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Numbers of bacteria and algae and their interrelations in some Amazonian waters

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From October 1967 until July 1968 investigations were carried out on the population densities of the bacteria and algae and on their relations to each other in some waters near the city of Manaus, State of Amazonas, Brazil. The waters referred to were the Rio Solimões (Amazon River), the Rio Negro and a lake of the várzea-region of the Solimões (Lago do Castanho). At the same time they represent typical examples of the most important types of waters which exist around the city of Manaus.

Two fractions of the bacteria were differentiated. The first one was the total number of bacteria, determined by direct counting according to the membrane filter method; the second one was the number of saprobiont bacteria (saprophyta) as number of colonies, which was obtained by incubating the water samples on a standard nutrient medium. In connection with the bacteria, the algae were regarded only in their total number, without any systematical specification.

Methods

To determine the total number of bacteria, the membrane filter method was used. For this, membrane filters of the type MF 50 (Membranfilter-Gesellschaft Göttingen, Germany) were applied. A sample of either 25 or 50 ml water was passed through each filter. The only 25 ml water samples were diluted by 25 ml membrane filtered distilled water to a total of 50 ml to get a comparable covering in all filters. If using more than 50 ml of Solimões water per filter, the counting became very difficult because of the considerable amount of mineral suspensoids in that "white" water. After the filtration the filters were fixed during 10 min. at 70° C and stained with erythrosin. Finally, parts of the filters were placed on microscopic slides and turned transparent by canada-balsam. The countings were made at 1250 times magnification. To facilitate the first countings, some slides were as well prepared from bacterial suspensions of the plates mentioned below (see also SCHMIDT 1969a). By means of staining with erythrosin, it was very easy to distinguish the bacteria and the inorganic sediment particles of the Solimões water during the counting process, if the layer was not too thick. In the same samples which served for counting the total number of bacteria, the total number of algae was determined, too. By the application of the membrane filter method for the estimation of algae numbers, a slight error can occur due to the destruction of soft algae. But in our case this error may be negligible because of the scarcity of these types.

To determine the number of saprophyta, special membrane filter sets were used. These filters (Nährkartonscheiben, Membranfilter-Gesellschaft, Göttingen, Germany) are combined with a nutrient medium of the standard type, which corresponds to conventional broth agar plates. The manipulation was performed according to the producer's description. Two dilutions of the samples were always applied, normally with 0.1 and 1.0 ml original water. In each series there were some blind samples for control, too. After the inoculation the plates were incubated under aerob conditions at 30° C, and after 24, 48 and 96 hours the colonies were counted. By means of a colouring system, inserted in the plates by the factory, the majority of the colonies was coloured and the final count was very easy to make. In general the number of colonies did not increase any more after 48 hours. Occasionally running colonies appeared at this stage, which overgrew their neighbours. In most cases the corresponding samples showed very good results. By using the standardized plates a considerable comparability was guaranteed. The number of colonies grown on these plates was considered to be the number of saprobiont bacteria per water volume.

Sampling places

In the Rio Negro the samples were taken midstream near the city of Manaus at about 0.2 m depth; they represent in fact surface samples. At the sampling point there is no influence of the sewage of the city. The samples from the Rio Solimões were collected upstream the Ilha do Careiro, equally in the middle of the river and from 0.2 m depth like those ones from Rio Negro.

The Lago do Castanho is a typical representative of the lakes of the periodically inundated land in the Amazon valley (*várzea*) and is located about 60 km distant from Manaus. During the whole year it is connected with the Solimões by a long canal, so that the fluctuations of the water level of the river immediately effect the water level of the lake. The lake receives no important tributaries from the terra firme, its water can be regarded to be practically decanted Solimões water. That is confirmed also by chemical water analyses (SCHMIDT 1968, and other unpublished data of the author).

Four series of samples were taken in a three-monthly rhythm, representing 4 different water levels and, at the same time, one annual cycle, too. Fig. 1 shows the water levels of the Rio Negro at Manaus. They are more or less valid also for the Rio Solimões near the mouth of the Rio Negro, and thus for the Lago do Castanho, too. In 1967, the minimum level was reached in October. In the beginning of 1968 a renewed short-term subsidence of the level of the Solimões occurred, although the minimum had already passed. This phenomenon is not unusual in that season and causes repeated flush of the lakes. The maximum level was reached in May 1968. This means, that in July, at the sampling time, the water already started to flow out of the lake.

Results

The results of the countings of the Rio Negro samples are shown in Fig. 2. In all four samples the total number of bacteria was nearly constant at 200000 to 300000 indiv./ml. However, the number of algae was less than 10000 cells/ml and thus very low and showed only little fluctuation as well. The amount of bacterial colonies/ml was very small and did not vary very much in the course of the year. Obviously the life conditions of the studied organisms remain more or less the same in this water body in spite of the considerable water level fluctuations. Unfortunately, up to now no publications exist

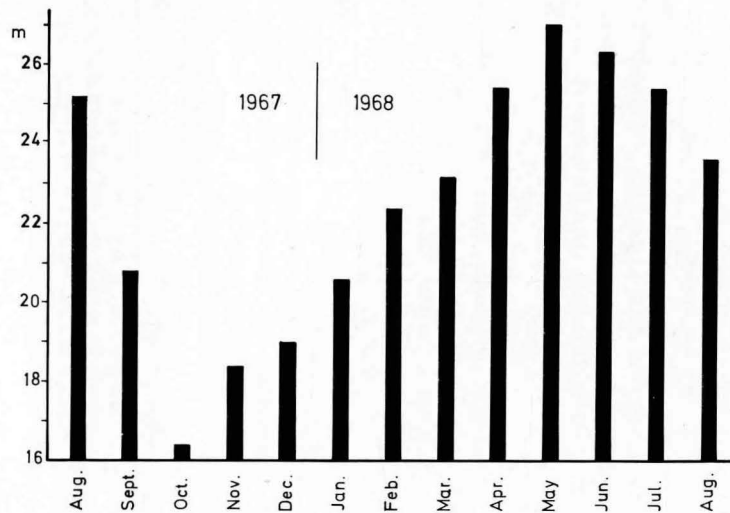


Fig. 1: Mean water level of the Rio Negro near Manaus during the investigation period according to the measurements of the Manaus Harbour Administration.

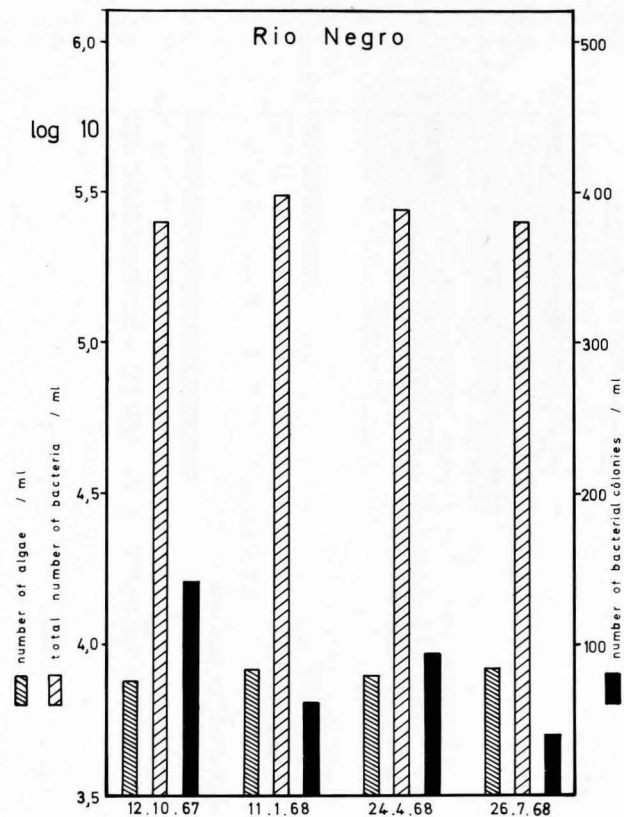


Fig. 2: Bacteria and algae content of surface Rio Negro water near Manaus at four different periods of a year. (total number of bacteria and algae represented as logarithms)

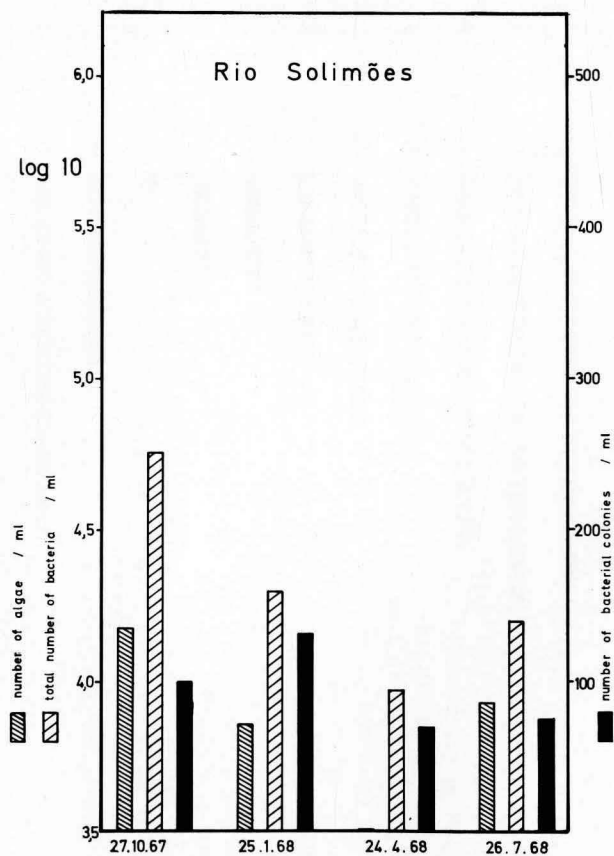


Fig. 3: Bacteria and algae content of surface water of the Rio Solimões (Amazon River) near Manaus at four different periods of a year. (total number of bacteria and algae represented as logarithms.)

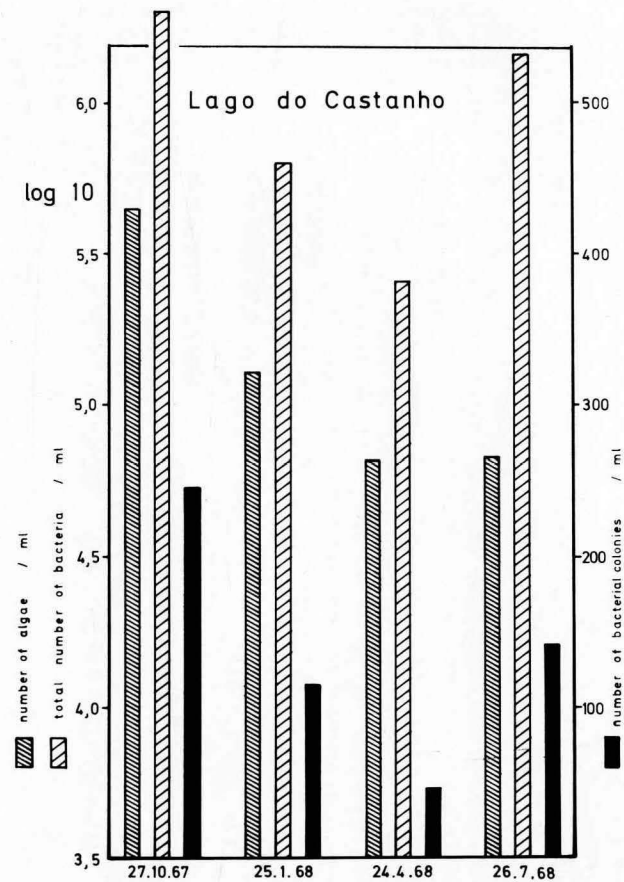


Fig. 4: Bacteria and algae content of the surface water of the Lago do Castanho at four different periods of a year. (total number of bacteria and algae represented as logarithms).

which prove this situation also for the inorganic nutrients for the phytoplankton. Since the entire drainage area of the Rio Negro system is located in a region of relatively uniform geological and climatological characteristics, it is likely to be so.

In the Solimões, however, more distinct differences in the total numbers of bacteria and algae were found. The greatest amount of bacteria, 50000/ml, was counted in October. At this time the number of algae also reached its highest peak with almost 15000/ml. In April, on the other hand, the number of algae was less than 3000/ml, and the number of bacteria had its minimum, too. Thus the amplitudes between the extremes were obviously greater in this water body than they were in the Rio Negro. The causes will be given furtheron. But in their totality the numbers of bacteria and algae were rather low in the Solimões and mostly below the population density found in the Rio Negro. As far as the algae are concerned, this low population density can be explained very easily. As the transparency in the Solimões during the whole year is very small, alternating in this region between 0.3 and maximum 0.5 m, but the current being very rapid (average 1—2 m/sec.), development of an autochthonous phytoplankton in this water body is not possible. Due to the extremely limited penetration of light in ratio to the depth of the river and the violent turbulences in the water body, the assimilation of freefloating plants will remain always below the compensation point, i. e. the cells will die sooner or later. Thus, if algae are found at all in this river, they originate in its tributaries, and especially in the lakes being connected with it. Comparing figures 3 and 4, a clear resemblance between the total numbers of bacteria and algae of Lago do Castanho and the Solimões is at once noticable. In October, at a considerably sinking river level, the lakes connected with the river outflow in correspondingly high degree, too. A distinct rise of the amount of bacteria and algae in the Solimões is the result of that drainage. When, at rising water level, the supply of plankton organisms from the lakes stops, the population densities in the river arrive at their minima, as can be seen from the April data (Fig. 3). Although the number of lakes adjacent to the Solimões is very high, the absolute quantities of plankton organisms found in the river are quite lower than in the lakes, due to the enormous dilution of the lakewater in the great river.

The number of saprophyta in the Rio Solimões, similar to that in the Rio Negro, remains at a relatively constant low level during the whole year (Fig. 3). In this respect there were differences to the lake, for in the surface water of the Lago do Castanho considerable differences in the number of saprobiont bacteria appeared at all sampling times (Fig. 4).

In this lake, during October 1967, at the time of the lowest water level, all organisms referred to reached their maximum in quantities, and in the following April, at rising water, they arrived at their minimum. As is described in another paper, in this water body even greater differences existed at other depths (SCHMIDT 1969b).

Comparing the numerical relationships between the different groups of the studied organisms, some remarkable parallels can be found: The ratios between the numbers of algae and of bacteria in the upper layers of Lago do Castanho and the Rio Solimões are almost identical at the time of falling water level, especially in October.

Table: Ratios between the number of algae and the total number of bacteria and between the number of saprophyta and the total number of bacteria

1. Rio Solimões, surface		
data	algae : bacteria (total)	saprophyta : bacteria (total)
27. 10. 1967	1 : 4	1 : 600
25. 1. 1968	1 : 3	1 : 150
24. 4. 1968	1 : 3	1 : 150
26. 7. 1968	1 : 2	1 : 200
2. Rio Negro, surface		
12. 10. 1967	1 : 40	1 : 2 000
11. 1. 1968	1 : 40	1 : 5 000
24. 4. 1968	1 : 40	1 : 3 000
26. 7. 1968	1 : 30	1 : 5 000
3. Lago do Castanho, surface		
27. 10. 1967	1 : 5	1 : 8 000
25. 1. 1968	1 : 5	1 : 5 000
24. 4. 1968	1 : 4	1 : 5 000
26. 7. 1968	1 : 20	1 : 12 000

They amount to about 1 : 5. In addition, a remarkable similarity between Lago do Castanho and the Rio Negro exists in the ratio of the number of saprophyta to the total number of bacteria. In both water bodies these values amounted normally 1 : 3000 up to 1 : 5000. The ratio of 1 : 9000, until now found in the Rio Negro in a singular case only (SCHMIDT 1969a), was also of the same order of those noted in Lago do Castanho, at the surface at the 27th October 1967 with 1 : 8000, and at the 26th July 1968 with 1 : 12000. As can be seen from the data of OVERBECK (1965), in this lake these ratios were remarkably greater than they are in some German lakes.

On the other hand a relatively high saprobiontal fraction of the entire bacterial population was stated for the Solimões. The numbers ranged between 1 : 150 and 1 : 600. The same situation was as well encountered in some very dirty waters in the urban region of Manaus, with much higher absolute quantities of bacteria, however (SCHMIDT 1969a). The relative rise of the saprobiontal numbers in the Solimões is probably caused by the death and decomposition of algae and other easily decayable organic matter, being carried into the river from lakes and affluents.

Discussion

As from the presented data results and was mentioned above already, no significant fluctuations, neither in the total number of bacteria nor in the number of algae, occurred in the Rio Negro during the investigation. Therefore the ratios of organism numbers varied only slightly in that river, too. The turbulence of the running water, which is carrying the algae into lightless depths, is also in the Rio Negro one of the causes of the small quantities of phytoplankton. But the lack in plant nutrient elements in this river and in its drainage area which has been proved by other authors (SIOLI 1955, SIOLI and KLINGE 1961, KLINGE and OHLE 1964), is emphasised additionally by the small population densities of algae and also of saprophyta, although in the Rio Negro the

current is remarkably slower and the transparency better than they are in the Solimões. As shown in the table, the total number of bacteria in relation to that of the algae was higher in the Rio Negro compared to the other studied waters. Perhaps this fact hints on the existence of certain specialists among the bacteria which may particularly use the humic matter abundant in the blackwater of the Rio Negro. The presence of special bacterial types is eventually indicated by the following as well. Although within the scope of this study the organisms treated could not be specified more systematically, some interesting observations were made. As mentioned above, the colonies on the standard plates were generally coloured reddish or yellowish. But on the plates with samples of the Rio Negro water always comparatively large and distinctly blue colonies developed (20—50% of the total colony number). In Rio Solimões and in Lago do Castanho these species were apparently much rarer, for reddish colonies predominated, and there were either none or only up to 5% blue colonies to be seen. In polluted blackwater the fraction of the blue colonies was also lower than in the pure Rio Negro water (SCHMIDT 1969a). It seems well possible that these bacteria represent specialists, which are particularly adapted to the acid and humic blackwater.

As in many other features, these two great streams, the Rio Negro and the Solimões, differ from each other also with regard to their microflora. Whereas the Rio Negro seems to have in a certain degree an autochthonous development of algae and bacteria, the conclusion is justified that the Solimões in this respect depends extremely upon the lakes.

The situation in the Lago do Castanho showed in its total considerable parallels to that found in lakes in the northern hemisphere by other authors, especially by KUSNETZOV (1958) and OVERBECK (1967 and 1968). This has been treated furthermore in another paper in more detailed manner (SCHMIDT 1969b).

Summary

In the Rio Solimões (Amazon River), in the Rio Negro and in a várzea lake (Lago do Castanho) in a three-monthly turn in the course of a year, the total numbers of bacteria and algae and the numbers of saprobiont bacteria (number of bacteria colonies) were determined and the relation between these numbers was studied.

In the Rio Negro the numbers of algae and bacteria, and thus as well the relation between them, remained relatively constant and showed no significant fluctuations. The absolute quantities of these organisms were always very small.

The latter was also the case in the Rio Solimões, however here, during the investigation period, more distinct alterations of the population densities of bacteria and algae occurred which were closely related to the situations in the lake. At the time of sinking water level the content in bacteria and algae which practically can originate only in the lakes connected to the river, increased considerably in the Solimões water.

Resumo

Os números totais das bactérias e das algas e os números das bactérias “saprobiontes” (números de colônias de bactérias) de amostras d’água do Rio Solimões (Rio Amazonas), do Rio Negro e dum lago da várzea (Lago do Castanho) foram determinados e as relações entre esses números foram estudados durante um ano, de três em três meses.

No Rio Negro, os números das algas e das bactérias e também as relações entre essas quantidades sempre ficavam relativamente constantes e não mostravam quaisquer flutuações nítidas. As quantidades absolutas desses organismos eram sempre muito pequenas.

Também no Rio Solimões, as quantidades dos organismos estudados eram pequenas, mas apareceram, aqui, nas densidades das populações daqueles organismos, variações mais distintas as quais dependiam estreitamente das situações nos lagos. Especialmente clara é esta dependência na época da vazante, pois os números das algas e das bactérias, produzidas praticamente só naqueles lagos ligados com o rio mesmo, aumentaram então notadamente na água do Rio Solimões.

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