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Thermochimica Acta 328 (1999) 99–103

thermochimica acta

Microcalorimetric study of some Amazonian soils

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Accepted 1 October 1998

Abstract

Microcalorimetric method was applied to study some Amazonian soils in order to establish the way by which the microbial soil activity is affected by the actual deforestation and burning suffered by the Amazonian rain forest. Different soil samples were collected in the Amazonian State of Brazil. Places with autochthonal vegetation and places that which had been deforested or burnt were elected due to its use in agriculture and cattle raising in an attempt to explore the difference in microbial growth behaviour. An LKB 2277 heat-flow microcalorimeter was used for all measurements at 298.15±0.02 K. The microcalorimetric data are presented together with some other measurements such as the physicochemical parameters and the number of microorganisms in soil samples. Power–time curves recorded from soil samples amended with the same quantity of glucose showed significant differences among soils used in the study. Results obtained were systematically studied in a more quantitative way and the values of the microbial growth rate constant, μ, total thermal effect, Q_T, and duration of the peak-time, PT, were calculated from power–time curves. The collected data showed again important differences in the microbial activity among the soil samples suggesting that the native microbial activity of soils in tropical rain forests are dramatically affected by the deforestation and burning.

Keywords: Amazonian soils; Microcalorimetry; Deforestation; Soil microbial activity

1. Introduction

Deforestation of the Amazon basin is occurring at an ever-increasing rate [1]. The effects of the destruction of the Amazon tropical rain forest on the environment are well known as described elsewhere [2–4].

Two of the reasons for the deforestation and burning of the Amazon basin are the conversion of primary forest into grazed pasture and land exploitation for agricultural purposes. It is also well known that most Amazonian pastures are only productive for short periods varying from four to eight years [5]. The reason is not yet well established in the literature.

Some studies about the effect of soil deforestation on changing in soil organic matter (SOM) have been done lately, since SOM is an important factor influencing site fertility [6,7]. Nevertheless, the results obtained have not been well understood. This lack of understanding together with a total absence of data about the soil microbial activity in the Amazonia affects the ability to manage tropical soils for agricultural purposes.

In this publication is reported the first series of data in terms of microbial activity for some Amazon soils.

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0040-6031/99/$ – see front matter
PII: S0040-6031(98)00629-7

For this purpose microcalorimetry is applied in this study since this method provides more qualitative and quantitative information than other analytical techniques. Thermal effect directly related to the enthalpy change, microbial growth rate constant for microbial growth, the energy involved in metabolic processes as thermal effect and so on, can be calculated by microcalorimetry to report data about soil microbial activity in a more quantitative way [8,9]. A comparative study of the soil microbial activity, in tropical rain forests and in territories converted from primary forests in grazed pastures and in agricultural exploitations, was done in order to detect how the microbial activity of these soils is affected by the deforestation and burning.

2. Material and methods

2.1. Soil sampling

Soil samples were collected from the Amazonia State in the forest of Brazil, surrounding a small village called Nova Airão, nearly 200 km away from Manaus city up Rio Negro at spring season. Two distinct regions named as P and T were selected to sample. The main difference between soils sampled in these regions is related to their percentages in organic matter.

Sampling was carried out at about 10 randomly chosen points from each site. After the removal of the very top layer of soil samples were collected from a depth of 5–10 cm. All samples from one site were mixed and sieved (mesh size 2×2 mm). Water content, pH, percentages of organic matter, carbon, hydrogen and nitrogen were calculated for all samples by routine methods. All samples were stored in polyethylene bags at 282 K at least one month before microcalorimetric measurements. The number of living bacteria and fungi was determined by colony forming unities (CFU).

Samples p_1, p_2 and t_4 correspond to soil collected in primary forests, p_3 was sampled in a cassava plantation, sample t_2 corresponds to soil collected in a citric plantation and t_3 was sampled in a grazed pasture.

2.2. Calorimetry

The calorimetric system was an LKB 2277 thermal activity monitor. This instrument has a four channel system in which the sample and reference are introduced simultaneously in a thermostated cylinder. All calorimetric experiments were performed in hermetically closed 5.0 cm^3 stainless steel ampoules. All soils were previously left in a thermostated room at 298 K for one day before submitting to calorimetric measurements. Thus, 1.0 g of soil sample was amended with 0.20 cm^3 of a solution containing 1.5 mg of glucose and 1.5 mg of ammonium sulphate. As reference, 1.0 g of soil sample amended with 0.20 cm^3 of distilled water was used. In each case, both sample and reference were identically homogenized by ampoules agitation before introducing into the respective position of the channel. The time between mixing and starting the measurement is nearly one hour. This normal procedure was also used before [10,11], to record all power–time curves, which measurements were performed at 298.15 ± 0.02 K. Each obtained value resulted from a triplicate independent recorded curves.

3. Results

Table 1 shows some properties of the soil samples used in this study. A significant difference can be observed in the percentage of organic matter in soils sampled in P and samples collected in T regions. Sample p_2 shows the highest organic matter percentage, probably due to the deposition of lime from the seasonal flood of Rio Negro. Sample p_3, collected in a cassava plantation, shows only a slight decrease of the percentage of organic matter if compared to sample p_1 collected in a tropical rain forest. Sample t_4, collected in a tropical rain forest in T region, shows a very low percentage of organic matter. Soils t_3 and t_2, collected also in the same zone T, in places destined to citric plantations and grazed pastures, respectively, show an increase in organic matter percentage if compared to sample t_4.

A significant increase in the percentage of nitrogen is observed in all the samples collected in places destined to pasture and agriculture, if compared to samples collected in primary forests. However, pH values are very similar in all samples, except soil t_3 collected in a grazed pasture.

Figs. 1 and 2 show the power–time curves recorded from soil samples collected in P and T regions,

Table 1
Organic matter, carbon, nitrogen, hydrogen and moisture percentages, and pH values for some selected Amazonian soils

Soils	Organic matter (%)	C (%)	N (%)	H (%)	pH	Moisture (%)
p_1	6.11	3.90±0.23	0.52±0.09	0.55±0.01	3.40	21.40
p_2	12.90	10.89±1.97	0.45±0.13	1.07±0.40	3.90	35.04
p_3	5.70	4.21±1.01	0.74±0.10	0.83±0.10	3.74	28.95
t_2	2.40	1.55±0.35	0.83±0.15	0.19±0.14	3.75	11.64
t_3	3.30	1.56±0.36	0.79±0.21	0.17±0.14	4.52	14.11
t_4	1.10	1.43±0.06	0.05±0.04	0.35±0.09	3.70	6.37

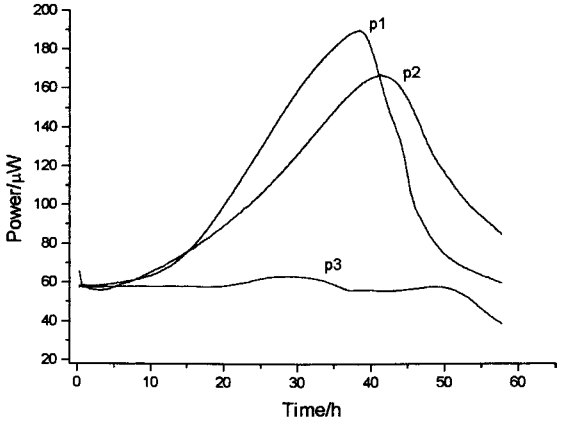

Fig. 1. Power–time curves recorded from Amazonian soil samples collected in P region.

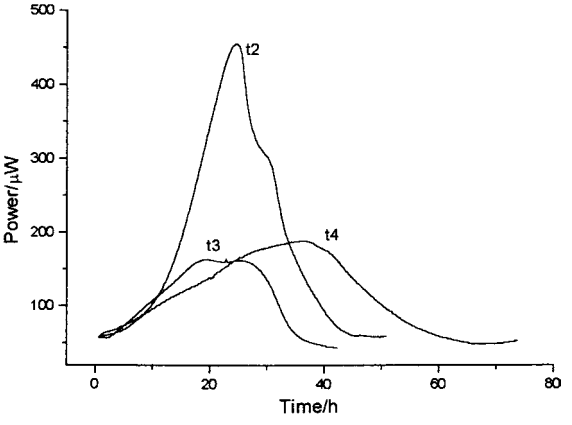

Fig. 2. Power–time curves recorded from Amazonian soil samples collected in T region.

respectively. In Fig. 1 it can be observed a clear depletion of the power–time curve recorded from sample p_3. Power–time curves recorded from samples p_1 and p_2 are similar in shape. Fig. 2 shows the power–time curves recorded from samples collected in T region and some differences can be observed even from a qualitative point of view. All of them show differences in the duration of the peak-time and peak-height representing the maximum amplitude of the curve, which are very noticeable in sample t_2.

In order to show the results in a more quantitative way, the total thermal effect, Q_T, the microbial growth rate constant, μ, and the value of the peak-time, PT, were calculated from power–time curves for all samples used in this study. The method to quantify the above parameters is well established [12,13]. These results are shown in Table 2 together with the number of microorganisms of each soil sample. A significant decrease can be observed in the number of microorganisms of sample p_3 of the cassava plantation, if compared to p_1 and p_2 samples, both collected in tropical rain forests. Sample p_2 shows a slight decrease in the number of microorganisms too, if compared to sample p_1, which is followed by the increase in the value of the peak-time. The value of the peak-time for p_3 sample is not clear. The shape of the power–time curve recorded from this sample strongly suggests important changes on its degradation activity, probably as a consequence of the deforestation and burning suffered to establish the cassava plantation.

The number of microorganisms in t_2 and t_3 samples is much higher than in the t_4 sample. The variations of the peak-time calculated for these samples are in good agreement with the number of microorganisms. Sample with the largest number of microorganisms shows the lowest value of peak-time as it was expected.

Microbial growth rate constant values calculated for p_2 and p_1 samples do not show significant differences, but a drastic depletion of this value in sample p_3 is observed. These same values calculated for t_2 and t_3

Table 2
Total thermal effect, Q_T, peak-time, microbial growth rate constant, μ, and the number of microorganisms calculated for all selected soils

Soils	Q_T (J)	Peak-time (h)	μ (h^{-1})	No. microorganisms (g 10^5)
p_1	10.82±1.33	35.68±1.92	0.064±0.016	8.30±3.90
p_2	9.29±1.80	29.22±1.81	0.055±0.015	6.30±5.50
p_3	2.98±0.72	–	0.010±0.003	3.00±2.20
t_2	23.59±1.59	24.87±1.55	0.081±0.003	42.25±14.53
t_3	9.44±1.86	22.83±0.97	0.045±0.017	53.50±37.00
t_4	17.69±2.44	41.70±6.74	0.028±0.005	0.52±0.29

samples are higher than the value obtained for t_4 sample. These changes show that microbial soil activity in P region is strongly inhibited after the deforestation and burning, but the conversion of primary forest to agriculture plantations and pasture in T region, stimulates the microbial soil activity in these samples. Table 2 even shows that values of the total thermal effect, Q_T, calculated for all samples vary a great deal. Once again sample p_3 shows the lowest value.

4. Discussion

The obtained results with this series of soil samples show that the change observed in the soil organic matter percentages (SOM) caused by the deforestation and burning of the primary forest may be related to data about the microbial soil activity.

Variation in SOM values and also in nitrogen percentages in all samples used are in good agreement with literature. A clear increase in SOM values was detected in soils destined to grazed pastures and agricultural exploitations in T region. Several studies conducted in the Amazon basin have shown that when forest is cleared and converted to pasture, an increase in the SOM percentage is observed [14,15]. The reason may be, on one hand, the continuous deposition of plant debris in well-established pastures, and on the other, the existence of a non-equilibrium between the rate of deposition of fresh source of carbon and the loss of indigenous carbon, since deposition occurs at a higher rate [6].

The percentage in nitrogen increased in all samples collected from places supporting agriculture plantations and pasture. The reason may be the fixation of atmospheric dinitrogen molecules by free-living nitrogen fixing bacterias associated with pasture grasses, as well as the change in the inorganic nitrogen pools used by pasture grasses compared with the nitrogen pools used by trees of the original forests [16].

Microcalorimetric data related to soil microbial activity show changes in the degradation activity of soils affected by the burning and deforestation processes. Results obtained from p_1 and p_2 samples, collected in tropical rain forests, do not show significant differences in terms of microbial activity. Values of the microbial growth rate constant, μ, indicate that the soil organic matter is decomposed at a slow rate in these soil samples. The SOM percentages calculated for samples collected in P region are higher than values of the SOM quantified for soils sampled in T region. This feature strongly suggests that the rate of deposition of the organic matter in tropical rain forest is higher than the rate of decomposition. The deforestation and burning of the primary forests in P region to be converted in cassava plantations involve big change in soil microbial activities. The low values of the microbial growth rate constant, total thermal effect and the initial number of microorganisms calculated for sample p_3 strongly suggest that an inhibition of the microbial soil activity in this sample occurred. The slow decomposition rate in p_3 sample allows the rapid deposition of the organic matter, which could explain the high values of SOM percentages calculated for this sample in comparison with those obtained from samples collected in T region. Similar effects were found by other authors in other studies developed with different analytical devices. It has been found that burnt areas in the Amazon basin were characterized by reduced soil respiration in the soils relative to the natural forests [17]. The quantification of the carbon dioxide liberated to the atmosphere by soils in Amazonia in a six months period

after being burnt showed that respiration in burnt areas could be 50% smaller than that ones obtained in primary forests [18]. The area where sample p_3 was collected had been burnt one year before sampling. These results are in very good agreement with the microcalorimetric data reported for this sample.

The results obtained from samples collected in T region widely differ from the above data. Also sample t_4 collected in a primary forest shows lower values of the microbial growth rate constant and the initial number of microorganisms than p_1 and p_2 samples. These results are probably related to the low SOM percentage of this sample if compared to soils collected in P region. The microbial growth rate constant value suggests that decomposition takes place at a very low rate in this sample too. However, these samples were collected in a dry season. Studies about seasonal trends in organic matter decomposition in the Amazonia report that degradation occurs at a lower rate during this period of the year. During the rainy season, conditions for the SOM decomposition become very favourable and microorganisms increase their degradatory activity [19].

The introduction of agriculture exploitations and pastures in T region increased the soil microbial activity as shown in the data from the microbial growth rate constant. However, this increase in microbial growth rate constant values is followed by the increase in the number of microorganisms too. All the above values are much higher than those obtained from sample t_4. It is possible that in T region the organic matter is more available to microbial attack. Organic matter in P region could be in some way protected against microbial degradation specially by silicon and aluminium elements [20]. The increase in the number of microorganisms in soils sampled in agriculture exploitations and pastures in T region could bring problems of immobilization of nutrients for plant growth in these lands which could explain the low productivity of agriculture plantations in this part of the Amazonian region.

Acknowledgements

The authors are indebted to FAPESP for financial support and CNPq for fellowships to FDB and CA. The authors also thank Suely S. Freitas from Instituto Agronômico (IAC), Campinas, for the quantification of the microorganisms in all soil samples.

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