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Pre Impoundment Studies in Monday River, Eastern Paraguay I: Soils and Submerged Soils

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Abstract: Monday River, at Eastern Paraguay is located south of the Itaipu Dam, and discharges into the Paraná River. At the point of discharge it has been projected to build a Hydroelectric power Plant and the reservoir will extend upstream the Monday. As a result of the impoundment of a river, the flooded soil can provide a certain amount of nutrients into the aqueous medium setting new conditions for aquatic life and affecting to a greater or lesser degree the ecosystems. The aim of this work is the assessment of the impact on the water quality of the incorporation of major nutrients into the water body after damming Monday River. Samples from soil profiles were taken at selected sites on both banks of the river; the amount of phosphorus, nitrogen, potassium, calcium and magnesium as well as other parameters as pH, organic matter, exchangeable bases were determined using standard procedures. Granulometric analysis was also performed. Phosphorus availability was determined by isotopic exchange. In addition the samples were submitted to submersion/incubation experiments along 60 days, and the concentration of elements incorporated into the water analyzed. Results show that flooded soils are low in phosphorus and nitrogen which is scarce in some cases; so does other nutrients. Submersion experiments also indicate generally limited incorporation of such nutrients into the water body. Significant negative impact of these soils on the water quality of the reservoir cannot be expected.

Key words: Alto Paraná Dpt, Monday River, Soils, *E*-value, Incubation experiments.

1. Introduction

Eastern Region of Paraguay or Eastern Paraguay is located between the latitudes ~22º6S and 27º45′ S and longitudes ~54º10′ W and 58º43′ W [1]. It covers an area of 159.827 km^2 and is seated between two big rivers, the Paraguay River to the West, on the former western margin of Gondwana and to the East, the Parana River that is a constituent of the border between Paraguay and Brazil. On the latter, the stretch from its origin at the confluence of Grande and Paranaiba Rivers to ~26º S, is called Alto Paraná (AP); at the time of the impoundment of the Itaipu Reservoir, it had a medium discharge of ~9,000 m^3/s. The Alto Parana Basin is mainly formed from volcanic flows in the Mesozoic [2]. Differences in land level and slopes in the rivers of the area have allowed the installation of dams and hydroelectric power stations in both countries, Paraguay and Brazil. The most important is the Itaipu Dam (12.6 Gw) on the border between both countries, which shared its management.

On the Paraguayan side, the basin is drained by several tributaries discharging into the AP: among them, the Monday River [3].

This River flows from the confluence of the Guyraungua and the Capiibary Creeks at ~25º31′25″ S & 55º28′38″ W coordinates and discharges into the Parana at ~25º36′18″ S. It has an extension of ~150 km and a Basin of 6,557 km^2. [4]. Segments of the river run in oxisol, alfisol, and ultisol soils [5]. Monday has a tropical climate. The average annual temperature in M is 25.2 °C. The rainfall is 1,962 mm per year.

At approximately 4 km from its point of discharge in the Parana, is a waterfall of ~40 m jump. There is a project to build a hydropower station after its impoundment. At approximately 3 km from its point of discharge in the Parana is a waterfall of ~40 m jump. There is a project to build a hydropower station by its

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impoundment. The future Monday Dam will be located in the vicinity of the Acaray, Iguazu and Itaipu dams. It will be connected with the Yguazu Dam through an underground channel/tunnel. In this way a power of about 800 Mw shall be attained. Prior its damming, several studies on water quality, eutrofication, soil and sediments as well as its ichthyology [6] have been/are conducted.

This paper includes the study of soils of Monday River catchment and the releases of nutrients into the water after flooded; the work follows the methodology of papers regarding pre impoudment studies on the Itaipu Dam [7, 8]

The study aims to:

- know the physical (structure) and chemical properties of soils that border the river, especially those chemical compounds that can influence the development of aquatic life.
- determine the value of available/mobilizable soil phosphorus (*E*-value), using radiometric methods of isotopic exchange.
- determine the potential flow of nutrients into the water body by experiments of submerged composite soil samples in up a 60-day lapse.

2. Experimental

2.1 Sampling Sites

They were selected five stations M-1 M-2 M-3 M-4 M-5, distributed on a stretch of 100 km upstream from the waterfall to the small village of Puerto Armonía. At them were established in the left *L* and the right *R* banks, sampling points close to the water, on the riverside B (Riverside soils referred to as LB;RB) as well as others distanced approximately 1,500 m from it (distanced soils referred to as LD;RD). Thus sampling points are identified for example as *1LB* for station *1*, left bank *L*, close to the water B or *1LD* for station *1*, left bank *L*, distanced *D*.

M-1 is located on about 0.2 km from the waterfall; M-2 approximately at 7 km; M-3 about 50 km, small village of Puerto 22 de Mayo; M-4 is located on the site called Puerto Dolores ~87 km and M-5 at the small village of Puerto Armonía ~100 km from the waterfall.

2.2 Soil Sampling Procedures

Soil sampling was performed in pits/wells made to study and describe soil profiles; in them the two layers were considered “*a*” 10 cm depth & “*b*” from 10 down to 60 cm; one sample was collected per layer. Among them, no major differences were found. In the above example, 1LDb corresponds to a sample from the layer *b* of the soil profile. It is estimated to state that generally, penetration and exchange of water in contact with the ground is active until about 60 cm deep and the largest transfer around to 10 cm.

After careful quartering, 2.5 kg of soil per layer were assembled in polyethylene bags.

Samples were dried at room temperature, grinded and sifted through 0.25 mm sieve.

2.3 Soil Analyzed Parameters and Methodology

2.3.1 Physics

Granulometry: the Robinson method was employed [9, 10].

2.3.2 Chemistry

pH: potenciometry, soils-water ratio of 1:2.5. organic matter (OM): method of Walkley-Black [11] with potassium dichromate. Total nitrogen: Kjeldahl method; Ammonia: distillation. Extractable phosphorus: Olsen solution and colorimetry [12]. Potassium extractable: Olson solution & potentiometry. Calcium and magnesium: extraction with KCl 1 N and complexometry with EDTA. Cation exchange capacity: extraction with ammonium acetate and subsequent volumetry.

2.4 Analyzed Parameters and Methodology in Water Incubation

In the incubation, water quality parameters were analyzed according to standard methods [13]: pH; OM; o-phosphate; total phosphorus; ammonia nitrogen;

organic nitrogen; K, Ca, Mg, Fe(total).

2.5 E-Values Analysis

This method uses the radioisotope ^{32}P as the tracer.

2.5.1 Principles

When a sediment or soil sample is shaken with a solution of ^{32}P, after a time an equilibrium with the exchangeable P of the soil is achieved:

$$^{32}P_{(solute)} + {}^{31}P_{(soil)} = {}^{32}P_{(soil)} + {}^{31}P_{(sol)}$$

The equilibrium constant approaches 1. If a carrier is added to the solution, the fraction of exchangeable P is expressed:

$$Et = \left(\frac{SAi}{SAf} - 1\right) B$$

where *Et* is the fraction of exchangeable phosphorus, *SAi* and *SAf* are the initial and final specific activities and B is the amount of ^{31}P added to the solution.

2.5.2 Procedure

The technique for *E* values in soils, described in detail elsewhere [14] was employed as follows: 5 g of sediments plus 60 mL of an stock solution of KH_2PO_4 with 0.1 mg ^{31}P/mL and 1.2 uCi of ^{32}P shaken for seven days: then, specific activities of the stock and the equilibrium solutions were determined measuring suitable aliquots of each with a GM; the final phosphorus concentration in the equilibrium solution was determined by spectrophotometry [15].

3. Results and Discussion

3.1 Physics and Chemistry

3.1.1 Physics

Texture. The results of the mechanical analysis of granulometry are shown in Table 1.

There is a close relationship between the profiles description and the texture analytical data.

In general at the sampling points B located near water, sand fractions are ~40 to 50% higher than at points of distance D, except for M3.

Table 1 Soils granulometry—Monday River Left and Right Banks.

Station	Layer	Sand (%)	Silt (%)	Clay (%)	Class
M-1-Left bank	a	85	8	7	Sandy loam
M-1- Left bank	b	80	10	10	Loamy sand
M-1-Left distanced	a	47	18	35	Sandy clay loam
M-1-Left distanced	b	43	16	41	Sandy clay
M-2-Left bank	a	80	12	8	Sandy loam
M-2-Left bank	b	76	12	12	Loamy sand
M-2-Left distanced	a	49	15	36	Sandy clay
M-2-Left distanced	b	48	8	44	Sandy clay
M-3-Left bank	a	88	7	5	Sand
M-3-Left bank	b	72	14	14	Loamy sand
M-3-Left distanced	a	74	14	12	Loamy s and
M-3-Left distanced	a	66	16	18	Sandy loam
M-4-Left bank	a	83	10	7	Loamy sand
M-4-Left bank	b	76	14	10	Loam sand
M-4-Left distanced	a	54	16	30	Sandy clay loam
M-4-Left distanced	b	50	12	38	Sandy clay
M-5-Left bank	a	89	4	7	Sandy
M-5-Left bank	b	82	8	10	Sandy loam
M-5-Left distanced	a	46	16	38	Sandy clay loam
M-5-Left distanced	b	40	18	42	Sandy clay loam
M-2-right bank	a	57	10	33	Sandy clay loam
M-2-right bank	b	50	12	38	Sandy clay
M-2-right distanced	a	73	12	15	Loamy sand
M-2-right distanced	b	66	13	21	Sandy clay loam

There is a prevalence of sandy soils on the banks along the river in comparison to distance points . These points D have soils with sandy-clay characteristics except in point 3LD (plain basin) that, even at a distance of 1,500 m, is still similar to those of the riverside i.e., they are sandy soils. Soils of points at both riversides (RB&LB) have similar characteristic and along the river, there are not significant changes on them. The maximum percentage value of the sand fraction was 89% in 5LBa; maximum value of silt, 18% in the points 1LDa and 5LDb. The clay fraction had a maximum of 42% in M5, Puerto Armonía, point 5LDb.

3.1.2 Chemistry

Analysis was performed in single and *compositum* samples. Results are breaking down in Tables 2 and 3.

pH. This parameter indicates a relative state of soil fertility; it affects the availability of nutrients for growing crops. Soil reaction is directly related to the amount of exchangeable nutrients absorbed by plants, and indirectly with chemical and biological secondary processes that determine the availability of nutrients. Mineralization of organic matter is also a function of pH. Rates of ammoniation processes as well as mineralization of sulfur and phosphorus compounds are in close relation with pH. These processes occur at its best under conditions of neutral pH. In addition, pH has a great influence on the microflora present in the soil, regulating the activities of bacteria and fungi.

Changes in this parameter are observed along the river body.

(a) Soils of the banks have pH values between 6 and 6.3, i.e., little variation along the river. (b) Also among the two layers (*a* & *b*) of the bank soils, there is no appreciable variation of this parameter. (c) On

Table 2 Soil results chemical parameters.

Stations		pH	OM	P	N	K	Ca	Mg
	Layer		%	ppm	ppm	ppm	ppm	ppm
M1-Left bank	A	6.1	1.77	2.15	722	47.4	485	89.4
M1-Left bank	B	6.2	1.9	1.75	954	36.3	663.6	145.0
M1-Left distanced	A	6.6	2.7	3.61	1.617	164	2,024.4	309.5
M1-Left distanced	B	7.2	1.2	5.26	548	140	2,501.3	323.0
M2-Left bank	A	6.3	1.51	3.76	724	45	677.0	90.0
M2-Left bank	B	6.2	1.5	2.15	765	54.2	602.0	135.5
M2-Left distanced	A	6.4	1.25	2.65	750	126	1,371.0	141.0
M2-Left distanced	B	6.9	0.97	3.26	485	207	1,315.0	121.4
M3-Left bank	A	6.0	1.1	3.0	425	77.1	326	54.5
M3-Left bank	B	5.9	2.1	1.3	1,300	77.5	759.5	108.0
M3-Left distanced	A	5.8	2.89	3.75	1,471	49.2	534	63.0
M3-Left distanced	B	6.0	1.06	1.75	602	29.6	242	82.0
M4-Left bank	A	6.0	1.82	1.3	804	71.6	355	36.0
M4-Left bank	B	6.1	1.15	1.75	535	36.3	301.0	90.0
M4-Left distanced	A	7.2	1.7	2.1	984	123	985	119.0
M4-Left distanced	B	7.2	0.85	2.65	560	128.3	1,107	183
M2-Right distanced	A	7.0	1.7	2.00	950	182.3	2,305.0	174.0
M2-Right distanced	B	6.0	1.2	2.65	785	126.5	921.0	155.0
M4-Right distanced	A	5.4	2.4	1.8	1,476	124.5	688.5	150.0
M4-Right distanced	B	5.5	2.45	3.50	1,497	120.0	214.0	147.0
M5-Left bank	A	6.0	0.65	1.6	172	59.3	409.0	73.0
M5-Left bank	B	6.0	1.4	1.3	568	62.4	642	107.5
M5-Left distanced	A	6.5	2.5	3.0	1,491	160.3	589	141.0
M6-Left distanced	B	6.4	1.63	4.0	989	193.0	1,074.0	172.4

Relative SD is between 5-8%.

Table 3 ***Compositum* Soils Results. Chemical Parameters.**

Stations	Layers	pH	OM	P	N	K	Ca	Mg
			%	ppm	ppm	ppm	ppm	ppm
M1-Left bank	A+B	6.2	1.87	1.83	907	38.5	628	134
M2-Left bank	A+B	6.2	1.54	2.47	757	52.4	617	126
M2-Right distanced	A+B	6.2	1.3	2.52	818	158.0	1,198	159
M3-Left bank	A+B	5.95	1.9	1.64	1,125	77.4	673	98
M3-Left distanced	A+B	5.96	1.41	2.15	936	33.6	301	78
M4-Left distanced	A+B	7.2	1.02	2.54	645	127.0	1082	171
M5-Left bank	A+B	6.0	1.25	1.36	489	62.0	596	100

Relative SD are between 6-9%.

the other hand, there are more variations on the pH values in the distanced points D, both, between one point and another, as well as along the river. Limiting values of 5.8 and 7.2 pH units were found. At the layer "*b*" of D points, soils tend to be higher values than in the layer "*a*", especially those from 3LD downstream to the mouth of the river.

There is a tendency for soils in D points to have higher pH than those of the banks B, except the 3LD point where such a differentiation is not seen. On the right bank they were found lower pH values, such as at point 4RD.

In regard to organic matter OM, its concentration varies from 0.65 to 1.82% and from 1.15 to 1% in layers *a* and *b* respectively on the river banks; at the distant points D it varies from 0.97 to 2.89% and from 0.85 to 1.63% in layers *a* and *b* respectively. That is, sandy soils are poorer in OM than sandy-clay soils. In addition layers *b* are poorer in OM than layers *a*.

On considering composite samples OM varies from1.25 to 1.9% on the river banks and from 1.02 to 1.41% in sampling points D.

Low temperature, high rainfall, soil acidity and low biological activity are conditions that contribute to organic matter accumulation in soils, but that is not the case here.

Phosphorus. In the analyzed samples, the concentration of extractable phosphorus ranges from 1 to 5.3 ppm, referring to poor soil in available phosphorus. In the banks soils, it varies from 1.3 to 3.76 ppm in layer *a* and from 1.3 to 2.15 ppm in *b* layer. At the distanced soils (more clayed), it ranges from 1.8 to 3.61 ppm and from 2.65 to 5.26 in layers *a* and *b* respectively. In addition, it can be mentioned other small differences; at the bank soils, the extractable phosphorus content increases downstream toward the mouth of the river; this aspect is less significant on distanced soils (points D). Also, on the banks soils, phosphorus concentrations at the layer A are greater than in the layer B in M-1 and M-2, and almost uniform in both layers in the M-4 and M-5 points. On the other hand, at distanced soils, layer b has higher phosphorus content than layer a. Further, the tenor of this parameter is similar at the two sides of the river.

Nitrogen. The concentration of extractable organic nitrogen ranges from 172 to 1,617 ppm, In the banks soils, varies from 172 to 804 ppm in layers a and from 425 to 1,300 ppm in b layers. At *distanced soils* (more clayed), range from 750 to 1,617 ppm and from 485 to 1,497 in layer a and b respectively. Under similar conditions of climate and vegetation, texture is decisive [16]. Clay soils have a higher percentage of this element than sandy and silty soils. There is much oscillation of values among one point and another, and within the same point between the layer A and B, especially on the left bank, being more uniform nitrogen values between the layers on the right bank. In the banks soils, tenor of the layer A is less than the B layer, the reverse that occurs at distanced soils.

Cations, concentration of K, Ca, Mg showed to be low. Each of the three cations occurs in almost uniform values along the river and usually low at Banks soils. Distanced soil D from the right bank, a marked difference has been found in Ca content between *a* and *b* layers; in other respects exists similar behavior on both sides.

In relation with the texture, clayed soils have K, Ca & Mg concentrations higher than sandy soils. In the case of K, almost all samples from distanced soils present relatively high values.

In conclusion these are soils with low content of OM and nutrients (except K in some samples) as well as low exchangeable cations values. In most the cases along the river there is a prevalence of the sand fraction on the soils

3.2 E Values

The *E* values of the soils samples analyzed appear in Table 4.

The registered values are low and consistent with the type of soils. These are latheritic.

The exchangeable phosphorus refers to inorganic fractions which, under entropic effects and independent of any biological activity, are transferred into the solution in reversible process.

The inorganic fraction is a mobility index of the elements in the soils/sediment-water system [17]. In addition as phytoplankcton uses only soluble compounds, when algae takes up phosphorus, the same amount is restored to the solution by the exchangeable fraction. Further, it has been shown that exchangeable phosphorus is related to the dissolution rate of surficial minerals in the sediments complex. They, in turn, are replaced by phosphorus moving upward from the inner layers.

3.3 Incubation Experiments

Soil samples were prepared with 20% of layer *a* and 80% of layer *b*. Distilled water was used and was replenished when necessary. The experiments were carried out under aerobic and anaerobic conditions.

The aerobics are performed on open *aquaria* with a small pump and filter in order to maintain a reasonable concentration of dissolved oxygen (DO). The anaerobic experiments were carried out on demijohns bearing an inlet tube and an outlet faucet, with the top chopped up for soil loading, replaced and sealed; before and after the water filling, the container was saturated with nitrogen.

These reactors were kept at temperature of 22-25 ºC.

The results of the experiment are presented in Table 5.

3.3.1 pH

In natural waters pH depends largely of CO_2/H_2CO_3 i.e. protons from carbonic acid and carbonate i.e. OH generated during hydrolysis of bicarbonates [18]. At the surface waters of Alto Parana region such as the dams and rivers that discharge into the Paraná, their average values vary between 5.5 and 7.5 and 6.2 and 7.5 at Acaray and Yguazú Dams respectively and 6.7-7.5 at Itaipú; [19-21]. It should be noted that during the beginning of the Yguazu Dam filling, the pH got values as low as 4.3. In natural waters of the globe, values from 2 to 12 are recorded; in most lakes, the pH varies between 6 and 9 [22].

Table 4 *E* value (meq/100gr) compositum samples.

Station	Layer	*E* value
M1-Left bank	A + B	12 (0.9)
M2-Left bank	A + B	11.6 (1.0)
M-2 right distanced	A + B	18 (1.6)
M-3 Left bank	A + B	12.8 (1.0)
M-3 Left distanced	A + B	15.5 (1.26)
P.D. Left distanced	A + B	20 (1.6)
Left bank	A + B	7.0 (0.6)

SD = (x)

Table 5 Flooded Soils. Aerobic and anaerobic experiments.

M-1-Left Bank-Layer A (single sample)					M-2-Left Bank-Layer A+ B (compositum sample)			
	Aerobic		Anaerobic		Aerobic		Anaerobic	
Period	30 days	60 days	30 days	60 days	30 days	60 days	30 days	60 days
Parameters	Results				Results			
pH	6.47	4.52	6.64	6.51	5.05	5.3	5.49	6.53
Color	37.5	62.5	37.5	62.5	6.25	25	12.5	37.5
COD (ppm O_2)	12.8	0.8	3.2	36	9.60	29.2	3.20	17.60
Ortofosfate(ppm P_4)	0.003	0.000	0.007	0.00	0.005	0.000	0.0030	0.00
Total phosphorus (ppm P_4)	0.003	0.009	0.007	0.014	0.0005	0.017	0.0030	0.005
Org. Nitrogen (ppm N_2)	0.5	1.03	0.2	1.37	0.40	0.97	0.13	0.57
N-Ammonia (ppm N_2)	1.33	1.10	1.96	2.64	0.18	0.51	0.16	1.10
Potasium (ppm K)	0.8	1.15	0.84	1.2	0.20	0.55	0.20	0.62
Calcium (ppm Ca)	4.0	14.42	3.2	4.8	6.40	11.22	5.60	16.03
Magnesium (ppm Mg)	1.45	4.27	4.08	4.17	3.79	1.16	2.04	3.39
Iron (ppm Fe)	1.93	0.336	0.014	0.18	0.10	0.40	ND	0.40
M1-Left Bank-Layer A + B (compositum sample)					M-2. Right distanced-Layer A + B (compositum sample)			
pH	5.00	5.44	5.37	5.53	5.68	5.63	5.85	5.49
Color	25	25	25	50	6.25	6.25	6.25	6.25
COD (ppm O_2)	33.2	32.8	46.8	22.4	24	2.00	26.00	8.4
Ortofosfate (ppm P_4)	0.01	0.00	0.005	0.00	0.0025	0.00	0.008	0.00
Total phosphorus (ppm P_4)	0.01	0.01	0.005	0.0050	0.0025	0.013	0.008	0.0080
Org. Nitrogen (ppm N_2)	0.24	0.67	0.36	1.29	0.39	0.75	0.23	0.42
N-Ammonia (ppm N_2)	0.43	0.66	0.55	1.24	0.11	0.22	0.20	0.88
Potasium (ppm K)	0.40	0.94	0.25	1.23	1.15	1.37	1.05	1.88
Calcium (ppm Ca)	6.40	14.42	8.8	7.21	5.6	12.02	7.2	7.21
Magnesium (ppm Mg)	4.27	0.86	4.66	4.56	0.58	1.45	2.62	4.07

Relative SD is between 6.5-10%.

M-3 Left Bank-Layer A + B (compositum sample)					M-3. Left Distanced. Layer A + B (compositum sample)			
	Aerobic		Anaerobic		Aerobic		Anaerobic	
Period	30 days	60 days	30 days	60 days	30 days	60 days	30 days	60 days
Parameters	Results				Results			
pH	7.22	6.83	7.28	6.48	5.05	5.12	5.28	4.87
Color	1437.5	1750	1250	1750	6.25	12.5	12.5	18.75
COD (ppm O_2)	95.60	145.00	54.80	99.60	4.8	7.2	12.4	2.8
Ortofosfate (ppm P_4)	0.0100	0.0010	0.0050	0.01	0.005	0.0	0.006	0.0
Total phosphorus (ppm P_4)	0.0100	0.0010	0.0050	0.008	0.005	0.009	0.006	0.006
Org. Nitrogen (ppm N_2)	1.50	2.85	4.25	4.60	0.35	0.92	0.1	0.27
N-Ammonia (ppm N_2)	2.64	4.40	3.65	6.83	0.1	0.18	0.11	0.18
Potasium (ppm K)	2.10	1.37	1.45	2.75	0.29	0.6	0.19	0.44
Calcium (ppm Ca)	12.80	12.02	10.40	12.02	3.2	20.04	7.2	8.01
Magnesium (ppm Mg)	4.37	5.34	5.24	8.74	1.65	2.41	0.19	0.48
Iron (ppm Fe)	11.65	33.58	9.87	32.40	0.22	0.16	0.28	0.14

Relative SD is between 6.5-10%.

M-4-Left distanced-Layer A + B (compositum sample)					M-5-Left bank. Layer A+ B (compositum sample)			
	Aerobic		Anaerobic		Aerobic		Anaerobic	
Period	30 days	60 days	30 days	60 days	30 days	60 days	30 days	60 days
Parameter	Results				Results			
pH	6.65	6.62	6.48	6.51	5.67	5.15	5.74	5.61
Color	6.25	6.25	25	37.5	37.5	37.5	37.5	100
COD (ppm O_2)	3.20	26.80	33.60	34.40	13.60	38.80	22.00	52.40
O-phosphate (ppm P_4)	0.0050	0.0000	0.0050	0.00	0.0030	0.0000	0.0015	0.00
Total phosphorus (ppm P_4)	0.0050	0.0160	0.0050	0.0060	0.0030	0.0140	0.0015	0.0100
Org. Nitrogen (ppm N_2)	0.50	2.05	0.07	0.36	0.36	0.7	0.20	0.86
N-Ammonia (ppmN_2)	0.11	0.31	0.18	0.26	0.51	0.51	0.68	1.20
Potasium (ppm K)	0.35	0.68	0.35	0.8	0.52	0.78	0.45	0.94
Calcium (ppm Ca)	9.60	12.02	8.80	5.61	2.40	5.61	8.00	8.01
Magnesium (ppm Mg)	1.55	0.48	3.69	3.98	1.36	2.03	4.37	7.28
Iron (ppm Fe)	0.10	0.42	0.10	0.43	0.08	0.47	0.10	0.65

Relative SD is between 6.5-10%.

In Monday river extreme values were 5.6-7.4 and average ca 6.8 [23].

There are several interesting studies in different types of flooded soils as well as under different weather conditions, among them the well known paper of Ponnamperuma [24].

In the experiments here carried out. the lower pH values (~5) were registered at the first 30 days and a value around 6 after 60 days in both, bank and distanced soil.

3.3.2 Chemical Oxygen Demand (O.M.)

This parameter indicates the amount of oxidizable substances that occur in the water. For incubated waters, these substances are organic matter and elements in the reduced state. passing from the interface to the water.

In submerged soils. respiration (decomposition) is the main transformation of O.M.; its decomposition is slower than in aerated soil and the end products are different. In the latter the OM produces CO_2 and resistant materials (altered lignine); the heavy energy released contributes to the decomposition of OM and synthesis of cell substances. In the former. the decomposition of OM is almost entirely the work of facultative and obligated anaerobe that operate at much lower energy [25] and the release of CO_2, H_2. CH_4 humic residues etc. can be expected. In anaerobic medium, the decomposition produces a sharp decrease in oxygen levels and the development of anoxic conditions. Usually, soil oxygen is absent within a few hours after flooding. The lack of oxygen resulted in lower rate of organic matter decomposition [26]. Oxygen plays a significant role as terminal electron acceptors of anaerobic respiration in submerged soil.

The availability of alternative electron acceptors used by microorganisms is some oxidants usually present in natural water like Fe (III),. NO_3^-, Mn (IV), SO_4^{2-} etc. It has been mentioned that the absence of such electron acceptors in the aquatic media leads to a lower rate of O.M. decomposition in sediments/submerged soils [27].

It was found in this work as was seen in the Soils Section. that the concentration of OM in the analyzed samples is low. Soils are poor in OM; as a consequence the amount of OM released into the water is low.

It can be see the different values of pH and of COD attained in the periods of 30 and 60 days. The pH values of submerged soils are very sensitive to loss of CO_2 and to redox reactions particularly from iron [24]. It seems that not only carbonate system (faster) is involved with pH buffering but silicate system (slower) [28].

3.3.3 Phosphorus

This element is a major constituent in the living cell being *sine qua non* for the cell activity. In nature, it is widely distributed in rocks, plants, animals. Its larger use encompasses fertilizer, detergents etc. Phosphate concentrations above 0.05 mg/L appear to stimulate the growth of algae and other aquatic plants and can contribute/stimulate eutrophication processes. It is mentioned that in about hundred years of lake eutrophication research. P remains a primary target for eutrophication control [29].

After impoundment concentration of P in soil solution can increase *inter alia* due to:

(a) The fast and wide diffusion of the $H_2PO_4^-$ ions in soil solutions. (b) Reduction of ferric to ferrous phosphate, the latter being more soluble. (c) Availability of soluble phosphorus compounds caused by prior dissolution of oxidized layer surrounding the particles of phosphates. (d) Hydrolysis of some compounds of iron and aluminum combined with phosphates on acid soils. (e) Increased mineralization of organic phosphates in acid soils caused by the increase of soil pH in between 6 and 7. (f) Increasing solubility of apatite in calcareous soils when pH decreases from ca 8-7 etc.

The results here found indicate the following:

(a) There is a trend to increase phosphorus content in the waters incubated, especially in the first month but decreasing in the values at the second. (b) Aerobic incubation samples have a larger and more rapid accumulation of phosphorus. (c) There is a correlation between phosphorus solubilized in water, its content in soil and soil pH; pH values between 6.2 and 7.2 tend to increase the incorporation of the element from soil to water. (d) The element in the form of orthophosphate dissolves quickly in water and then seems to be totally consumed by bacteria. (e) The content of phosphorus in these waters is not significant factor for excessive and accelerated development of algae in floodwater.

3.3.4 Nitrogen

The remineralization of organic N and P leads to an increase in ammonium and phosphate and below the sediment-water interface. Also, as a result of the decomposition of organic matter, there is an increase in alkalinity and a decrease in pH. A sharp decrease in nitrate and sulfate very near the interface occurs (even below it) and MnO_2 (s) is only a few centimeters of sediment near the surface. The redox processes that occur near the sediment-water interface have important implications for the geochemical cycles of metals. nutrients and organic microcontaminates .

In the determination of ammonia and organic nitrogen in waters incubated, the results reflectedthe following:

(a) Both aerobic and anaerobic incubations have developed ammonia and organic nitrogen, with increasing trend in the second month. reaching double the concentrations of both forms of nitrogen in comparison with the first month.

(b) Ammonia concentrations were ranging from 0.10 ppm values and 2 ppm in the two months of incubation, except the number 5 sample, which has developed up to 4.25 ppm in two months. While, the tenor of organic nitrogen has ranged from 0.10 ppm and 1.25 ppm of nitrogen. except sample No. 5, which has come up to 6.83 ppm at 60 days.

(c) The aerobic incubation produces more ammonia than anaerobic, especially when the soil pH is less acidic.

3.3.5 Cations Ca Mg K

These elements are not directly affected by redox processes due to the flood in the soil. Very much of their salts are soluble and easily go to the water; calcium often goes through colloids system.

In the experiments, K behaves in the same way in both media. Potassium increases its concentration that almost become twice at 60 days.

Potassium incorporated into the water did not show a direct relationship with its concentration in soil; it is regulated by pH, and soil texture, and appears to be independent of bacterial activity. Low pH seems to have favored its incorporation into the water.

Its concentration ranged from 0.25 to 2 ppm.

Calcium increases its concentration during the whole period in the aerobic experiment, while in the anaerobe increase during the first month and after it tends to stabilize.

Its tenor in water is independent of its concentration in the soil; it depends on the pH, and soil degradation. Its incorporation levels into water range from 2.5 to 20 ppm.

Mg has an inverse behavior to Ca as the anaerobic incubations tend to increase their concentration while aerobic incubations tend to stabilize. The low pH and the leachable soil texture favor its incorporation into the water. Bacterial activity is also involved. Its incorporation level into water was ranging from 2.5 to 20 ppm.

4. Conclusions

In comparison with the riparian soils and the distanced soils, the riverside soils of the Monday river are more sandy, decreasing in depth the content approximately 80%, while there is an increase in the clay content that also occurs in the distance soils.

Bank soils are more permeable, very friable, with little plasticity and stickiness, showing a tendency to crumble easily, which makes them more susceptible to erosion; thus they can more easily give their mineral constituents to the water. In regard to distanced soils, most of them are heavier in texture with a clay content up to ca 40%.

The study of the chemical properties has allowed characterizing soils in their ability to provide nutrients or other elementswater. Flooded soils have very different chemical conditions than aerated soils.

There is a gradual increase of clay in depth; then, they are of greater retention capacity of water and nutrients, increased aggregate stability, plasticity and stickiness, conditions that make them more resistant to water erosion.

According the studied profiles it has been found that most soils are acids, increasing the acidity with depth. When these soils were incubated in water there is a tendency to raise the pH of acidic soils and a decrease in those originally neutral. These changes were less pronounced in the lower layers of the soil profile.

Taken in account the low level of OM present in the soils, high release of N-compounds cannot be expected [30]. In addition in soils without plants, in the surficial interphase rapid NH_4 depletion occurs [31] probably due to volatilization. In organic soils ~50% of NH_4 was found to be lost. In regard to phosphorus, its concentrations in soils, as well as the *E*-values and incubation experiment, suggest that the transfer to the flooded water will be low.

Therefore, results indicate that eutrophication and other deleterious effects that could be originated in the flooded soils should not be expected.

It is interesting to note that at pre-dam studies of Itaipú at the Paraguayan side of Paraná River, same area and soils, after a similar research the forecast generated (and that showed to be correct), was very alike to the one aroused in the present work [21].

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