The decomposition of drowned biomass during filling of reservoirs[1]

Bianchini, I. Jr.[2,3]
Cunha-Santino, M. B.[3]

ABSTRACT

This paper is aimed at discussing issues associated with the degradation of organic resources (leaves, branches, barks and litter) that usually remain within the basin of new man-made reservoirs. In these environments, the short-term variation of limnological parameters is mainly connected with decay of phytomass drowned during the filling operation. The kinetics of the degradation processes in reservoirs is discussed on the basis of information about detritus sources and the properties of the various types of compounds (*i.e.* labile and refractory). Overall, the mineralization of refractory fractions is a slow process, constituting the main route for decomposition and being affected by changes of environmental variables. The mineralization of labile and hydrosoluble compounds is responsible for the short-term changes on decomposition; basically, the intensities of these changes depend on the labile/soluble compounds content of detritus and their chemical composition.

Key words: decomposition kinetics, particulate organic carbon, dissolved organic carbon, oxygen budget, man-made reservoir, greenhouse effect gases.

---

[1] International Seminar on Greenhouse Gas Fluxes from Hydro Reservoirs & Workshop on Modeling Greenhouse Gas Emissions from Reservoir at Watershed Level, Rio de Janeiro (RJ), 2005.

[2] Departamento de Hidrobiologia, Universidade Federal de São Carlos. Via Washington Luiz, km 235. Cx. Postal 676. 13565-905. São Carlos, SP, Brasil. e-mail: irineu@power.ufscar.br

[3] Programa de Pós-Graduação em Ecologia e Recursos Naturais, Universidade Federal de São Carlos. Via Washington Luiz, km 235. Cx. Postal 676. 13565-905. São Carlos, SP, Brasil. e-mail: pmbc@iris.ufscar.br

INTRODUCTION

In the formation of artificial reservoirs, the incorporation of the vegetation from the basin constitutes an abundant source of detritus. During the filling phase, when the indigenous vegetation in the flooded area is drowned, an intense release of elements (minerals and organic) derived from decomposition process occurs. The degradation of submerged plant resources can affect the water quality owing to eutrophication and to pressures in the budget of dissolved oxygen (Baxter & Glaude, 1980; Garzon, 1984; Ploskey, 1985). These events can - for a long period - affect negatively the aquatic ecosystem metabolism, the uses of water and the equipment for energy generation (Paiva & Salles, 1977). The rate of decomposition depends on the environmental conditions (physical and chemical), the heterotrophic activity of organisms and the quality and amount of plant resources. Usually, the kinetics of decomposition is correlated with the disappearance of the substratum and the appearance of products. When the processes occur in aerobic conditions, it is further assumed that the oxygen uptake varies linearly with the formation of products such as carbon dioxide (Stumm & Morgan, 1981; Jfrgensen, 1994). It is also frequently assumed that the aerobic decomposition is faster (Wetzel, 1983). Experiments related to aerobic mineralization of several kind of debris indicated that the oxygen uptake kinetics could reflect qualitative aspects of detritus (Bitar & Bianchini Jr., 2002), in addition to variation in the stoichiometric values of decomposition processes (Cunha-Santino, 2003; Peret & Bianchini Jr., 2004). The stoichiometric relation determines the extension of the biochemical transformations of organic matter (Brezonik, 1993), presenting quantitative information about reagents consumption and products formation (Characklis, 1990).

The microbial fermentation of submerged detritus can result in the formation of methane and other gases. The amount of evolved gases depends on the concentrations of the organic substances, microbial composition and nutrients. Strong differences in the yield of gases were recorded among sediments from lakes with high and low primary production rates; the higher values of gases production reached 1000 fold in lakes that received sludge waters, in comparison with non-impacted lakes (Sorokin & Kadota, 1972). The detritus oxidations generate other products such as humic substances (Lu *et al.*, 2001), which are high molecular weight, dark compounds, thus causing changes in the water color. Several properties can be attributed to these colored compounds, for instance, light attenuation in the water column that interfere negatively in the primary productivity of the aquatic system. On the other hand, the presence of these substances can influence positively the growth of algae and bacterioplankton. Other properties, including formation of trihalomethane, decrease the potential for using waters in supply systems (Bruchet *et al.*, 1989). The ability of humic compounds to complex metallic ions (Ashley, 1996; Petrovic & Kastelan-Macan, 1996) controls the availability of cations in the water column. Considering the importance of the decomposition of drowned resources (leaves, branches, barks and litter) for the understanding the greenhouse gases emissions from reservoirs and their biogeochemistry cycles, this work aims at: i) discussing and parameterizing equations used to describe decomposition processes; ii) establishing connections between the environmental variables and the parameters of decomposition models and iii) describing some effects of detritus degradation on the chemical and physics characteristics of the water.

from the
hen the
elements
lation of
1 and to
Ploskey,
osystem
& Salles,
ical and
of plant
ance of
aerobic
rmation
t is also
riments
uptake
ddition
, 2003;
of the
itative
)).
ethane
rganic
f gases
rates;
sludge
etritus
ch are
everal
ion in
stem.
vth of
hane,
bility
acan,
tance
r the
nistry
cribe
ables
ritus

DECOMPOSITION KINETICS OF THE DETRITUS

The decomposition process can be represented from the kinetics point of view using a set of monomolecular reactions that are irreversible and first order (Bianchini Jr., 1997). In general, this set is formed by multiple reactions (parallel and in series). Due to detritus heterogeneity, the reactions should be described for each chemical compound/element or structural element (Mindermann, 1968). Therefore, decomposition should be represented as a sum of several exponential functions (Lousier & Parkinson, 1976). On the basis of the model proposed by Bianchini Jr. (1997), Equations 1 through 5 describes the mineralization processes, where the chemical heterogeneity of the detritus is considered (Figure 1). In this model the mineralization is assumed to occur via three pathways. In the first, the labile compounds are oxidized quickly, simultaneously to leaching. The second way comprises the consecutive processes of leaching and catabolism of the dissolved fractions of organic matter (DOM). In the third route, the oxidation of the refractory particulate organic matter (RPOM) is responsible for the mass loss.

1 - Decay of particulate organic matter (POM): DOM formation and oxidation of the particulate fractions.

$$POM = LSPOM \times e^{-k_T t} + RPOM \times e^{-k_4 t} \qquad (1)$$

where:

LSPOM = labile and/or soluble fractions of the detritus, (%);
RPOM = refractory organic matter of the particulate fractions, (%);
k_T = global decay rate of LPOM (k_1+k_2), day^{-1};
k_1 = mineralization rate of the labile compounds, day^{-1};
k_2 = leaching rate (formation of soluble compounds), day^{-1};
k_4 = mineralization rate of the refractory compounds, day^{-1}.

2 - Mineralization of the labile organic matter (LPOM) and time variation of DOM.

$$IN_1 = LSPOM \ \frac{k_1}{k_T} \times (1 - e^{-k_T t}) \qquad (2)$$

$$DOM = LSPOM \ \frac{k_2}{k_T} \times \frac{k_T}{k_3 - k_T}(e^{-k_T t} - e^{-k_3 t}) \qquad (3)$$

where:

IN_1 = labile organic matter mineralized, (%);
DOM = dissolved organic matter, (%);
k_3 = mineralization rate of the organic dissolved matter, day^{-1}.

3 - Formation of inorganic compounds from the mineralization of DOM.

$$IN_2 = LSPOM \; \frac{k_2}{k_T} \times \left[1 + \frac{k_3}{k_T - k_3} e^{-k_T t} + \frac{k_T}{k_3 - k_T} e^{-k_3 t} \right] \qquad (4)$$

where: IN_2 = dissolved mineralized organic matter (%).

4 - Mineralization of the refractory particulate detritus (RPOM).

$$IN_3 = MOPR \quad \times (1 - e^{-k_4 t}) \qquad (5)$$

where: IN_3 = refractory particulate mineralized organic matter, (%).

The average values of LSPOM, RPOM, k_T and k_4, calculated for the proposed model (Equations 1 to 5) are shown in Table 1. Also shown are the half-time ($t_{1/2}$) corresponding to the rates k_T and k_4. For such estimates the results from 4 experiments of decomposition were considered; these experiments were performed in field (Delitti, 1993) and laboratory (MDK/CENCO/COPEL, 1988; FAI-UFSCar/CESP, 1998; Bitar *et al.*, 2002) conditions and used resources (leaves, branches, barks and litter) derived from tropical (Brazilian) plant typologies. The fittings (parameterization) were performed using non-lineal regressions (iterative algorithm of Levenberg-Marquardt), following Press *et al.* (1993).

According to the data obtained by the kinetic fittings one infers that detritus are heterogeneous resources (Table 1). Considering all experiments data summarized in Table 1, the refractory fractions were estimated to encompass ca. 86.3% and the labile/soluble fractions comprised 14.7%. These results emphasized the importance of the 3rd mineralization route in the process, which means that most detritus have slow decomposition. This feature makes this process intrinsically susceptible to temporal changes of the environment controlling factors (*e.g.* temperature, oxi-reduction potential, availability of nutrients, and type of decomposing organism). Considering the high $t_{1/2}$ of this process (average value of 192 days) it is possible to assume that in this pathway are included processes that require stringent conditions, such as fermentation and methane formation. On the other hand, the losses of mass linked to the dissolution and mineralization of labile fractions are faster (average value of $t_{1/2}$: 0.5 day); in general, the time these processes take is mainly related with the detritus quality and not with the environment controlling factors. Therefore, the decay of submerged resources within reservoirs generates two types of effect with regard to the detritus quality. In the first stage of decomposition, the dissolution of elements and oxidation of labile compounds prevail. Depending on the amount of detritus, such predominance generates in the short-term, conditions for fertilization of water column and depletion in the dissolved oxygen concentrations. After this phase, when the decomposition processes of refractory compounds (*e.g.* lignin, cellulose, hemicellulose) predominate, the reservoir tends to possess greater availability of dissolved oxygen and emissions of gases (*e.g.* methane). In particular, the methanogenesis is mainly conditioned to the appearance of favorable

---

conditi
In this c
as prim
increm
were ob

Oth
of evol
refracto
2005). I
and CC
yield of
results f
43.4% c
1st mine
half-tim
in new
perman
substan
of phyt

On
anaerob
of aerol
oxygen
of labile
experim
litter w
coeffici
cm) an
convert
and we
the refr
of hum

THE K

The
were ob
1988; I
conduc
al., 200
Marqu
fitted t
and th

conditions (*e.g.* lowering of oxi-reduction potential and increase of nutrients availability). In this context, laboratory studies pointed to the importance of refractory fractions (fibers) as primary resource for fermentation that drives methanogenesis; in this in case, the increments of cellulase activities together with the increases of rates of CH_4 formation were observed (Cunha-Santino, 2003).

Other experiments carried out under controlled conditions confirmed that the amount of evolved gases (especially CH_4) depends on temperature, on the concentrations of refractory organic substances and on nutrients availability (Bitar, 2003; Romeiro, 2003; 2005). In these experiments, aquatic macrophytes were used as primary resource of carbon, and CO_2 was found as the main product of anaerobic decomposition. Furthermore, the yield of CH_4 varied from 2.0 to 30.0% of detritus (in carbon basis). Comparing the results from experiments carried out in the laboratory (Table 1), one notes that on average 43.4% of LSPOM will be converted into DOM and the remainder (56.6%) comprises the 1st mineralization pathway (oxidation of labile compounds). In agreement with the mean half-time of DOM mineralization (69.4 days) it is supposed that this process generates, in new reservoirs, oxygen demands of medium-term period. Owing to its time of permanence, these dissolved compounds assist in the formation of dissolved humic substances, maintenance of microbial loop (*sensu* Pomeroy & Wiebe, 1988) and growth of phytoplankton (Bianchini Jr., 1985).

On average, the kinetics coefficients of aerobic processes were higher than for the anaerobic ones (k_T: 1.2; k_3: 3.5 and k_4: 1.5 times; Table 1), indicating that the maintenance of aerobic conditions in the reservoirs tends to intensify degradation. The presence of oxygen seems to have favored the mineralization routes associated with the conversion of labile compounds (IN_1), in detriment of DOM formation (Table 1). Regardless of the experimental conditions (aerobic or anaerobic medium), on average the leaves and the litter were the resources with smallest contents of refractory material and higher coefficients of degradation. The branches (in general with diameter smaller than 1.5 cm) and the barks are the most refractory detritus, although its labile/soluble fractions convert quickly (IN_1, IN_2). These results indicate that - in spite of high temperatures and weak resources - degradation processes in tropical reservoirs are slow. In this way, the refractory resources tend to support the colmatation of sediments and the formation of humic substances in the particulate fractions of the detritus.

THE KINETICS OF OXYGEN CONSUMPTION DURING MINERALIZATION

The oxygen consumption from mineralization of leaves, branches, barks and litter were obtained from 5 different experiments (CNEC/ELN, 1987; MDK/CENCO/COPEL, 1988; FAI-UFSCar/CESP, 1998; Antonio *et al.*, 1999; Bitar & Bianchini Jr., 2002) conducted under laboratory conditions, similar to those in BOD tests (Bianchini Jr. *et al.*, 2003; Cunha-Santino & Bianchini Jr., 2003). Using a non-lineal method (Levenberg-Marquardt iterative algorithm; Press *et al.*, 1993) the results of these experiments were fitted to 1st order kinetics model (Equation 6), where the deoxygenation coefficient (k_D) and the total amount of consumed oxygen were estimated (OC_{max}).

$$OC = OC\,\mathrm{max}\times(1-e^{-k_D t}) \qquad (6)$$

where:

OC = accumulated consumed oxygen (mg.g^{-1} detritus (DW));
OCmax = total amount of consumed oxygen (mg.g^{-1} detritus (DW));
k_D = deoxygenation constant rate (day^{-1});
t = time (day).

The temporal variations of the O/C stoichiometry (ratios of consumed oxygen and oxidized carbon) were calculated through the ratios among the daily rates of consumed oxygen (dOC/dt) and the one of oxidized organic carbon (dCOC/dt); Cunha-Santino & Bianchini Jr. (2002). The drowning of plant biomass, during the filling phases of reservoirs, interferes significantly in the water quality of these systems. This event modifies the global budget of dissolved oxygen, causes the pH to decrease and increases the water color and the electric conductivity of water (Baxter & Glaude, 1980; Antonio *et al.*, 1999). From the kinetics in Figure 2 one notes that the oxygen uptake is relatively a fast process (mean value of $t_{1/2}$: 5.2 days; Table 2); after 20 days the consumption rates tend to decrease. The decay of leaves was the process that consumed higher quantity of oxygen (average: 228.0 mg g^{-1} DW); the decay of branches and barks, on average, consumed less and practically the same amount (average: c.a. 112 mg g^{-1} DW). The changes of stoichiometric relations reflect the global trend of oxygen consumption; the amplitude of coefficients variation suggests that during the initial phases of vegetation decomposition, higher demands of oxygen were generated, which derived from the oxidation of low concentrations of organic matter. After the system reaches stability there is a smaller demand for oxygen, but which continues to exist (Cunha-Santino & Bianchini Jr, 2002).

In the aerobic process, the oxidation is complete and the products are inorganic. It is assumed that the complete oxygen uptake is used in the carbon oxidation (Brezonik, 1993). Using the mass balance, an estimate of the stoichiometric coefficients may be made with the relation between consumed oxygen and oxidized carbon. In contrast to a constant value (*e.g.* oxidation of glucose O/C c.a. 2.666), the coefficients indicated that the stoichiometric relations depended on the type of detritus and time (Figure 2). The variations of the stoichiometric coefficients probably were related in a first stage with the chemical oxidation of labile fractions and with the chemical nature (original organic matrix) of the debris. In a second stage, these coefficients depended on the biochemical oxidations (metabolic routes) and types of microorganisms responsible for the heterotrophic activity.

The microorganisms can use a huge organic variety of compounds as source of energy. The catabolism of these substances leads to the production of intermediary substances that supply raw material for the biosynthesis reactions and release of energy. The stoichiometric relations are related with the metabolic routes of degradation by which organic compounds are processed. Thus, the set of predominant metabolic routes (**pentose-phosphate pathway, glycolysis** and Entner-Doudoroff pathway) of the microorganisms (fungi and bacteria) governed the values of stoichiometric relations. Therefore, the variations of the stoichiometric values can be attributed: (i) to the chemical oxidation among the various organic compounds involved in the decomposition process, (ii) to the reactions mediated by enzymes (*e.g.* cleavage of benzene nuclei of the polyphenolics compounds by oxidases, deamination of nitrogenous substances by dehydrogenases and partial oxidation of the fatty acid); (iii) to the alterations of the predominant metabolic routes, (iv) to the variations of the amounts and species of microorganisms involved and (v) to the variations of the amount and quality of the available organic compounds (Cunha-Santino & Bianchini Jr., 2002).

The higher stoichiometric coefficients were observed in the incubations with barks (Figure 2), even though this resource was constituted basically of waxes, cutin and suberins (Harwood, 1997). Probably the chemical nature (mainly polyphenols derived from suberins) of the reactive material of this debris in the beginning of the experiment was more susceptible to oxidations (chemical and biochemical). The values of O/C relations in the incubations with litter and leaves did not change after the 9th day, indicating a probable structural similarity (resource type and chemical composition) of these resources in the final periods of decomposition (Figure 2). The higher values of stoichiometric coefficients observed in the decomposition of plant resources suggest that, in the initial phases of formation of the reservoirs, low carbon concentrations are necessary to generate high demands of oxygen; consequently the aquatic system tends to anoxia. The decreasing trend in the stoichiometric coefficients suggests that in the stabilization phase of the recently formed reservoir, even the basin concentrate great amounts of available carbon (remaining of phytomass submerged), the oxygen consumption could be low, generating a continuum and low intensity bottom demand.

Based on the discussion above, it becomes clear the difficulty of using variable stoichiometric coefficients in the estimates of oxygen consumption due to submersion of plant resources in reservoirs. A comparison between OCmax and initial carbon concentration of the resource allows one to evaluate "the labile" carbon content (reactive) of detritus for quantitative studies (*e.g.* simulation). In this way, it is proposed that the value of OCmax is divided by 2.666 (constant stoichiometric O/C of glucose oxidation). It is then possible to estimate the labile content of organic matter (in carbon basis). With this assumption, the percentages of labile C of leaves, barks, branches and litter were calculated and are shown in Table 2. Only small fractions of the debris (8.2% (barks) to 20.7% (leaves) consumed oxygen. It is assumed that these experiments are capturing mainly the oxygen consumption due to the mineralization routes of labile compounds (IN_1) and dissolved (IN_2), as in the kinetics model of Figure 1.

Figure 1 - Kinetics model for illustrating the mineralization processes. k's = reaction rates (day^{-1}); IN = inorganic compounds originating from mineralization; k_T = global decay rate of POM due to oxidation processes of labile fractions and due to dissolution; k_1 = oxidation rate of labile fractions; k_2 = leaching rate; k_3 = oxidation rate of DOM; k_4 = oxidation rate of refractory POM (RPOM); (Bianchini Jr., 1997).

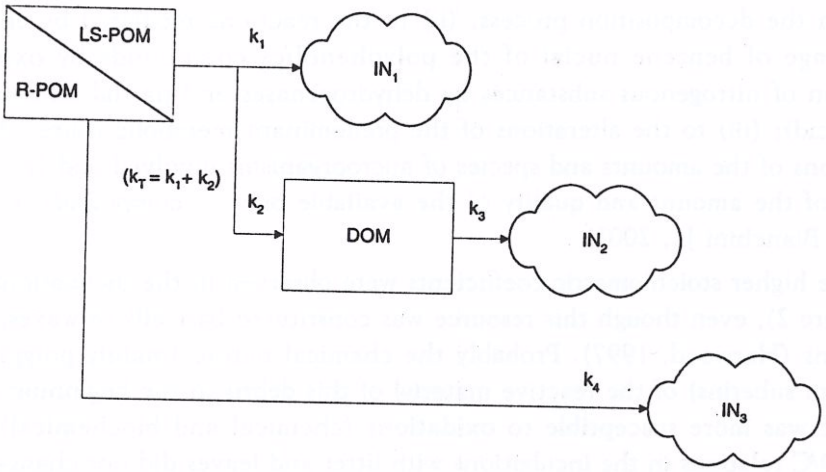
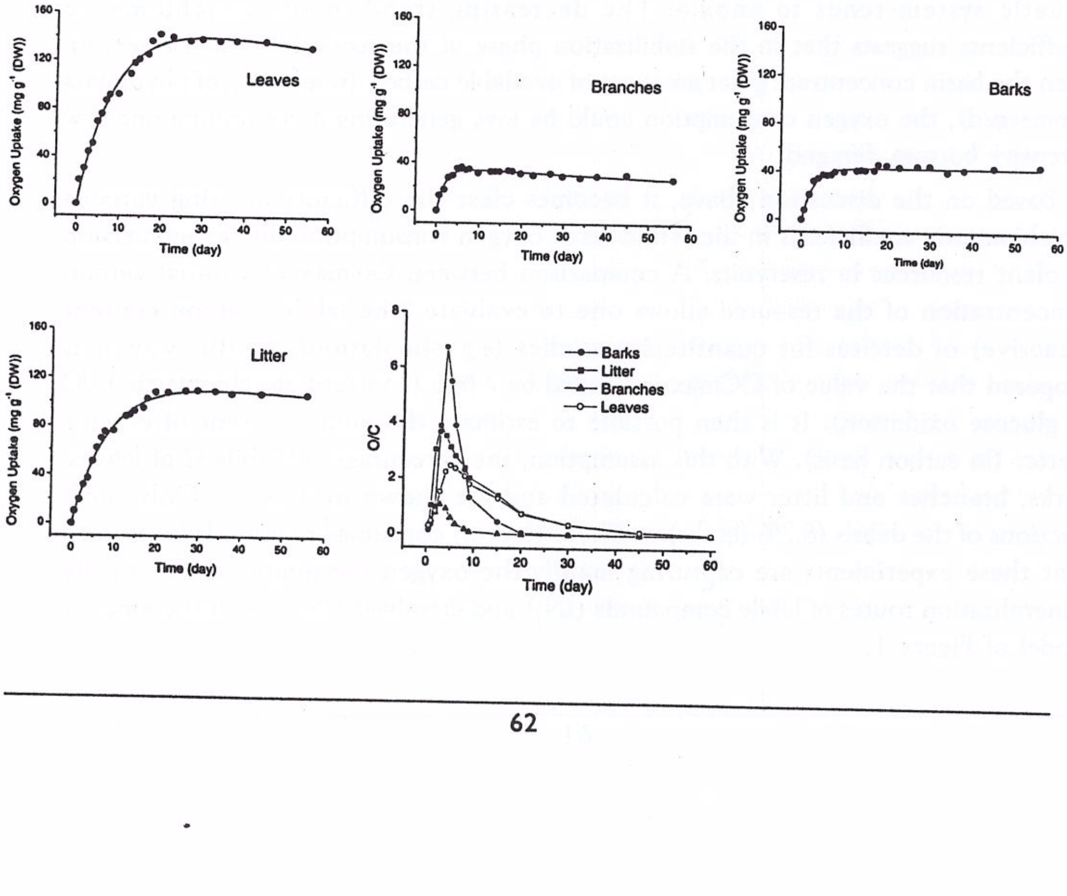


Figure 2 - Oxygen uptake during mineralization of drowned leaves, branches, barks and litter (modified from Antonio *et al.*, 1999) and O/C temporal variation during aerobic decomposition of plant detritus (Cunha-Santino & Bianchini Jr., 2002).



eaction
global
to
ion rate
97).

barks
ring
2).

Barks

50 60

Table I - Kinetics model parameterization.

Resource	O_2	k_T	k_1	k_2	k_3	k_4	IN_1	IN_2	IN_3	Reference
		(d^{-1})	(d^{-1})	(d^{-1})	(d^{-1})	(d^{-1})	(%)	(%)	(%)	
Leaves	+	2.00	1.19	0.81	0.0143	0.0136	17.0	11.6	71.4	FAI-UFSCar/CESP (1998)
	+	1.23				0.0023			80.9	MDK/CENCO/COPEL (1988)
	-	0.61	0.25	0.36	0.0042	0.0052	6.3	9.1	84.7	Bitar *et al.* (2002)
	-	1.23				0.0014			83.2	MDK/CENCO/COPEL (1988)
Average L		1.27	0.72	0.59	0.0093	0.0056	11.6	10.3	80.0	
Branches	+	4.12	2.96	1.16	0.0182	0.0012	10.5	4.1	85.4	FAI-UFSCar/CESP (1998)
	+	0.12				0.0002			82.8	MDK/CENCO/COPEL (1988)
	-	1.42	0.63	0.79	0.0101	0.0019	3.9	4.9	91.3	Bitar *et al.* (2002)
	-	0.23				0.0006			92.5	MDK/CENCO/COPEL (1988)
Average B		1.47	1.80	0.97	0.0142	0.0010	7.2	4.5	88.0	
Barks	+	2.02	1.32	0.70	0.0156	0.0019	8.9	4.7	86.4	FAI-UFSCar/CESP (1998)
	+	0.40				0.0007			81.2	MDK/CENCO/COPEL (1988)
	-	3.64	1.37	2.27	0.0013	0.0032	3.1	5.1	91.8	Bitar *et al.* (2002)
	-	0.60				0.0015			86.3	MDK/CENCO/COPEL (1988)
Average B		1.67	1.35	1.48	0.0085	0.0018	6.0	4.9	86.4	
Litter	+	2.00	1.26	0.74	0.0144	0.0172	15.0	8.8	76.2	FAI-UFSCar/CESP (1998)
	-	1.80	0.86	0.94	0.0018	0.0040	4.4	4.8	90.8	Bitar *et al.* (2002)
Average L		1.90	1.06	0.84	0.0081	0.0106	9.7	6.8	83.5	
Average	+	1.70	1.08	0.62	0.0156	0.0053	12.9	7.3	79.9	
Average	-	1.36	0.58	0.78	0.0044	0.0025	4.4	6.0	89.6	
Average	+/-	1.53	1.23	0.97	0.0100	0.0039	8.6	6.6	84.6	
$t_{1/2}$ (d)		0.5	0.6	0.7	69.4	176.9				
Leaves		0.09				0.0043			96.4	Delitti (1993)
Branches						0.0005			100.0	Delitti (1993)
Barks		0.22				0.0017			85.6	Delitti (1993)
Average		1.36				0.0036			86.3	
$t_{1/2}$ (d)		0.5				192.0				

Table 2 - Labile C content calculation according to oxygen consumption (OC_{max}).

Resource	C^* (%)	OC_{max} ($mg\ g^{-1}$)	k_d (d^{-1})	$t_{1/2}$ (d)	Reference	Labile C (%)
Leaves	41.4	250.0	0.007	96.3	CENEC/ELN (1987)	22.7
		381.0	0.046	15.1	MDK/CENCO/COPEL (1988)	34.5
		124.4	0.198	3.5	FAI-UFSCar/CESP (1998)	11.3
		156.6	0.113	6.1	Antonio *et al.* (1999)	14.2
average		228.0		7.6		20.7
Branches	44.3	140.0	0.013	55.5	CENEC/ELN (1987)	11.9
		173.0	0.032	21.9	MDK/CENCO/COPEL (1988)	14.6
		74.0	0.156	4.4	FAI-UFSCar/CESP (1998)	6.3
		35.4	0.529	1.3	Antonio *et al.* (1999)	3.0
		140.5	0.166	4.2	Bitar & Bianchini Jr. (2002)	11.9
average		112.6		3.9		9.5
Barks	51.3	105.0	0.012	59.2	CENEC/ELN (1987)	7.7
		256.0	0.042	16.4	MDK/CENCO/COPEL (1988)	18.7
		43.8	0.124	5.6	FAI-UFSCar/CESP (1998)	3.2
		44.2	0.364	1.9	Antonio *et al.* (1999)	3.2
average		112.3		5.1		8.2
Litter	39.4	152.2	0.095	7.3	FAI-UFSCar/CESP (1998)	14.5
		118.2	0.118	5.9	Antonio *et al.* (1999)	11.3
average		135.2		6.5		12.9
Total average	44.1	146.3	0.134	5.2		12.6

(*) Elemental analysis from Cunha-Santino & Bianchini Jr. (2002).

CONCLUSION

On the basis of the results from experiments in the field and under laboratory conditions we can conclude: i) The processes for decomposition of leaves, branches, barks and litter are affected by resources quality (chemical composition) and the changes (temporal and spatial) of chemical, physical and biological variables of reservoirs (*e.g.* aerobic and anaerobic conditions, temperature, ORP); ii) In the short term, the changes of physical and chemical characteristics of water derived from decomposition of the labile carbon fraction. These processes are mainly related with leaching and the oxidation of labile fractions ($t_{1/2}$ = 0.5 d) that corresponds to about 14% of the detritus mass; the DOM mineralization is an intermediate process ($t_{1/2}$ = 69 d). iii) The decomposition of refractory fraction (≈ 86% of detritus) is mainly affected by environmental conditions and supports the organisms and processes related to humification of particulate detritus and sediments colmatation. The

---

mineraliz
average »
of DOM
(2.6 time
are affect
the form
bacteriop
these reso
= 5.2 d)
eutrophic
(average
litter = 1
to distinc
action du
and the a

ACKNO

The au
Gas Fluxe
from Rese
also indel
the manu

REFERE

Antonio, R.
serapilh
Ashley, J. T.
33(11):
Baxter, R. M.
Can. Bi
Bianchini Jr.
UFSCar
Bianchini Jr
Hydropo
Ed. Tec
Bianchini Ji
aquátic
Bitar, A. L.;
Limnol.
Bitar, A. L.;
(4A):55
Bitar, A. L.
Carlos (
Brezonik, P.

mineralization of refractory fractions is responsible for slow mass loss of the detritus ($t_{1/2}$ average » 192 d) and for the benthic oxygen demand; iv) On average, the mineralization of DOM is a slower process than the decay of labile/soluble LSPOM (153 times) and faster (2.6 times) than mineralization of refractory fractions (RPOM). The losses of DOM mass are affected mainly by the chemical composition of cytoplasm fractions. DOM supports: 1) the formation of dissolved humic compounds and 2) the growth of phytoplankton and bacterioplankton. Depending on the way the input of detritus occurs (filling operation), these resources can generate high pressures of short term on the oxygen budget ($t_{1/2}$ average = 5.2 d) and induce the generation of colored compounds (*e.g.* humic substances) and eutrophication. v) Considering the oxygen consumption, we can adopt the following (average values) C labile contents: leaves = 20.7%; branches = 9.5%; barks = 8.2% and litter = 12.9%. vi) The removal of native vegetation presents different efficiency in relation to distinct areas of the reservoirs. The deforestation can be considered a complement action due to hydraulic characteristics of the future reservoir (*e.g.* low residence times) and the amounts and chemical properties of the detritus.

ACKNOWLEDGMENTS

The authors thanks the Organizing Committee of International Seminar on Greenhouse Gas Fluxes from Hydro Reservoirs & Workshop on Modeling Greenhouse Gas Emissions from Reservoir at Watershed Level for the opportunity of presenting this paper. They are also indebted to Dr. Osvaldo N. Oliveira Jr. (IFSC-USP) for his critical proofreading of the manuscript.

REFERENCES

Antonio, R. M.; Bitar, A. L.; Bianchini Jr., I. Consumo de oxigênio na mineralização de folhas, galhos, cascas e serapilheira. *Acta Limnol. Brasil.*, 11(2):1-16, 1999.

Ashley, J. T. F. Adsorption of Cu(II) and Zn(II) by estuarine, riverine and terrestrial humic acids. *Chemosphere*, 33(11):2175-2187, 1996.

Baxter, R. M.; Glaude, P. Environmental effects of dams and impoundments in Canada: experience and prospects. *Can. Bull. Fish. Aquat. Sci.*, 205:1-34, 1980.

Bianchini Jr., I. *Estudos dos processos de humificação de Nymphoides indica (L.) O. Kuntze.* São Carlos (SP):PPGERN-UFSCar. 1985. 285p. (Tese)

Bianchini Jr., I. The degradation process of organic matter in reservoirs. In: Rosa, L. P.; dos Santos, M. A. (Eds.). *Hydropower Plants and Greenhouse Gas Emissions. Energy Planning Program.* Rio de Janeiro:COPPE Report/ Ed. Tecnologica. pp. 6-27, 1997.

Bianchini Jr., I.; Bitar, A. L.; Verani, J. R.; Peret A. C. Experimento de mineralização aeróbia para ambientes aquáticos: determinação do número de réplicas. *Acta Scient.*, 25(2):245-252, 2003.

Bitar, A. L.; Antonio, R. M.; Bianchini Jr., I. Degradação anaeróbia de folhas, galhos, cascas e serapilheira. *Acta Limnol. Brasil.*, 14(2):17-26, 2002.

Bitar, A. L.; Bianchini Jr., I. Mineralisation assays of some organic resources of aquatic systems. *Braz. J. Biol.*, 62 (4A):557-564, 2002.

Bitar, A. L. *Mineralização e formação de gases da degradação de Eichhornia azurea Kunth e Egeria najas Planch.* São Carlos (SP):PPGERN-UFSCar. 2003. 119p. (Tese)

Brezonik, P. L. *Chemical kinetics and process dynamics in aquatic systems.* Boca Raton: Lewis, 1993. 754p.

Bruchet, A.; Anselme, C.; Duguet, J. P.; Mallevialle, J. Effect of humic substances on the treatment of drinking water, In: Suffet, I. H.; MacCarthy, P. (Eds.). *Aquatic Humic Substances - Influence on fate and treatment of pollutants*. Washington: Americam Chemical Society. pp. 93-106, 1989.

Characklis, W. G. Kinetics of microbial transformations. In: Characklis, W. G.; Marshall, K.C. (Eds.). *Biofilms*. New York: John Wiley & Sons, pp. 233-264, 1990.

CNEC/ELN. *Estudos de Viabilidade UHE Ji-Paraná: Ensaios de Degradação da Vegetação a ser Submersa (Escala de Laboratório)*. MAD-16V-7.510-NT. Brasília: CNEC/ELN, 1987.

Cunha-Santino, M. B.; Bianchini Jr., I. Estequiometria da decomposição aeróbia de galhos, cascas serapilheira e folhas. In: Espíndola, E. L. G.; Mauad, F. F.; Schalch, V.; Rocha, O.; Felicidade, N.; Rietzler, A. C. (Eds.). *Recursos Hidroenergéticos: Usos, Impactos e Planejamento Integrado*. Série: Ciências da Engenharia Ambiental. São Carlos: Rima. pp. 43-56, 2002.

Cunha-Santino, M. B. *Atividade enzimática, cinética e modelagem matemática da decomposição de Utricularia breviscapa da lagoa do Óleo (Estação Ecológica de Jataí, Luiz Antônio-SP)*. São Carlos (SP): PPGERN - UFSCar. 2003. 140p. (Tese)

Cunha-Santino, M. B. & Bianchini Jr., I. Effect of initial concentration of dissolved oxygen in aeration coefficient for long-term experiments. *Acta Scient.*, 25(2): 253-256, 2003.

Delitti, W. B. C. *Decomposição de materiais biológicos em ambiente aquático*. THEMAG/ENGEA/UMAH. São Paulo (SP), (Relatório técnico), 1993.

FAI-UFSCar/CESP *Projeto Básico Ambiental, Complexo Hidrelétrico Canoas. Subprograma: Modelagem Matemática - I Ensaios de degradação da Fitomassa*. São Carlos (SP), (Relatório Técnico) 67p., 1998.

Garzon, C. E. Water quality in hydroelectric projects: considerations for planning in tropical forest regions. *The World Bank Tech. Pap.*, 20:1-33, 1984.

Harwood, J. L., Plant Lipid Metabolism In: Dey, P. M.; Harborne, J. B. (Eds.). *Plant Biochemistry*. San Diego: Academic Press, 1, pp. 237-272. 1997.

Lu, X. Q.; Hanna, J. V.; Johnson, W. D. Evidence of chemical pathways of humification: a study of aquatic humic substances heated at various temperatures. *Chem. Geol.*, 177:249-264, 2001.

Jfrgensen, S. E. *Fundamentals of ecological modelling*. 2nd ed. Amsterdam: Elsevier, 1994. 628p.

Lousier, J. D.; Parkinson, D. Litter decomposition in a cool temperate deciduous forest. *Can. J. Bot.*, 54, p.419-436, 1976.

MDK/CENCO/COPEL *Usina Hidroelétrica de Segredo- Programa de Caracterização da Área Diretamente Afetada/ Inundação da Vegetação*. Curitiba (PR), (Nota Técnica) 43p., 1988.

Mindermann, G. Addition, decomposition and accumulation of organic matter in forests. *J. Ecol.*, 56: 355-562, 1968.

Paiva, M. P.; Salles, P. V. *Desmatamento de represas hidrelétricas no Brasil*. Rio de Janeiro (RJ): ELETROBRÁS, 28p. (Relatório Técnico), 1977.

Peret, A. M.; Bianchini Jr., I. Stoichiometry of aerobic mineralization (O/C) of aquatic macrophytes leachate from a tropical lagoon (São Paulo - Brazil). *Hydrobiologia*, 528: 167-178, 2004.

Petrovic, M.; Kastelan-Macan, M., The uptake of inorganic phosphorus by insoluble metal-humic complexes. *Water Sci. Technol.*, 34(7-8): 253-258, 1996.

Ploskey, G. R. Impacts of terrestrial vegetation and pre impoundment clearing on reservoir ecology and fisheries in USA and Canada. *FAO Fish. Tech. Pap.*, 258: 1-35, 1985.

Pomeroy, L. R.; Wiebe, W. J., Energetic of microbial food webs. *Hydrobiologia*, 156:7-18, 1988.

Press, W. H., Teukolsky, S. A., Vetterling, W. T.; Flannery, B. P. *Numerical recipes in C: The art of scientific computing*. Cambridge University Press, New York, 1993. 994p.

Romeiro, F. Efeito da qualidade do detrito na decomposição anaeróbia de *Cyperus papyrus* L. São Carlos (SP): DHb - UFSCar. 2003. 40p. (Monografia)

Romeiro, F. Bioensaios de decomposição anaeróbia de macrófitas aquáticas da lagoa do Óleo (Estação Ecológica de Jataí, Luiz Antônio-SP). São Carlos (SP): PPGERN - UFSCar. 2005. 90p. (Dissertação)

Sorokin, Y. I.; Kadota, H. *Techniques for the assessment of microbial production and decomposition in fresh water*. IBP nº 23. Oxford: Blackwell, 1972. 112p.

Stumm, W.; Morgan, J. J. *Aquatic chemistry*. New York: Wiley/Interscience, 1981. 789p.

Wetzel, R. G. *Limnology*. Philadelphia: Saunders College Publishing, 1983. 860p.