarthropods

D. A. Crossley, Jr.

Studies of rates of elemental accumulation and loss by macroarthropods continue to be essential to the understanding of the impact of arthropods on soil processes. Unlike the microarthropods, the larger arthropods tend to be consumers of large amounts of raw organic matter. They are much more amenable to direct measurement of nutrient accumulation and excretion than are microarthropods. Previously we have investigated nutrient turnover by such diverse and important forms as millipedes (Webb 1977), centipedes (Yates and Crossley 1980) and crickets (Webster and Crossley 1978). During the current contract period we have had two manuscripts accepted which deal with nutrient and weight dynamics of macroarthropods (Seastedt, Mameli and Gridley 1980; Yates and Crossley 1980. See Table 1). Also, we have begun investigations of stable isotope accumulation by crickets (Acheta domesticus) in laboratory cultures under controlled conditions (1979 Proposal). That research is ongoing and not ready for final analysis and reporting.

Turnover of Cobalt-60 by Earthworms

D. A. Crossley, Jr., E. R. Blood and R. T. Seastedt

Summary: Current research is using experimental measurements of ^{60}Co turnover by earthworms to generate conceptual and working models of elemental accumulation by earthworms. Results to date indicate low assimilation and slow turnover rates, properties to be expected for pollutants such as heavy metals. Research will continue towards development of models addressing the value of earthworms as biological monitors for soil pollutants.

Introduction: The importance of earthworms in soil systems has long been recognized. Earthworms are invertebrates but not, of course, arthropods. Nevertheless, they occupy an important niche in soil systems and fall within the purview of research performed under this contract. Earthworms directly affect soils by channeling and mixing superficial and deeper layers, consuming organic matter, and redistributing elements within the soil column. They link abiotic (soil) with biotic (food chain) properties of soils. Recently, interest has developed in designing composting systems for municipal wastes with earthworms as key components. Questions have arisen about the possible redistribution of heavy metals in these systems, and the significance of such pollutants in composting systems generally (Hartenstein 1978). More recently, an EPA workshop (States et al. 1980) proposed the use of earthworms as biological monitors for pollutants in terrestrial ecosystems. Laboratory and field studies have shown that earthworms are capable of accumulating heavy metals from soil and sewage sludge. Gish and Christensen (1973), Van Hook (1974) and Ireland (1975) have shown that earthworms are capable of accumulating Cd, Ni, Zn and Pb from soil. Higher levels of these elements were found in earthworms that in the surrounding soils, usually when soil concentrations were relatively low. Ireland (1975) found earthworms had higher concentrations in soils with high Zn and Pb, but were lower than soil concentrations when soil levels were low. Hartenstein et al. (1980) found that Eisenia foetida accumulated Cd, Ni, Pb, Zn, Ag and Cr from sewage sludge, but only Cd continued to accumulate (increase in concentration) throughout the experiment.

Also, Cd was the only element which was concentrated above exposure levels. Unlike Ireland's study, no correlation was observed between exposure dose and accumulation (except for Cd). Other important variables affecting such experimental results include organic matter, clay content and microbial activities in substrates, all of which affect the availability of metals. Crossley et al. (1970) exposed earthworms to organic litter or soil containing ^{137}Cs. Earthworms could assimilate the radioactive tracer only from organic matter, not from soil alone.

Research reported here was initiated to develop information on the assimilation and turnover of ^{60}Co by a common earthworm (Eisenia foetida), to help in developing predictive models of elemental accumulation by earthworms. Clearly, if earthworms are to be used as biological monitors for pollutants, better information must be obtained about the dynamics of accumulation and turnover. Cobalt is a trace micronutrient which shares many aspects of nonessential heavy metals. Cobalt itself is a dominant component of fly ash and coal ash, and thus may become increasingly important as a pollutant.

Methods: Soil and manure obtained locally were each tagged with ^{60}Co as follows: One hundred grams of each were air dried, homogenized by hand mixing, and tagged with 20 ml $^{60}2$ solution containing 1 uCi $^{60}CoCl_2$. Both substrates were thoroughly mixed to provide even distribution of radioisotope. Samples revealed concentrations of 0.151 $uCi.g^{-1}$ in manure and 0.070 $uCi.g^{-1}$ in soil (oven dry wt). Eisenia foetida were obtained locally. Ten worms were placed on radioactive soil and 10 on radioactive manure, for 48 hrs. Five additional earthworms were exposed to radioactive manure for 5 days. After the exposure period, earthworms were maintained individually in petri dishes containing nonradioactive manure. After each counting, earthworms were transferred to new petri dishes to minimize reingestion of radioactive excreta. All experimental units were kept at an environmental temperature of 22° C. Radioactive ^{60}Co was measured in a 3 x 3 in. Th-activated NaI well type scintillation crystal connected to a multichannel analyzer. Individual worms were cleared of debris and counted in glass tubes.

Results: Eisenia exposed to tagged soil rapidly became radioactive, reaching levels of 4.1×10^{-2} uCi $^{60}Co.g^{-1}$ (dry weight) after 48 hrs. Additional exposure times of 3 days did not increase the radioactivity of the earthworms; the level reached after 48 hrs. was maximal. Once transferred to nonradioactive soil, earthworms lost radioactivity rapidly (Figure 1), and in a manner which can be described by a single component exponential equation of the form

$$A_t = A_o \cdot e^{-bt}$$

where A_t is the radioactivity at time t (dpm per earthworm)

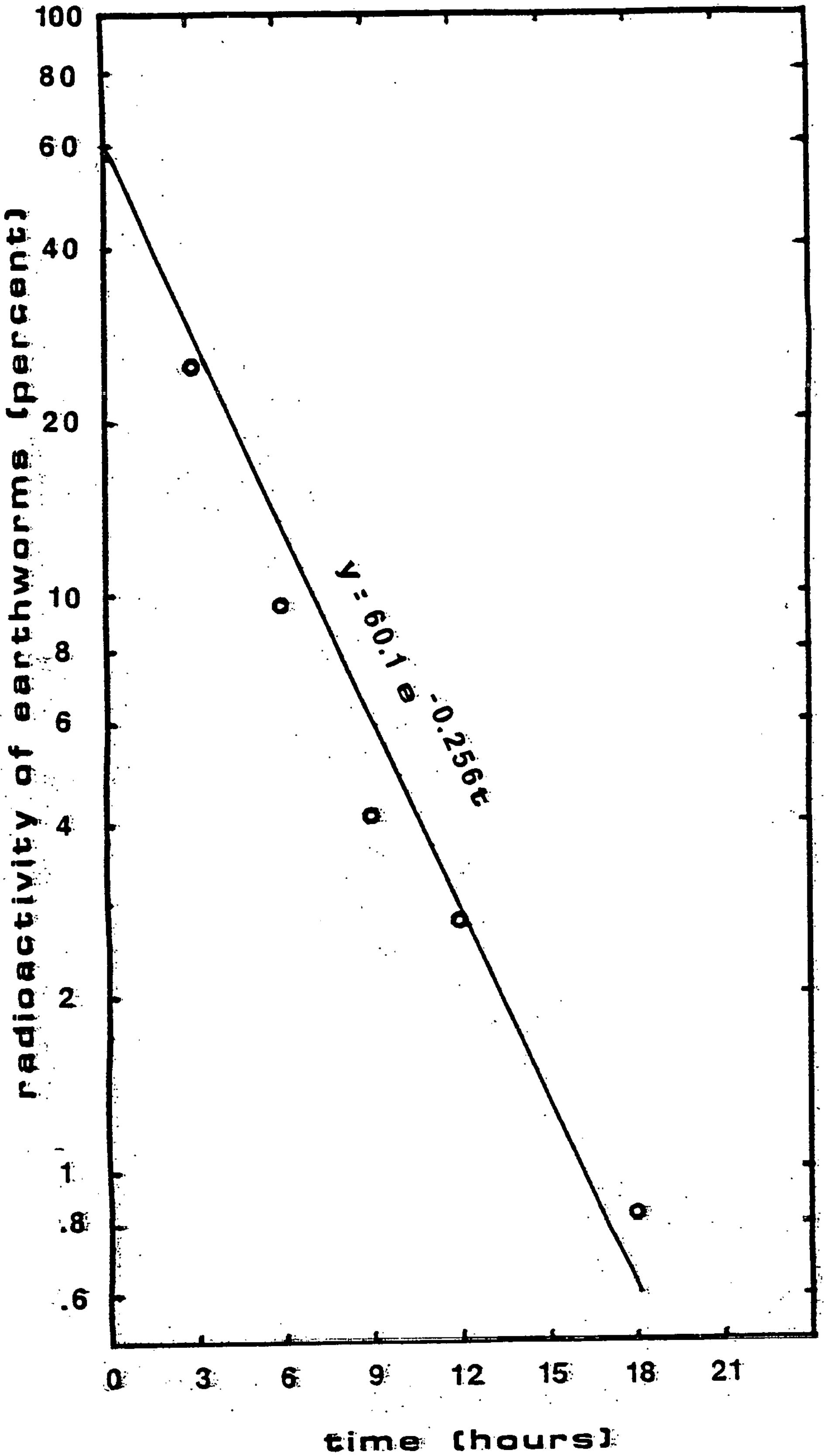
A_o is the initial radioactivity

b is the loss rate coefficient (hr^{-1})

t is time (hours)

The mean value for the loss rate coefficient b was 0.256($\pm$ 0.0048, n=7) per hour (Table 4). The linearity of the curve (Figure 1) suggests that little or no ^{60}Co was assimilated from the soil. The observed

Figure 1. Retention of ^{60}Co by earthworms (*Eisenia foetida*) removed to nonradioactive soil, following 48 hrs in tagged soil. Rapid loss and linearity suggest that no ^{60}Co became assimilated and loss observed was due to gut clearance of nonassimilated material.



100
80
60
40
20
10
8
6
4
2
1
.8
.6
radioactivity of earthworms (percent)
y = 60.1 e -0.256t
0
3
6
9
12
15
18
21
time (hours)

Table 4. Values for parameters of models describing retention of ^{60}Co by Eisenia foetida in nonradioactive substrates following exposure to radioactive soil or radioactive manure. Parameters defined in text.

Parameter	Soil (N=7)	Manure (N=6)
a_1	60.1%	89.5%
b_1	.256 ($\pm$ 0.0048)hr^{-1}	.424 ($\pm$ 0.0078) hr^{-1}
$t_{1/2}$	2.70 hr	1.63 hr
a_2		7.09%
b_2		0.0060 ($\pm$ 0.0007)hr^{-1}
$t_{1/2}$		115.1 hr
r*	.9789	.9399

*correlation coefficient

radioactivity presumably was due to the tagged soil in the guts of the earthworms, and the rapid decrease in radioactivity was due to gut voidance. Similar interpretations were made for 137 earthworms (Octolasium lacteum) containing ^{137}Cs-tagged soil by Crossley et al. (1971). The half-time for gut clearance ($\log_e 2/b$) for Eisenia foetida is estimated to be 2.71 hr, only slightly different from the 3 hr gut clearance time reported by Hartenstein et al. (1980).

These results permit calculation of soil turnover by Eisenia under laboratory conditions. Earthworms reached an equilibrium level of 1.37 x 10^{-3} uCi per earthworm. At this point intake of radioactive soil is balanced by turnover:

$$I = bQ$$

where I = rate of ingestion (uCi per hr)

b = loss rate coefficient (hr^{-1})

Q = equilibrium concentration (uCi per earthworm)

The rate of ingestion thus calculated is 120 $mg \cdot d^{-1}$, or 53% of the live weight of the earthworms per day. This is almost twice the rate (29%) reported by Crossley et al. (1971) for Octolasium, but the experiments differed in many factors, including size of organisms and experimental temperature.

Earthworms which accumulated radioactivity from manure were transferred to non-tagged manure, and lost radioactivity in a pattern described by a two-component retention curve (Figure 2). This curve can be described by the equation

$$A_t = A_o(p_1e^{-b_1t} + p_2e^{-b_2t})$$

where A_t = radioactivity at time t

A_o = initial radioactivity

P_1 = proportion of radioactivity lost at rate b_1

P_2 = proportion of radioactivity lost at rate b_2

$(p_1 + p_2 = 1)$

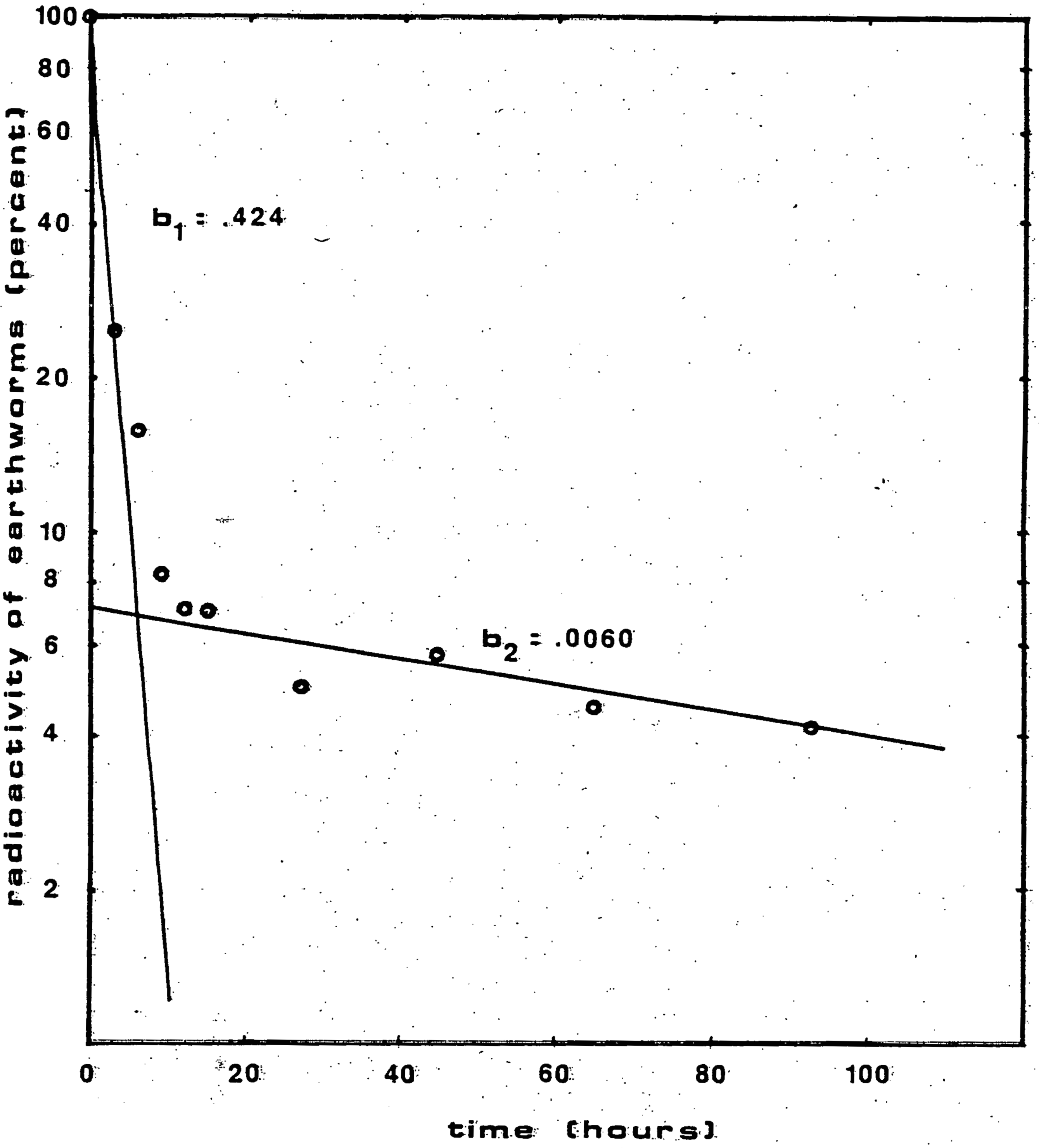
b_1 = initial, rapid loss rate component

b_2 = final, slow loss rate component

Values for the initial parameters were obtained by substracting the final component from the first one, in a manner analogous to the stripping method for graphically separating mixtures of radioisotopes with different half-lives (Chase and Rabinowitz 1962). Values are given in Table 4.

Discussion: Experimental results suggest that Cobalt is assimilated at a low rate (less than 10% of ingestion) and excreted slowly, with a half-time for turnover of about 100 hours. These findings are consistent with reports for other elements in earthworms and for terrestrial saprophytic invertebrates in general. Assimilation from soil itself appears to be nil; organic matter should be the major, if not the only, source of cobalt for earthworms. These results could be affected by abiotic factors such as soil type. Most heavy metals are associated with the

Figure 2. Retention of ^{60}Co by earthworms (_Eisenia foetida_) following 48 hrs exposure to tagged manure before transfer to non-radioactive food. Parameters b_1 and b_2 explained in text.



100
80
60
40
20
10
8
6
4
2
radioactivity of earthworms (percent)
b_1 = .424
b_2 = .0060
0
20
40
60
80
100
time (hours)

organic fraction of soil, compounds which are refractory and resistant to mobilization. Some elements (Hg, possibly Pb) may become more readily available due to microbial transformations. Soil moisture, seasonality and other biotic regimes may influence earthworm uptake and retention of pollutants in the soil.

The two-component curve of cobalt-60 retention also is typical of elemental retention by saprophytic terrestrial invertebrates (Crossley 1977). The general interpretation for these curves is that the first, short component represents loss of unassimilated material due to gut clearance and the second, slower component represents the excretion of assimilated tracer. The similarity of the short component for manure and the single component for soil sugests that this interpretation is correct for ^{60}Co in Eisenia. Previously, such an interpretation has been made in experiments with insects (Van Hook and Crossley 1969) and for retention of ^{137}Cs by earthworms (Crossley et al. 1971). In establishing the value for the short component, the longer component is stripped from it graphically, in a manner similar to the technique used for separating mixtures of radioisotope species with different decay rates. Examination of Figure (2) shows that the crude, uncorrected loss rate is much closer to the single component system (Figure 1) than is the corrected rate. That is, the loss rate coefficient calculated from the first points in Figure (2) is 0.262 hr^{-1}, a value closely resembling the rate 0.256 hr^{-1} obtained in the soil experiment. If the second component is stripped out, the rate of 0.262

hr^{-1} becomes 0.424 hr^{-1} (Table 4). We have re-examined some earlier experimental data, and posed the tentative hypothesis that excretion of assimilated tracer is delayed enough that curve stripping may be inappropriate for estimating the shorter component, in some cases. This effect would be true and valid where excretion rates are much slower than gut turnover rates, and where assimilation is low. Both are true for ^{60}Co in Eisenia. Previously, Goldstein and Elwood (1971) and Kowal (1971) objected to accumulation models based on the stripping method because those models are biologically unrealistic. The models require that assimilation be instantaneous, with ingested tracer instantly divided into two pools (assimilated and non-assimilated). Webster and Crossley (1978) showed that the Goldstein-Elwood model produced identical results in simulations of accumulation by insects, however. It would appear, then, that further model development should incorporate a time-lag for excretion of assimilated radionuclides.

Simulations are now being performed for cobalt accumulation under the conditions of parameters listed in Table (4). Results are not completed, but it appears that Eisenia is not likely to concentrate ^{60}Co above levels found in soil or manure. The longer component, with a half-life of about 100 hours, suggests that earthworms would equilibrate (to 95% of equilibrium) after about 500 hours or 25 days. With low assimilation, the concentration of ^{60}Co in Eisenia would be lower than concentrations in manure or soil. The interpretation of elemental concentrations in earthworms, as a means of biological monitoring of pollutants, will require more information about the abiotic and biotic factors which might alter rates of elemental assimilation or turnover.

Development of Arthropod Data Sets

D. A. Crossley, Jr., A. Y. Blumberg and D. C. Weems

This effort was begun two years ago at the suggestion of an anonymous external reviewer, who felt that the research described above was documenting rates of flow but not population sizes or elemental pools for soil arthropods. He questioned that nutrient budgets could be computed unless pool sizes were known. We responded that we have access to previous data sets (e.g. Duke and Crossley 1975, Crossley et al. 1975) and also have access to data sets developed in other research projects. However, we agreed with the merit of the criticism and began last year to accumulate new data sets on soil arthropod communities. All field work for that investigation is now completed and some of the work on population and community structure has been written for publication. Analysis of elemental content of the samples is not completed, so that laboratory work will continue. It should be completed this summer or early autumn.

In last year's Annual Report we described the advantages of working in the no-till agroecosystem project operated by the University of Georgia's Institute of Ecology. This system has the advantage of relatively uniform vegetation and known soil structure. In addition nutrient information regarding uptake by vegetation and mobilization during decomposition is being developed on that project, obviating the need to make those measurements as a part of this project. The information will be available for our use in interpreting the results from our arthropod studies.

Three types of data sets have been developed:

(1) Sampling of arthropods in vegetation with bumper traps. The need for a rapid, effective sampling system emerged during our granitic outcrop studies, when we attempted to evaluated the effectiveness of the insecticide applications we were using as perturbations. We needed to determine whether rates of reinvasion were so high as to make the insecticide treatments ineffective. We devised a set of obstacle traps ("bumper traps," see last year's Annual Report) and have now completed evaluation of their effectiveness by trapping in large, uniform areas of vegetation such as crop systems. All samples were completed last summer and catches were sorted and data coded during the past winter. We have not completed analysis of the data. We intend to produce a publication describing the trapping system and evaluating its effectiveness at the first opportunity. It is evident from the data that the system is successful in capturing a large variety of flying insects; it should become a valuable survey tool.

(2) Soil surface arthropods. A year-long survey of soil-surface arthropods (macroarthropods) was performed with a set of pitfall traps

(Gist and Crossley 1973). Results of the population and community survey are given in a technical report accompanying this Report and will not be repeated here (DOE/EV/00641-41, Comparison of soil surface arthropod populations in conventional tillage, no-tillage and old field systems).

A set of automatic pitfall traps was designed to yield hourly separation of collections on a 24-hr basis. Traps were designed and constructed, but completed too late for inclusion in the yearly survey of soil surface arthropods reported above. The automatic pitfall traps are now being field tested. The results will be included in next year's Annual Report. The design will be published providing it is successful.

(3) Microarthropod data sets. We accumulated an annual data set of microarthropods in broad categories (numbers per m^2 for Collembola, other insecta, immature Oribatei, adult Oribatei, Mesostigmata, Prostigmata and Asigmata) in the agroecosystem mentioned above. Some early results were presented in a Technical Report accompanying this Annual Report (DOE/EV/00641-40, Comparison of mineral element cycling under till and no-till practices: An experimental approach to agroecosystem analysis). This entire data set has been tabulated, analyzed, and is the subject of a Master's Thesis now in final typing (See Table 3). Next year's annual report will provide a complete summary of the data set and an interpretation of the results.

We emphasize that the collection of these data sets is completed, and we do not anticipate more activity of this type unless information becomes necessary on another type of ecosystem.

Subproject (2): Mineral Element Cycling and trophic dynamics in granitic outcrop systems.

D. A. Crossley, Jr.

This research has been performed in small depression communities on granitic outcrops, using the communities as small island ecosystems. All field work land analyses are completed. Two manuscripts were completed and reported last year, but have not yet been published. An additional manuscript has been completed this year, and is included as a Technical Report accompanying this Annual Report (DOE/EV/00641-42, Rainfall element content and acidity from 4/30/76 to 2/17/78, Athens, Georgia). Except for manuscript preparation and revision, we do not anticipate more activity under this subproject.

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