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Present Fluxes of Suspended and Dissolved Matter in Rivers

1. Discharges and River Flow

The relations between the variations of both rainfall and run-off are considered mainly in monsoon regions of West and Central Africa from Senegal to Angola. So, the fluxes coming from the desert boundaries will be disregarded here because they produce only a very low water volume. Except for the environments surrounding the Sahara Desert or the Kalahari Desert, the surface is dissected with rivers (Fig. 1a). The only inland drainage is the Chad basin, while the main peripheral rivers drain into the Atlantic Ocean (Senegal, Sassandra, Volta, Niger, Sanaga, Ogooué, Congo, Cuanza, and Kunene). The geographical distribution of these fluxes is schematised in Fig. 1b. The Congo River flux predominates and represents about 60% of overall river fluxes to the Gulf of Guinea from Cap des Palmes. These African rivers belong to two environmental types: (1) the tropical forest type as in the case of the Congo, the Ogooué and the Sanaga, and (2) the tropical savanna type as in the case of the Niger, the Sassandra or the Volta. The rivers of the first type run through equatorial basins with little relief and are characterized by moderate river flow: the ratio R between extreme monthly discharge or seasonality index is low (Lobaye, $R=1.7$, Kassai, $R=1.7$, Congo, $R=1.67$). The same discharge ratio between high- and low-flows reach very high values in arid or semi-arid regions, especially where the difference in level increases (upper Niger, $R=80$, Senegal, $R=354$, Benue, $R=600$). To a large extent, the "equatorial" river flows show two monthly maxima but with local perturbation reduced to one maximum, whereas the "tropical" river flows show only one maximum controlled by the boreal or austral climatic rule. Lastly, the Sahelian (or Kalaharian) flows are regulated by the seasonal rainfall and so, are easy to characterize. The flow of a large fluvial system like the Congo River is difficult to analyse because it results from composite climatic influences, partly in the Northern Hemisphere and partly in the Southern Hemisphere. The Congo is 4,700 km in length with a very low slope of 0.033%. It drains a large basin (3.7×10^6 km^2) in the central part of the African continent going from 11° to 31°E and from 9°N to 14°S. This river is the world's second largest river both for its mean flow (41,000 m^3/s) and for its drainage area. Its average annual discharge is estimated at 13,000 km^3 based on an 80-year period record (Probst and Tardy, 1987). It represents about 38% of the African continental drainage. The water balance of the Congo basin shows that the equatorial rain forest is responsible for intensive evapotranspiration leading to a run-off coefficient of only 21.6%.

The discharge fluctuations of the Congo regime are mainly due to the distribution of its tributaries on both sides of the Equator, namely Ubangui and Sangha-Likouala in the north and upper Congo and Kassai in the south. At the Brazzaville station, the hydrologic characteristics represent the mixing of these four main tributaries (Fig. 2a,b):

- The low water period, during July and August, corresponds to the low flows of the equatorial regime and to the recession of the tropical austral regime (Kasai).
- The maximum discharge, during November and December, is mainly induced by the high-flow period in the northern part of the basin (Ubangui).
- The second minimum discharge, centred on February and March, corresponds to the low-flow of the tropical-boreal regime, it is partly limited by the Kasai high water.
- The relative maximum during April and May is mainly controlled by the high-flow in the southern part of the basin (Kasai and Upper Congo).

Consequently, the Congo River discharge during eight months of the year represents more than 50% of the total annual discharge. During July, more than 50% of the discharge is provided from the equatorial region. During August and September, the northwestern supplies are prevalent but correspond to less than 20% from December to May (Fig. 2c). But it results in a high regularity of the discharge through the year, the ratio between maximum monthly flow/minimum monthly flow is only 1.74 (57,200 m^3/s during December, 32,800 m^3/s during August). The moderation of the flood discharge is a characteristic of the Congo River and shows that the equatorial rain forest is responsible for an intensive evapotranspiration and a low run-off. In point of fact, the relationship between the river discharge and the rainfall amount is linked to the velocity of propagation of floods from different origin: a lead or a delay of high water from the Northern or the Southern Hemisphere can induce a simultaneity of arrivals at Brazzaville (exceptional floods during 1961–1962).

Other western Africa rivers are less documented than the Congo River. The Ubangui River, the most important northern tributary of the Congo, is a perfect example of a "tropical" river with a contrasted unimodal regime with low waters from March to April and high waters from September to November. The seasonal variability is higher than for the Congo River, as indicated by a ratio of the extreme modules of ten. The flow deficit of 1,220 mm corresponds to a run-off coefficient of 18%. The discharge of Ogooué River at Lambarene is

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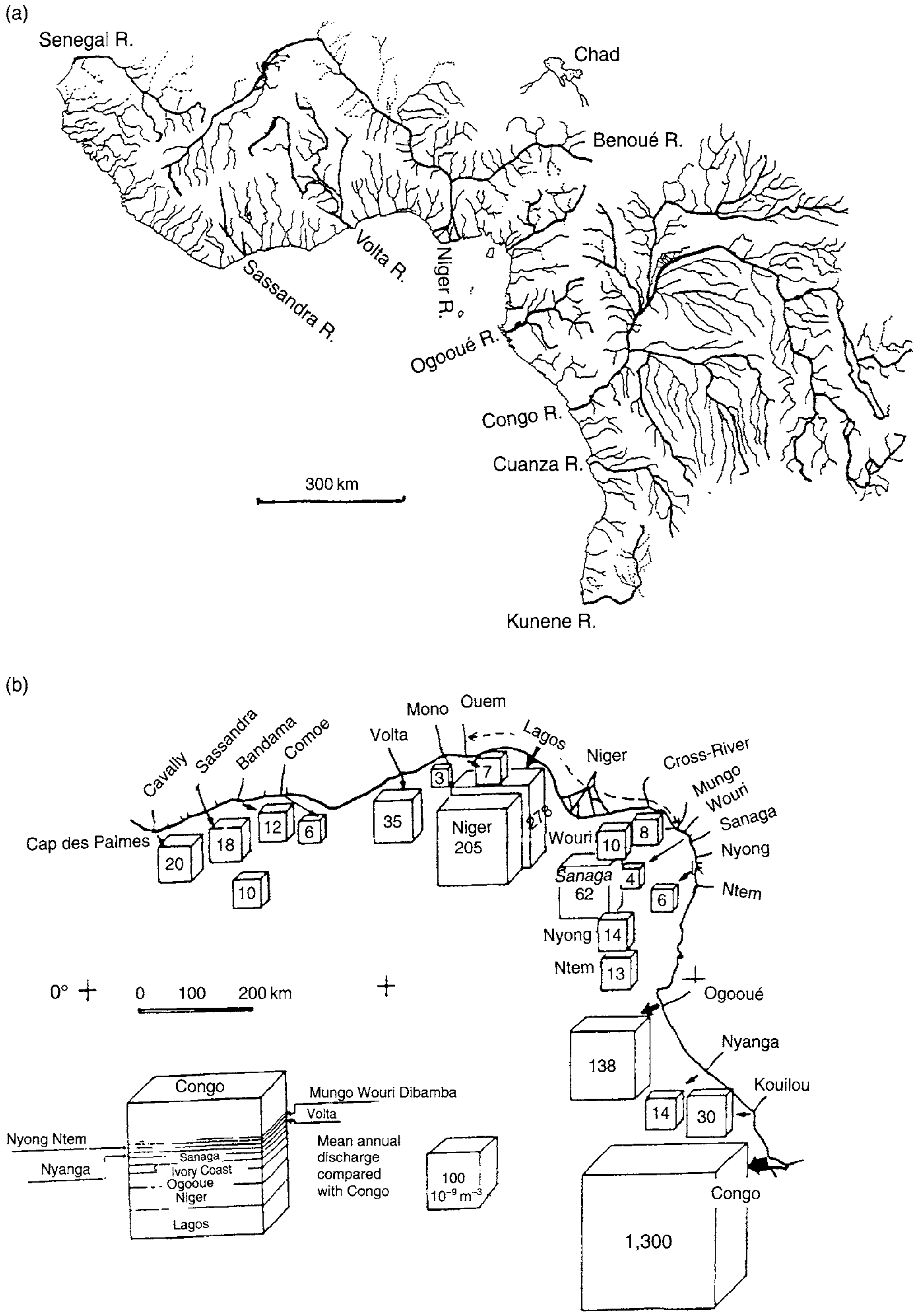

Fig. 1. (a) Simplified drainage pattern of western and central Africa, the main water courses are shown; (b) Multi-annual fluxes of various tributaries of the Gulf of Guinea, the side length of the cube is proportional to the cube root of the mean annual discharge, simplified after Mahé et al. (1983–1987).

controlled by a four-seasons equatorial regime with two high-water periods during spring and autumn. The Niger, rising from the more humid (precipitation, 1,500 mm/year), Fouta Djalon Highlands flows due northeast into the sub-desert zone, south easterly through the Sahelian zone into the tropical area, where it forms its delta. Discharge has also been measured in the Gambia River, West Africa (Lesack *et al.*, 1985). The annual mean discharge ranges from 90 to 460 m^3/s with a short maximum in early to mid-September. The rise and fall of the discharge is rapid and the plain is virtually dry from December to the beginning of July. At the southern limit, the Orange River drains 1.02×10^6 km^2 of semi-arid to arid areas; its average discharge of 360 m^3/s constitutes over 20% of the mean annual run-off of South Africa. Generally, the rate of groundwater/seepage may play an important role in highly seasonal rivers during low-flow periods. This is the case in some semi-arid and arid rivers and streams, where dry season flows are maintained only by springs and groundwater seepage.

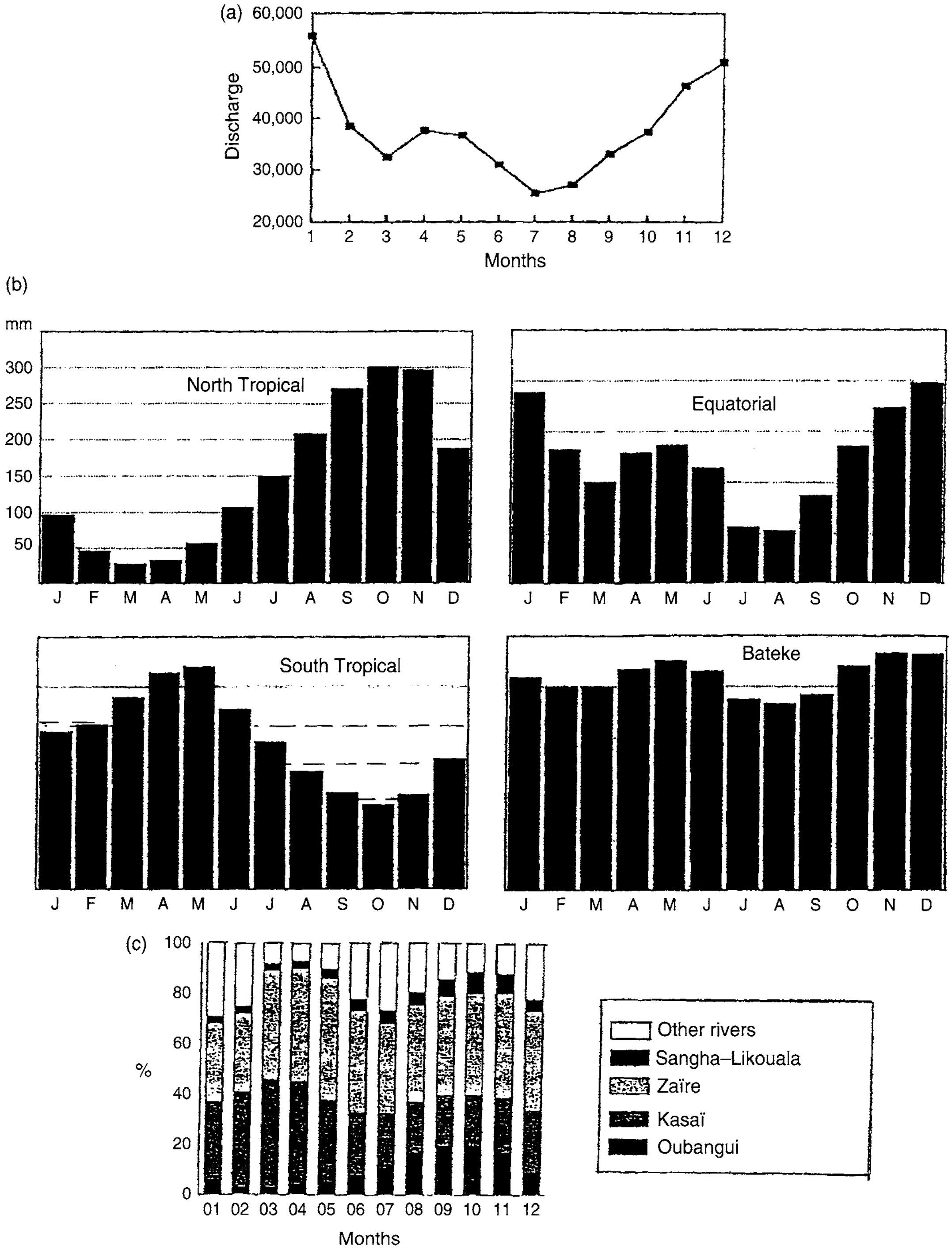

Fig. 2. (a) Mean monthly discharge of the Congo River; (b) Main types of hydrologic regimes in the Congo River basin; (c) Proportions of each tributary of the Congo River (after Bricquet, 1995).

Except the Nile River discharge record, which encompasses the two last centuries, the discharge of the main African rivers was registered only since the last century. The succession of dry and humid hydroclimatic conditions was more or less synchronous (Fig. 3b). However, one can detect some lags and even oppositions between the main hydroclimatic periods in the Northern and in the Southern Hemisphere (Martins and Probst, 1991). The slightly humid periods of 1930 and 1960, which affected the rivers of the Northern Hemisphere are opposite to a dry period in river of the Southern Hemisphere whereas the dry event of the year 1970 in the Northern Hemisphere corresponds to a humid period in the Southern Hemisphere. In contrast, one can notice that the drought period of 1940–45 has affected more or less all-African rivers in the two hemispheres. Fluctuation amplitudes decrease toward Equator. It is in the Sudano-Sahelian region and windward from the Guinea Mountains that the rainfall and run-off decreases since around 1970 are the highest. However, in the proximity of the Equator the decreasing trend gently diminishes and this evolution is hardly visible on the series of the South Gabon and Congo (Mahé, 1993). In West African regions, another decreasing trend is observed from West to East.

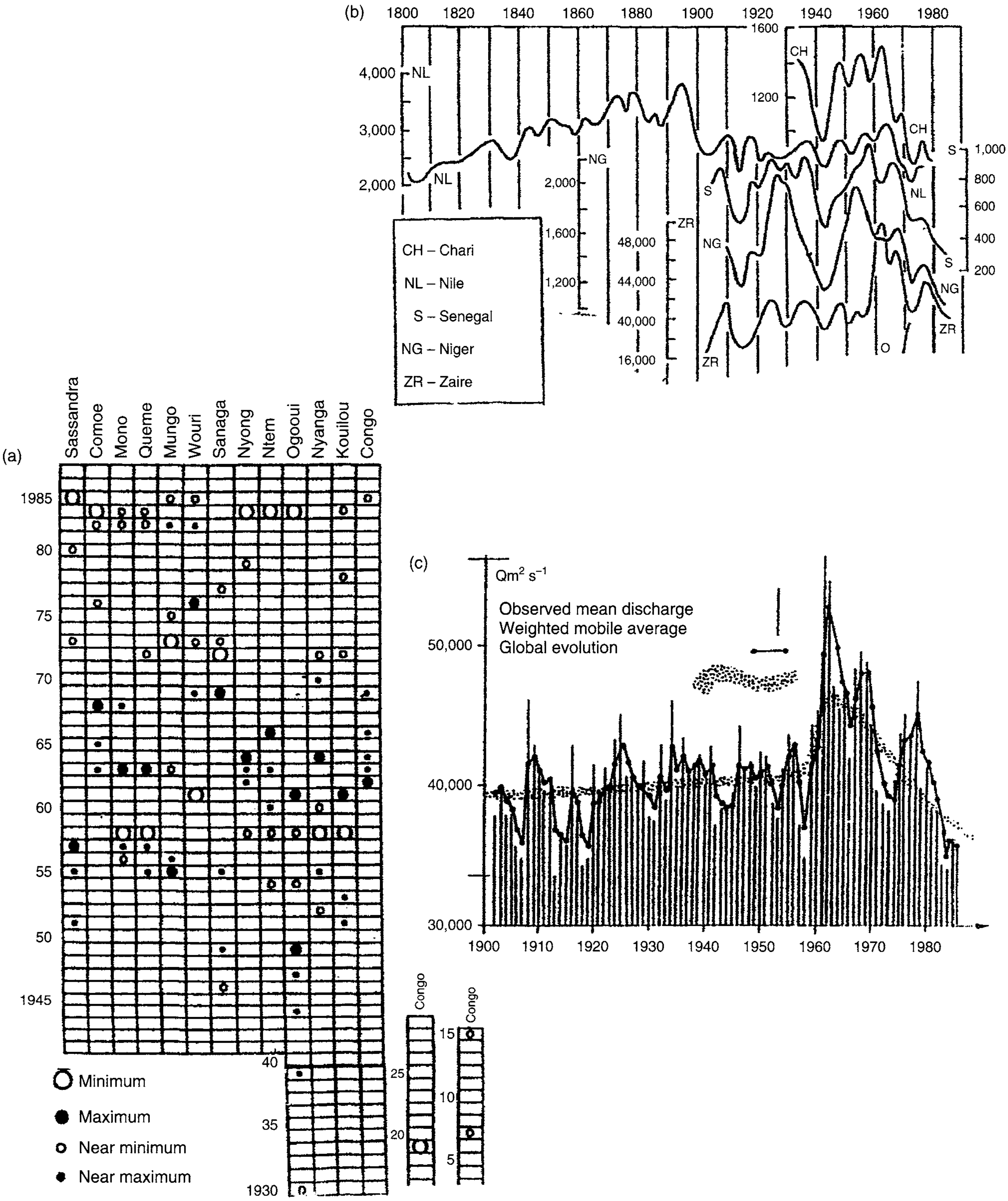

Fig 3. (a) Registration of extreme mean discharge to the Gulf of Guinea (after Mahé and Olivry, 1988); (b) Interannual fluctuations of the mean annual discharge (m^3/s) for some West African river-filtered data (5 years arithmetic mean) (simplified from Probst and Tardy, 1987); (c) Detailed record of the Congo River discharge at Brazzaville since 1902 (after Olivry et al., 1988).

This is partly due to Indian or South African flows, which lead to a particular interannual variability in eastern Central Africa, all of the Congo-Zaire basin and East and South of Angola.

During the last forty years, the interannual discharge fluctuations of the rivers to the Gulf of Guinea follow the same rythmicity (Fig. 3a). Maxima and minima are evidence of the same regional climatic processes: the rainfall fluctuations are linked to the general oceanic circulation of surface waters. Various authors show relations between cool water upwelling near the shoreline and the rainfall minima and consequent river discharge (Mahé *et al.*, 1988). The Congo

River provides the longest record (Fig. 3c). Through the last 84 years, average discharge was largely influenced by the very low values registered during the beginning of the century. Then, a slight growing trend is recorded until 1960–70. During the first 1960s, exceptional discharges were recorded delivering an on average 25% excess to the Gulf of Guinea. After 1980, a marked decreasing trend is observed and is linked to the Ubangui River deficit. The run-off shows an annual deficit of 7% during the 1970s and of 16% during the 1980s. The long-term persistence of the low water discharge is associated with a large reduction in groundwater storage (Olivry *et al.*, 1995).

2. Suspended Matter Fluxes

The relief of the African continent can be schematically divided by a line stretching from east of the lower Nile valley southwards across the upper Congo-Zaire basin, ending south of the Congo basin (Fig. 4). The area northwest of this line constitutes lowland plains whose altitudes range from 150 to 600 m (Martins and Probst, 1991). The most important drainage basins to the Atlantic are included in this lowlands area: Senegal, Niger, Sanaga, Ogooué and Congo. This part of Africa is an "old continent" where the erosion rates, the river fluxes, especially the solid transport, are very low in comparison with its discharge and its basin area, though our knowledge is still uneven (Table 1).

The Senegal River shows the highest concentration of suspended matter (196 mg/l), but the specific discharge (0.3 $l/s/km^2$) is very low (Gac and Kane, 1986a, b). As in many semi-arid rivers with highly seasonal flows and broad flood plains, the suspended matter concentrations attain a maximum before the peak discharge (Kattan *et al.*, 1987) (Fig. 4a). However the significance of this high concentration is largely balanced by the shortness of the discharge (mean 360 m^3/s). The ratio of suspended matter/dissolved matter reaches 2.4 whereas the recent building of dams could probably affect the particulate load. Nearly the same process is observed in the Gambia River, where with a higher water discharge, the mean suspended sediment concentration reaches only 19.5 mg/l. The low transport of particulate matter is generally attributed to lack of relief (Lô, 1984). In the upper part of the Gambia River (Fig. 4b), the proportion of suspended particulate matter (22 mg/l) is too low (Orange and Gac, 1990). But, in contrast, the rate of particulate organic carbon in suspended sediments is important (5.1%). The specific mechanical erosion (4.3 $t\,km^2\,yr$) is less than that measured for most other African rivers.

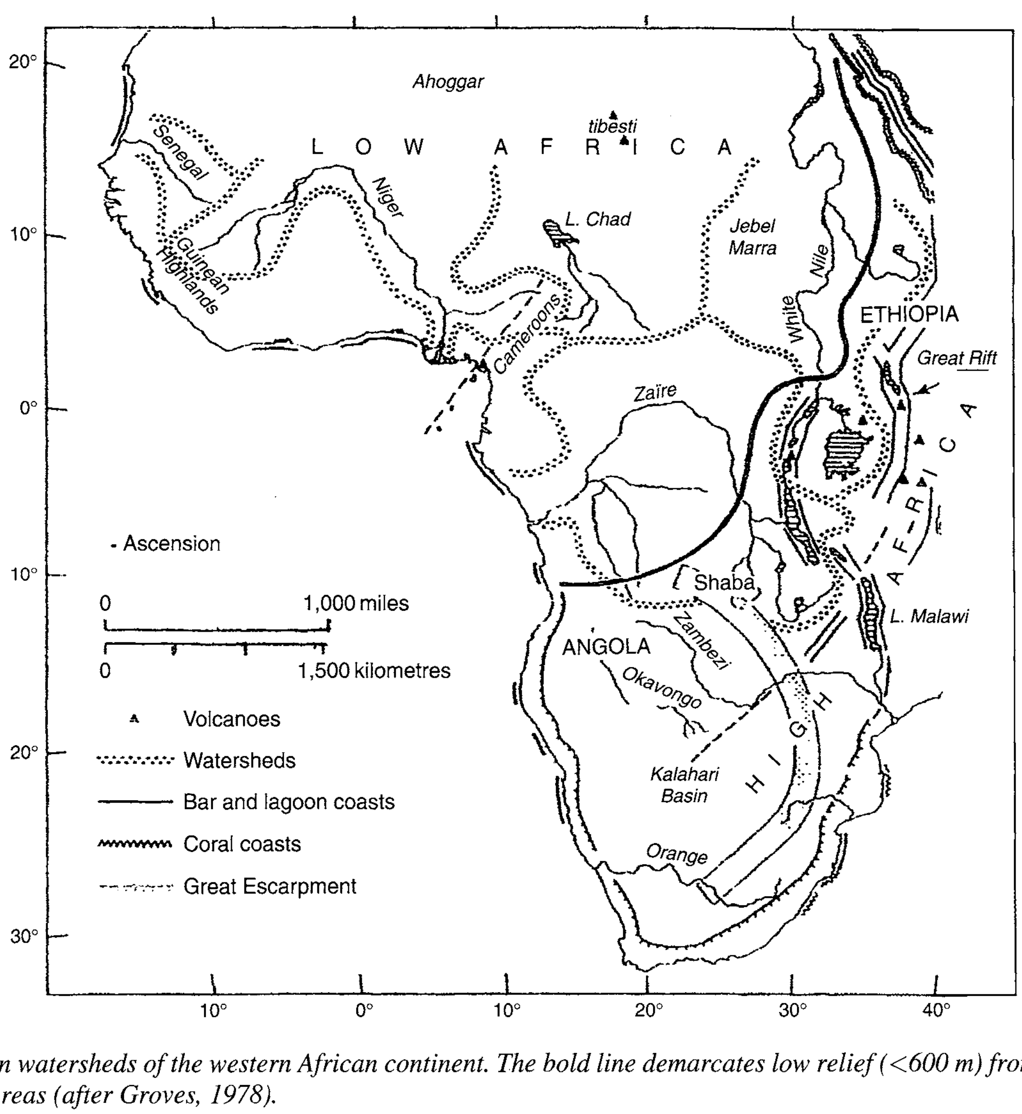

Fig. 4. Main watersheds of the western African continent. The bold line demarcates low relief (<600 m) from high relief (>100 m) areas (after Groves, 1978).

Table 1. A compilation of discharge characteristics of some western African rivers (after Martins and Probst, 1991).

River (station)	Drainage area (10^6 km^2)	Interannual discharge (m^3/s)			Specific discharge (l/s/km^2)	References
		Max.	Min.	Mean		
Zaïre (Brazzaville)	3.5	57 200	32 750	41 134	11.8	Nkounkou and Probst (1987)
Niger (Lokoja)	1.2	17 797	1 335	4 886	4.1	Martins (1982)
Orange (Vioolsdrip)	1.0	500	63	360	0.3	Hart (1985)
Senegal (Bakel)	0.27	2 000	0.19	330	1.2	Gac and Kane (1986a,b)

Similarly, in the Niger delta, the peak concentration of the total suspended solids is attained well before the maximum water discharge: concentration is highest in July (134 mg/l) dropping to about 80 mg/l during peak water discharge. It seems that large amounts of fines are transported during the first rains as run-off increases initially on bare surfaces. A secondary suspended matter concentration is suggested to be an effect of atmospheric dust input between December and January, as is generally the case throughout West Africa. Particulate organic matter constitutes between 2% and 9% of the total suspended sediments. It is suggested that *in situ* phytoplanktonic production should be dominant in the low concentrations of matter were confirmed: the specific load varies between 7 and 8 t km^2/yr for the upper Niger and 3 t km^2/yr for the Bain River. Seasonal variations of the matter fluxes are very different between the upper and the lower parts of the inner Delta. The 1992–93 input that reaches the inner Delta was about 2.2 M tons.

The suspended load of the Sanaga River has been measured in the two major sub-basins, Mbam and upper Sanaga representing more than 90% of the global discharge to the ocean. The peak in suspended sediment concentration in the two rivers precedes the peak in water discharge (Nouvelot, 1972), a phenomenon typical of many rivers. The average annual concentrations are 58 mg/l for the Sanaga River and 160 mg/l for the Mbam River. Suspended sediment loads in the Mbam during the wet season exceed those of the Sanaga by a factor 4–5, reflecting both the comparative steeply slopes of the Mbam catchment, and its high population density. According to the respective water discharge, the transport of suspended sediment to the ocean is near 3.5 M tons each year and for the Mbam sub-basin, this transport is near 2.5 M tons each year. Thus a mean of 6 M tons of suspended matter is transported annually to the ocean. Particulate organic carbon (POC) concentrations in the suspended matter of Sanaga and Wouri Rivers vary seasonally from 7% to 16%. During periods of high discharge, suspended sediment loads are high while POC contents are low. During low discharge periods, suspended sediment loads are low while POC contents are high. The average flux of the Sanaga River varies between 0.42 and 0.54 M POC tons/year.

The Ubangui River is the major northern tributary of the Congo River. In spite of this tributary function, this river was especially studied through recent surveys (Olivry *et al.*, 1988; Laraque and Olivry, 1996). Measurements made at Bangui give a sediment discharge of 2.9 M tons/yr and a mechanical concentration varying from 3 to 55 mg/l. Ubangui is another example of tropical river: the erosion ability increases during the rise of the high water and induces a concentration maximum before the maximum water discharge. Then, from a discharge threshold, a suspended matter diminution is registered. During the drop in water level the concentration decrease is related to the stop of the active erosion process. Lastly, near the end of the fall, only groundwater drainage of saturation level of the plain provides the discharge. A marked decrease of the suspended load is recorded. It is suggested that this low concentration is linked to the reworking of the restricted area of the channel. The load declines very quickly with the decrease of the moistened section and of the river competency.

The Congo River, in spite of a very important water discharge (40,600 m^3/s), supplies to the Atlantic a relatively low quantity of matter. After recording for six years, Laraque *et al.* (1995) concluded to a mean total transport of 91.8 t/yr in which the solid flux corresponds to an advanced level of erosion of 26.2 t km^2/yr (without correction for atmospheric supply). This erosion acts on an old peneplain relief (slope still <10 cm/km and near 3 cm/km in the central basin). The mean concentration of suspended matter rises to only 25.8 mg/l and can be subdivided in 6.54 mg/l of sandy matter ($>50\,\mu$m) and of 19.27 mg/l of fine matter (between 0.45 and 50 μm). The chemical and mineralogical composition of the solid material exported by the Congo River is in equilibrium with kaolinite and the suspended sediments are mainly composed of kaolinite and quartz (Nkounkou and Probst, 1987). Higher suspended loads are recorded in September–October during the rise of the main flood of the year. The concentration decreases in November–October during the maximum water discharge. Then, the solid load shows two maxima in February and in November (1,200 and 1,400 kg/s). The minima are observed in May and in August, especially during the last month in which only 430 kg/s is registered. The sandy fraction represents a nearly constant component (120–160 kg/s) except during July and August where a marked fall is observed (90–51 kg/s) (Olivry *et al.*, 1988) (Fig. 5b). The organic matter represents 15% of the annual suspended matter load with a particulate organic carbon flux between 1 and 2.5 mg /l.

3. Dissolved Material Export

Our basic knowledge concerning dissolved matter is slightly lower than for suspended solid, but it is enough to support comparison between the main rivers of western Africa (Table 2).

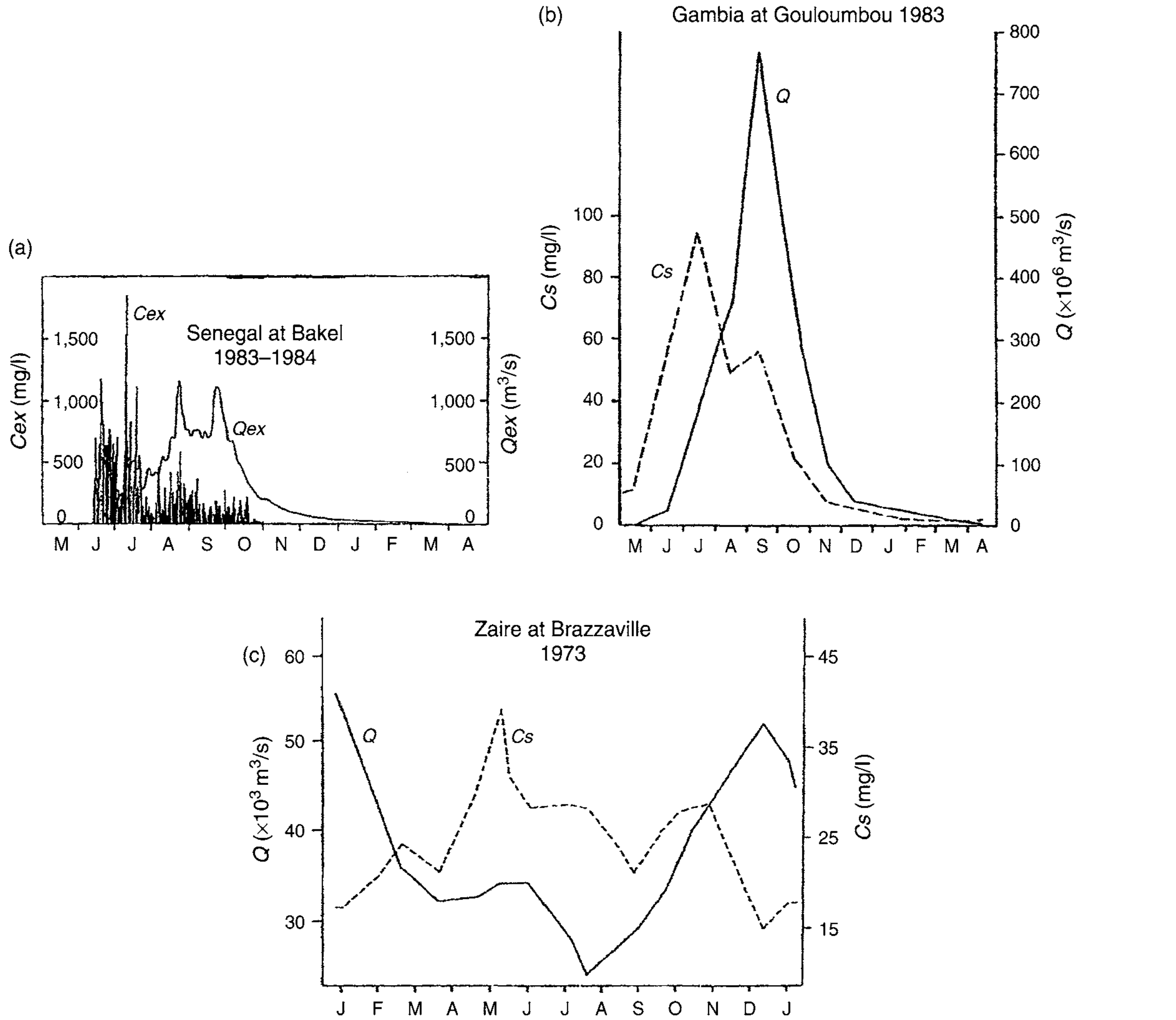

Fig. 5. Some examples of variations of suspended sediment concentrations (Cs or Cex) with discharge (Q or Qex) for (a) the Senegal River (after Kattan et al. 1987); (b) Gambia River (after Lô, 1984); (c) Congo (Zaire) River (Kinga-Mouzeo, 1986) (compiled by Martin and Probst, 1991).

The total dissolved substance (TDS) of the Senegal River is low (mean around 42 mg/l) and corresponds to a very low specific transport (1.8 tons km^2/yr) (Gac and Kane, 1986a,b). Salinity increases between December and June, dropping sharply at the beginning of precipitation towards the end of July. Then it remains stable throughout the high-water period from August to November. Dissolved inorganic carbon is present mostly as bicarbonate ions and constitutes more than 50% of the TDS. It should be emphasised that an important fraction of these bicarbonate ions is supplied by atmospheric CO_2 (Gac and Pinta, 1972).

Transport of solute by the Gambia River is also very low when compared to other African rivers (Table 2). The mean TDS is 17 mg/l and the mean chemical specific transport is 1.0 tons km^2/yr (Lesack *et al.*, 1985). The water is a dilute solution of SiO_2 and HCO_3^- (75% of total solute by weight), Na^+, K^+, Cl^-, and total dissolved nitrogen do not show a significant relation with discharge. However, Ca, Mg, HCO_3^-, conductivity and SO_4 decrease as discharge increases while total dissolved P increases with discharge. According to the typology of fluviatile transport of Meybeck (1976), Lesack *et al.* (1985) note that the Gambia River is classified as low run-off (<5 l/s/km^2), warm (>15°C) and low relief. It is predicted to have a solute transport rate of 5 tons/km^2/y, which is very close to their measurement (4.81 tons/km^2/yr). The total dissolved load of the Fouta-Djalon, in the upper Gambia basin is also low (33 mg/l) and the specific chemical weathering is estimated at 3.7 tons/km^2/yr, very similar to the value for the Senegal watershed (Orange and Gac, 1990). HCO_3^- is the main anion whereas Ca and Mg are the major cations; SiO_2 accounts for up to 33% of the total dissolved load.

The Niger River is also a river from semi-arid environment with moderate solute levels. TDS and alkalinity show a strong positive correlation thereby accentuating the predominance of bicarbonates (Martins and Probst, 1991). Ionic seasonal variations are slightly different from the values of the Senegal. Ionic concentrations increase between May through August, but a gradual rise in salinity was observed throughout the peak flood (September and October). Dissolved organic carbon (DOC) values reach about 3.5 mg/l. The annual chemical budget shows a saline deposit of 0.3 M tons in the inner delta.

Total dissolved substances for the Congo River as for the Ubangui River are higher than the total solid substances. During 1987, TDS rose to 72 M tons for the Congo and ranged 3.7–4.1 M tons for the Ubangui. A five-year long study of the waters of the two rivers demonstrated the

Table 2. Fluxes of some African rivers, TSS: Total Suspended Solids, TDS: Total Dissolved Substances (after Martins and Probst, 1991).

Rivers	Precipitation (mm)	Runoff (mm)	R/P (%)	TDS (mg/l)	TSS (mg/l)	Transport 10^6 t		TSS/TDS	Specific transports (l/km^2/year)		Organic Carbon concentration (mg/l)			Specific transports (l/km^2/year)			References
						TDS	TSS		Chem.	Mech.	DOC	POC	TOC	DOC	POC	TOC	
Zaïre	1520	338	22	28	37	36.6	48	1.39	9.9	13.8	8.5	1.1	9.6	2.9	0.8	3.7	Nkounkou and Probst (1987)
Niger	1140	124	11	67	127	14.0	25.4	1.86	11	20.5	3.5	3.7	7.2	0.4	0.5	0.9	Martins (1983)
Senegal	650	48	7	42	196	0.4	1.9	2.44	1.8	4.4	—	1.5	—	—	—	—	Gac and Kane (1986a,b)
Orange	380	15	4	140	57	1.6	0.7	0.44	1.6	0.7	2.3	0.9	3.2	0.03	0.01	0.04	Hart (1985), Hall *et al.* (1977)
Zambezi	1020	157	15	113	90	25.2	20	0.80	21	16.7	—	—	—	—	—	—	Milliman and Meade (1983)
Gambia	1100	219	20	17	19.5	0.08	0.09	1.10	1.0	1.1	2.4	1.1	3.5	0.3	0.1	0.4	Lô (1984) Lesack *et al.* (1985)

stability of the main chemical components through the hydrological cycle (Sondag *et al.*, 1995). The waters transport mainly bicarbonates (largely provided by the atmospheric CO_2 dissolution) and SiO_2. The Congo River waters are especially poor in dissolved mineral matter, the mean TDS of these five years (36 mg l^{-1}) is far lower than the worlwide average of the river waters (100 mg/l) or to the average of African rivers (~60 mg/l). Especially the low bicarbonate (15.7 mg/l) and calcium contents (2.2 mg/l) are responsible for this low value. However, the SiO_2 content (9.4 mg/l) is higher than worlwide average values. The Ubangui River waters show higher concentrations in Ca, Mg, bicarbonates and SiO_2. Differences in vegetation cover and in the lithology basement are suggested to explain these concentrations: the Ubangui watershed is characterised by an open landscape and by a calcareous basement and "crypto-karst" surfaces. The difference is especially emphasised during the low-water discharge period of Ubangui.

In the Congo River, TDS, the organic matter and the mineral matter represent, respectively, 18.5% and 47.6% of the total transport. The concentration of dissolved SiO_2 remains slightly constant through the year (between 8.5 and 10.5 mg/l). The last evaluation of the chemical specific transport is 12.1 tons/km^2/yr and reaches 5.4 tons/km^2/yr for the dissolved matter. The mean dissolved organic carbon exportation is 11.4 M tons/yr but the particulate organic carbon exportation is only 1.6 M tons/yr. The study of the seasonal fluctuations shows that the dissolved organic carbon comes mostly from the leaching of the watershed during the flood period and especially from the large marshy forest of the Congolese basin. Dissolved organic matter (DOM) exhibits the most significant fluctuations, the higher values (near 30 mg/l) are noted generally in December and January, during the main flood of each hydrocycle. During main low waters of July–August, the concentrations may fall to 1 mg/l. These seasonal variations seem very similar year-by-year (Fig. 6a).

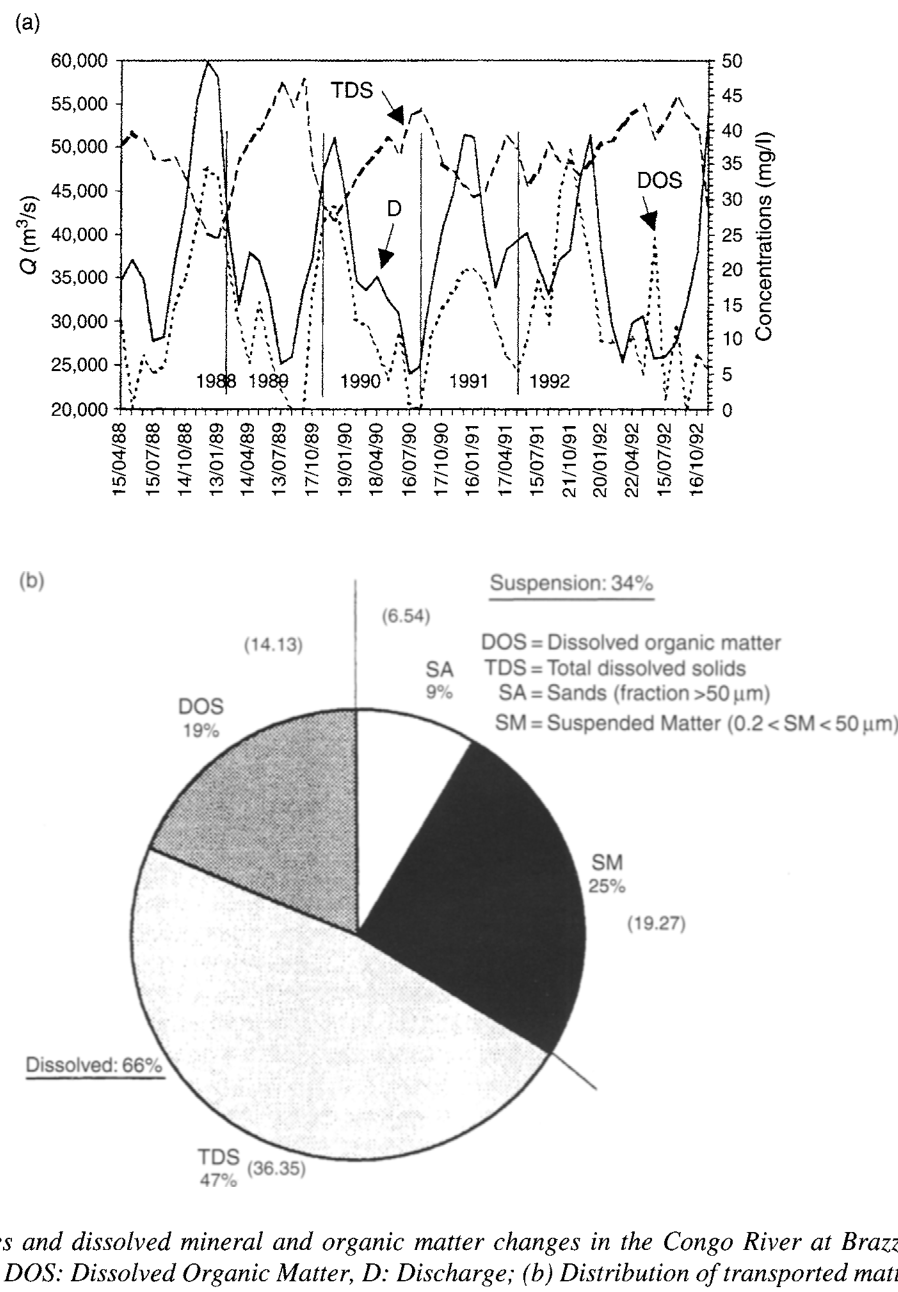

Fig. 6. (a) Fluxes and dissolved mineral and organic matter changes in the Congo River at Brazzaville, TDS: Total Dissolved Solids, DOS: Dissolved Organic Matter, D: Discharge; (b) Distribution of transported matter (mg/l) of Congo River at Brazzaville (1987–1992 average) (after Laraque and Olivry, 1996).

4. General Budget, Remarks

The specific transport of large African rivers ranges from 0.7 to 20.5 tons km^2/yr for particulate matter, and from 1 to 21 tons km^2/yr for dissolved matter (Martins and Probst, 1991). The ratios between TSS and TDS are very low and even <1. However, these ratios seem to be higher for rivers from tropical savanna like the Senegal, Gambia, Niger than for rivers from tropical forest like the Congo. The recent long-lasting studies of the Congo watershed indicate more significant values (TDS is only ~30% for the Congo at Brazzaville and 43% for the Ubangui at Bangui) but do not alter the general comment. The increasing part of the TDS at the boundary between tropical and equatorial climates shows the growing role of the chemical specific transport, this process mostly reflects organic matter production and exportation.

River export of organic matter from the continent to the ocean forms an important component in the global carbon cycle. Generally, the POC percentage of suspended matter decreases when the TTS increases going from the rivers of the tropical forest (Congo) to the rivers of the tropical savanna (Senegal and Orange). DOC and POC contents (except DOC in the Congo River), are lower than in the world's major rivers of other environments (e.g., subarctic, temperate). Consequently, the specific organic transport rates are also lower than in the other region, ranging from 0.04 to 3.7 tons km^2/yr. In Africa, the Niger and Congo Rivers are the two only ones for which organic matter exportation values are available:

- the Niger exports TOC load of 1.2 10^6 tons/yr of which 0.66×10^6 tons are attributed to POC and 0.53 to DOC. The specific rate of annual transport is 0.44 tons/km^2 for DOC and 0.5 tons/km^2 in the case of POC. Thus, the specific transport rate of TOC in the Niger drainage basin is about 1 tons/km^2/yr^1.
- the mean specific transports of Congo River are, respectively, 26.3 tons/km^2/yr for the total transport, 12.1 tons/km^2/yr^1 for the chemical transport, 8.8 tons/km^2/yr for the mechanical transport and 5.4 tons/km^2/yr for the dissolved organic matter. The total biochemical flux (17.5 tons/km^2/yr) of the Congo River sets this river as the first in Africa. But this total flux includes atmospheric inputs, so it expresses a total export and not a specific weathering transport. Nkounkou and Probst (1987) suggested that the atmospheric input represents nearly 34% of the total: 76% of the bicarbonate exported by the Congo River is produced by atmospheric CO_2.

The Congo water is more dilute than the world average, except for silica, which represents about 34% of the total, dissolved concentration and is at the cause for rapid diatom reproduction. It is also important to note that the Congo water is enriched in iron. Logically, the concentrations of each major element are maxima during the low-water period (June to August). Contrary to the first evaluation, the mechanical erosion (34%) of the Congo is markedly lower than the biochemical one (66%). The total of matter exported each year (91.8×10^6 tons) is constituted by ~34% of solid matter, namely 30.7×10^6 tons with 7.9×10^6 tons of sand fraction and 22.8×10^6 tons of suspended matter. The 66% dissolved matter correspond to 61.1×10^6 tons divided in 44×10^6 tons of total dissolved solids (TDS) and 17.1×10^6 tons of dissolved organic matter (Laraque *et al.*, 1995; Fig. 6b).

In spite of a relative prevalence, the chemical transfer is moderate because on this old peneplain surface, most of the soils are mature, there are large areas of lateritic covers with iron duricrusts and a large part of their soluble phase has been leached from long ago. However, this old surface is half covered by rain forest and still exposed to the intense leaching of the wet equatorial climate.