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Chemical properties of some waters in the tropical rain-forest region of Central-Amazonia along the new road Manaus–Caracarai

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In October and November 1968 some of the staff of the Brazilian road-building organisation DERAM collected water samples in some creeks of the rain-forest region along the new road BR-174 Manaus—Venezuela, section Manaus-Caracarai, under construction. These samples were given to the laboratory of Limnology of the Instituto Nacional de Pesquisas da Amazônia (INPA) for a chemical analysis. The primary purpose of this investigation was to test the usability of these waters in connection with the road-construction works. But at the same time, the results of the analyses were very interesting also in limnological aspect since the new road passes through a tropical rain-forest district, until now completely uninfluenced by civilization, and moreover the chemistry of the waters of that region was unknown as well.

Remarks on sampling area and sampling stations :

The sampling stations are shown in the map. Their numbers along the road BR-174 correspond to those of table 1. Due to the large area covered, the map does not show enough details for exact identification of all waters referred to. The localization of the sampling places is possible through the distance-marks „estacas" (20 m) used for the section under construction, which begins at a distance of about 30 km from Manaus. Up to this distance the road has been trafficable for some years.

Furthermore the map shows that the geological pattern of the superficial layers of the area crossed by the road is not uniform, but that rather formations of different geological periods can be found. All these formations are drained by creeks or rivulets represented by the water samples. The archean region with rocks of granite and gneiss is geologically the most ancient part under consideration. It belongs to the ancient massif of the Guianas, and extends over the northern part of the region shown in the map. Presilurian,

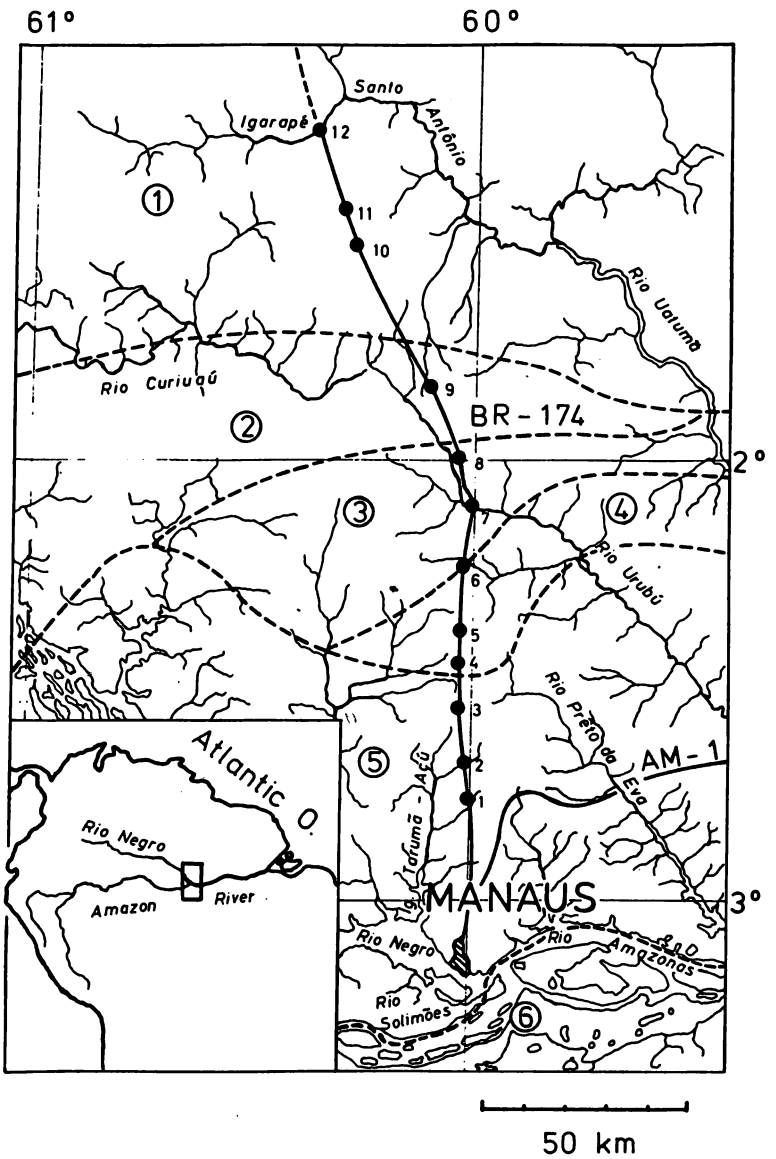

Figure:

Geological map of investigated area with sampling stations.

① archean
② presilurian
③ silurian
④ devonian
⑤ tertiary
⑥ quarternary

1 Sampling places
2 along new road

silurian, and devonian formations spread in southern direction. But the areas of these three formations are only of small extension. They represent the western outskirt of the northern series of strips bordering the plain of the lower Amazon on both sides of the river to the old archean massifs of Central-Brazil and the Guianas. At some places of these strips, carboniferous formations are additionally represented (SIOLI 1954a, 1963, 1968). The three first ones of the investigated waters originate from the tertiary („Barreiras-Series"), which covers the maior part of the Amazon basin. It consists mainly of deposits of the large tertiarian freshwater lake, which originate from weathering products of the older geological materials of the periods mentioned above (acc.t.SIOLI 1968).

As far as the author could observe on a trip along the line of the new track of the road up to about 15 km distance to the Rio Urubú, the relief is formed by a flat or moderately undulated plain, which is crossed through by deeply cut in creek valleys. The soils consist of the brown or red-brown, more or less sandy loams, which are the typical soils of the Amazonian „terra firme", known to each visitor. A new investigation exists (IPEAN 1969) on the soils near Manaus, which may be useful for a further understanding of the soil conditions along the new road, as in general the soils considered in that study will probably correspond to those along the track of the new road, at least as far as the tertiarian reach is concerned.

Methods:

The samples were taken from the surface of the waters by means of plastic bottles, and transported to the laboratory in Manaus and were immediately analysed.

The chemical methods applied in the investigation are standard methods with some adaptations to the specific conditions of the electrolyte-poor waters of the region. They are described in more details in another paper (comp. SCHMIDT 1971). SBV (=Säure-bindungsvermögen) means the alkalinity in mval/l. The COD (Chemical Oxigen Demand) was determined with $KMnO_4$. The concentrations of humic matters, given in table 3, were determined according to the method of MENEZES SANTOS & SANTOS (1970). This method is based on comparisons with a standard made on direct extraction of humic matter an thus allows to compare humic matter contents of different waters in a simple manner. To give some informations on the level of humic matter concentrations in Amazonian waters, determined by this method, some results for the main representatives of the three types of waters in that region (for dicussion of the three of waters in Amazonia comp. SIOLI 1965) may be presented :

Rio Negro	(near Manaus)	black water	20. 5.69	26,6 mg hum. matt./l
Rio Solimões	(near Manaus)	white water	27. 7.70	14,1 mg hum. matt./l
Rio Tapajóz	(near Santarém)	clear water	10.12.69	2,26 mg hum. matt./l

But it seems necessary to mention, that considerable fluctuations in humic matter concentrations are apparently possible in the same water body during a year. For instance (SCHMIDT unpubl.) in the Rio Solimões considerably higher concentrations were observed at very low water level. Therefore, further investigations have to clarify whether there are true correlations between the humic matter concentration and the color and other factors characterizing the three types of waters of Amazonia.

The determinations of sodium and potassium were carried out flame-photometrically with „ZEISS-Spektralphotometer". Unfortunately, these determinations could only be made in January 1971.

Table 1:

Location name	No	data	„estaca"	appearance of the water	μS_{20}/cm	pH	t°C	type of water
Ig. Tarumãzinho	1	4.10.68	45	brownish, clear	5,6	4.7	26.0	black water
Ig. Caí-Caí	2	25.10.68	491	colourless, clear	4,2	4.5	27,0	clear-water
Ig. da Lasqueta	3	25.10.68	1055	colourless, clear	7,0	4.6	29.0	clear water
Ig. da Enchente	4	26.10.68	1610	colourless, clear	6.2	4.6	26.0	clear water
Ig. do Urbano	5	25.10.68	1942	sl. brownisch clear	5.7	4.6	28.0	transitional type betw. clear and black water
Ig. do Sundia	6	25.10.68	2618	sl. brownisch clear	5.5	4.6	26.0	
Rio Urubú	7	25.10.68	3446	brownisch clear	9.0	4.4	29.0	blackwater
Ig. dos Veados	8	25.10.68	4061	brownisch clear	6.8	4.5	27.0	blackwater
Ig. Sta. Cruz	9	13.11.68	4887	brownisch clear	7.4	4.4	—	blackwater
Ig. da Coruta	10	25.10.68	7291	sl. yellowish clear	10,8	5.3	26,0	clear water
Ig. do Itaboré	11	4.10.68	7702	brownisch clear	10.8	4.8	—	black water
Ig. Sto. Antônio	12	3.10.68	—	brownisch clear	8.2	4.7	27.0	black water

Results:

The results are presented in the three tables. The first impression of these results shows at once, that all waters examined were very poor in electrolytes, and at the same time rather acidic and of extremely small buffering capacity. In most samples the electrical conductivity ranged below 10 μS, and the pH surpassed 5 only in the Igarapé da Coruta. In almost all waters the alkalinity was so low that it could not be detected with the applied method, which had an sensitivity of 0,03 mval/l. In most cases the result for Ca and Mg as well remained below the range of the sensitivity of the methods.

The concentrations of nitrite, nitrate and phosphorus showed similar conditions. Furtheron, they remained at almost the same level in all samples. But in contrast to the relative constant level of the results of some factors in all samples, there were clear differences between the last three creeks (Igarapé da Coruta, Ig.d.Itaboré, Ig.Sto. Antônio) and the other rivulets concerning the concentrations of some other matters. This is especially valid for the concentrations of calcium, magnesium, and iron, and is less significant for sodium and potassium, as there are not enough data for all waters with regard to these elements, due to lack in volume of some samples. The Ig.d.Coruta had also higher amounts of alkali-ions. It is probable that the Ig.d.Itaboré had alkali-concentrations similar to the Ig.d.Coruta, because these two rivulets showed also considerable parallels in other respects.

Table 2:

Location name	SBV mval/l	Ca^{++} μg/l	Mg^{++} μg/l	Na^{+} mg/l	K^{+} mg/l	$Fe_{diss.}$ μg/l	$Fe_{susp.}$ μg/l	Fe_{total} μg/l
Ig. Tarumãzinho	<0.03	<20	<10	1.05	0.79	39	32	71
Ig. Caí—Caí	<0,03	<20	<10	n.d.	n.d.	71	7	78
Ig. da Lasqueta	<0,03	<20	<10	n.d.	n.d.	87	0	87
Ig. da Enchente	<0,03	<20	<10	0.19	0,17	62	13	75
Ig. do Urbano	<0,03	<20	<10	n.d.	n.d.	39	52	91
Ig. do Sundia	<0,03	<20	16	0.21	0.08	63	112	175
Rio Urubú	<0.03	<20	<10	0.25	0.09	136	29	165
Ig. dos Veados	<0.03	<20	43	0.23	0.10	58	94	152
Ig. Sta. Cruz	<0.03	<20	43	n.d.	n.d.	91	26	117
Ig. da Coruta	0.05	178	163	0.61	1.38	317	146	463
Ig. do Itaboré	0.05	356	322	n.d.	n.d.	211	323	534
Ig. Sto. Antônio	0.05	142	22	0.23	0.15	220	207	427

n.d. = not determined

Table 3:

Location name	HCO_3^- mg/l	$N(NO_2)$ µg/l	$N(NO_3)$ µg/l	Kjeld.N. mg/l	N_{total} mg/l	P_{total} µg/l	Cl^- mg/l	$Si_{diss.}$ mg/l	Humic matter mg/l	COD mg/l
Ig. Tarumãzinho	<1.8	3	7	0.33	0.34	4	1.8	2.28	5.4	87.8
Ig. Caí-Caí	<1.8	<1	2	0.19	0.19	3	1.8	2.04	2.0	26.8
Ig. da Lasqueta	<1.8	1	2	0.19	0.19	5	2.2	2.43	2.7	34.9
Ig. da Enchente	<1.8	1	4	0.17	0.18	3	1.4	2.06	1.4	23.8
Ig. do Urbano	<1.8	<1	3	0.16	0.16	2	1.5	2.54	0.1	31.4
Ig. do Sundia	<1.8	3	3	0.12	0.13	4	3.5	2.65	0.1	31.1
Rio Urubú	<1.8	1	2	0.16	0.16	4	2.0	2.32	6.3	52.7
Ig. dos Veados	<1.8	<1	5	0.65	0.66	4	2.0	2.31	5.0	42.3
Ig. Sta. Cruz	<1.8	2	2	0.35	0.35	9	2.0	2.72	7.2	43.4
Ig. da Coruta	3.1	4	4	0.39	0.40	11	1.8	3.95	8.0	29.8
Ig. do Itaboré	3.1	2	6	0.49	0.50	12	1.2	3.1	17.9	70.3
Ig. Sto Antônio	3.1	<1	6	0.38	0.39	7	1.0	2.47	15.1	44.0

Within the group of the first nine waters, being rather uniform in their characteristics, only one of them showed some outstanding features. It was the Ig. Tarumãzinho, which had some higher amounts of nitrite, nitrate, Kjeldahl-nitrogen, sodium, potassium, and COD than the other waters of this group. Small, but just detectible influences by settlers must be taken into consideration as a reason for the increase of the mentioned factors, as this creek is the nearest of all waters of this study to the city of Manaus. By the way, although the new road penetrated a region up to recent times completely uninfluenced by civilization, during his excursion in 1968 the author observed scattered settlements of Amazonian farmers („caboclos") along the track just until about km 40 of the new stretch of this road.

In contrast to the poorness in electrolytes, all samples had rather considerable amounts of organic matter, as can be concluded from the results for Kjeldahl-N and COD, which ranged between 0,12 — 0,65 mg/l resp. 23,8 — 87,8 mg/l (comp. table 3). But this relatively high concentration of organic matter is not surprising in rain-forest waters, as always more or less large quantities of allochthonous organic matters are introduced from the enviroment.

Im comparison with the concentrations of the three rivers given as examples above, the concentration of humic matters, determined with the afore mentioned method, was very low in some samples, and in a middle range in the others. Furtheron, the results showed good accordance with the general aspect of the waters, i.e. the color as noted in table 1. Similar conditions can be stated as well for the organic matter contents, determinded as COD.

Discussion:

The results of these investigations show that the waters in the region along the new stretch of the road Manaus-Caracaraí come from similar out-washed and therefore very electrolyte-poor soils with extremely low contents of calcium and plant nutrients like those, which are typical for the major part of the Amazon basin, as until now is known, from many publications (e.g. SIOLI 1954a, 1954b, 1955, 1968, SIOLI and KLINGE 1961, KLINGE and OHLE 1964, FITTKAU 1964, 1967, IPEAN 1969 etc.).

SIOLI (1955) reported some higher concentrations of alkalis and earth-alkalis for waters of the archean zone of the upper Rio Negro drainage area in comparison with the corresponding averages of the waters of the tertiarian region. The results of this study confirm his findings. The three waters of the second group drain from the archean area. But there is a certain difference in iron content between the waters from the archean zone of the upper Rio Negro and those of this study, for the latter have considerably higher amounts of iron. This is especially valid for the three waters draining from archean area, but also the other samples along the road show considerable iron contents.

The samples originating from the presilurian, silirian, and devonian parts indicated — as to their chemistry examined — no remarkable differences from the others coming from the tertiarian reach. Therefore, it seemed justified to comprise all these waters in the first group, as has been done above. In the scope of this study there is no place for discussion of details concerning relationships between the geology of the underground and the chemistry of the draining waters of the region referred to, because until now all available data are too scarce. As can be seen from the map, there are some additional difficulties in this discussion with regard to the waters of the small strips formations, as due to the very limited extension of these formations along the new road, influences of other geological zones on these waters are very probable. In the case of the Rio Urubú the map proves this situation. Its water integrated affluents coming from different geological zones already when crossing the new road, i.e. the sampling place. Additional influences on the properties of the waters are possible by other local conditions of the drainage area. Special regard in this connection must be paid to soil conditions and vegetation types, as e.g. bleached sand layers of podsol soils covered with „caatinga"-forest drain black waters (SIOLI 1955, SIOLI and KLINGE 1961, KLINGE 1967). The presence of black waters

among the studied samples proves such conditions in the drainage area of some rivulets, also in the archean region.

The interpretation of the relation Ca:Mg of the samples is very difficult for the first group of waters, as the concentration of these elements was mostly too small. The Igarapé dos Veados and the Igarapé Sta. Cruz exhibited some more magnesium. On the other hand, all three creeks of the second group produced evidently more calcium than magnesium.

The influence of different seasons, causing different dilutions by rain etc., can be neglected in the discussion, as all samples had been collected in the same season and at relatively small intervals. In spite of the mentioned certain increase of concentrations of some factors, indicating probably first man-made pollutions, the Igarapé Tarumãzinho showed no essential differences from the other waters of the tertiarian region in its general chemical characteristics.

According to the presented results the investigated waters can be classified as clear and black waters in the sense of SIOLI (1965), at least at the sampling time. However, the black water characteristics are not so striking, as they are in other regions (e.g. SIOLI 1955). Some waters only can be classified as transitional forms between the two types of waters (comp. table 1). But such transitional types are quite common in Amazonia. It is even possible that the same creek can change its water type according to external conditions like rain falls etc. in a short time (SIOLI 1963).

Summary:

Water samples of 12 different rivulets along the new road Manaus-Venezuela, stretch Manaus — Caracaraí, were analysed and compared in their chemistry. They all were very salt-poor and acidic waters of a small buffering capacity. Some aspects of the water chemistry in relation to the geological pattern of the drainage areas were discussed. Three of the rivulets coming from archean formation had some higher concentrations of alkalis, earth-alkalis, and iron. The iron concentrations however, were relatively high in all water samples. According to the results of the investigation, the waters belong to the types of clear and black waters, but some creeks represent transitional forms between these classifications.

Resumo:

Amostras de água de 12 igarapés da região da rodovia em construcão Manaus-Venezuela, na seccão Manaus — Caracaraí, foram analisadas e comparadas quanto às qualidades químicas estudadas. Tôdas as águas eram muito pôbres em sais dissolvidos, bastante acidas e extremamente pouco tamponadas. Além disso, alguns aspectos da geologia da região em relacão com as qualidades das águas drenando aquelas áreas são discutidas. Na comparação das diversas águas resultou que os igarapés que drenam a área do arqueano possuem concentrações de alcalis, de alcalis terrosos e de ferro um pouco mais altas do que as outras águas estudadas. Mas geralmente as concentracões de ferro são relativamente consideraveis em tôdas as águas examinadas em comparacão com outras águas amazônicas. Conforme os resultados das investigacões, podem-se classificar as águas desta região como águas claras (águas transparentes) e águas prêtas, algumas porém, representando transições entre êsses tipos.

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