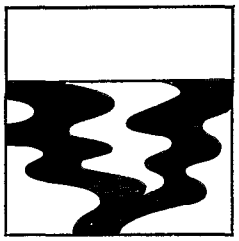

Seasonal variations of transparency, suspended matter, total residue, fixed total residue and volatile matter in Rosetta branch of the Nile

MASSOUD A. H. SAAD (1)(2), MAHDI H. ABBAS (1)

SUMMARY

Variations of transparency along the Rosetta branch of the Nile were pronounced during 1978-1979. The transparency values were generally higher in the estuarine region, due mainly to the effect of the entering sea water. The lowest transparency in January is attributed to the relatively high turbidity. The mineral particles contributed the main portion of suspended matter. The pronounced variations of suspended matter between different stations are related principally to the changes in current velocity and nature of the bottom deposits. The values of suspended matter are directly correlated with discharge. An inverse relationship was observed, generally, between transparency and the surface values of suspended matter.

The values of total residue and fixed total residue increased generally with depth. The variations of total residue, fixed total residue and volatile matter in the different seasons were remarkable in the estuarine region and slight in the rest of Rosetta branch. The seasonal variations of total residue and fixed total residue in the estuarine region coincided with those of chlorosity. In this region, the major bulk of volatile matter obtained in all seasons, except in January, seems to be produced by partial decomposition of minerals.

KEY WORDS : Africa — The Nile — Water transparency — Suspended matter.

RÉSUMÉ

LES VARIATIONS SAISONNIÈRES DE LA TRANSPARENCE, DES MATIÈRES EN SUSPENSION, DU RÉSIDU TOTAL, DU RÉSIDU APRÈS IGNITION ET DE LA MATIÈRE VOLATILE DANS LA BRANCHE DE ROSETTE DU NIL

Les variations de la transparence des eaux le long de la branche occidentale, dite de Rosette, du delta du Nil, ont été importantes en 1978-1979. Les valeurs les plus élevées ont généralement été observées dans la région estuarienne influencée par les marées. Les valeurs les plus faibles observées en janvier résultent d'une forte turbidité. Les particules minérales constituent l'essentiel des matières en suspension dont l'abondance est étroitement corrélée au débit. Les variations observées entre différentes stations dépendent principalement de la vitesse du courant et de la nature des fonds. Il y a une corrélation négative entre la transparence et la teneur en matière en suspension en surface.

Les valeurs du résidu total et du résidu après ignition augmentent généralement avec la profondeur. Les variations du résidu total, du résidu après ignition et de la matière volatile sont importantes dans la zone estuarienne et modérées dans le reste de la zone étudiée. Dans la région estuarienne les variations saisonnières du résidu total et après ignition suivent les variations de la chlorinité, et la plus grande part de la matière volatile paraît provenir d'une décomposition partielle des minéraux.

MOTS-CLÉS : Afrique — Nil — Transparence des eaux — Matières en suspension.

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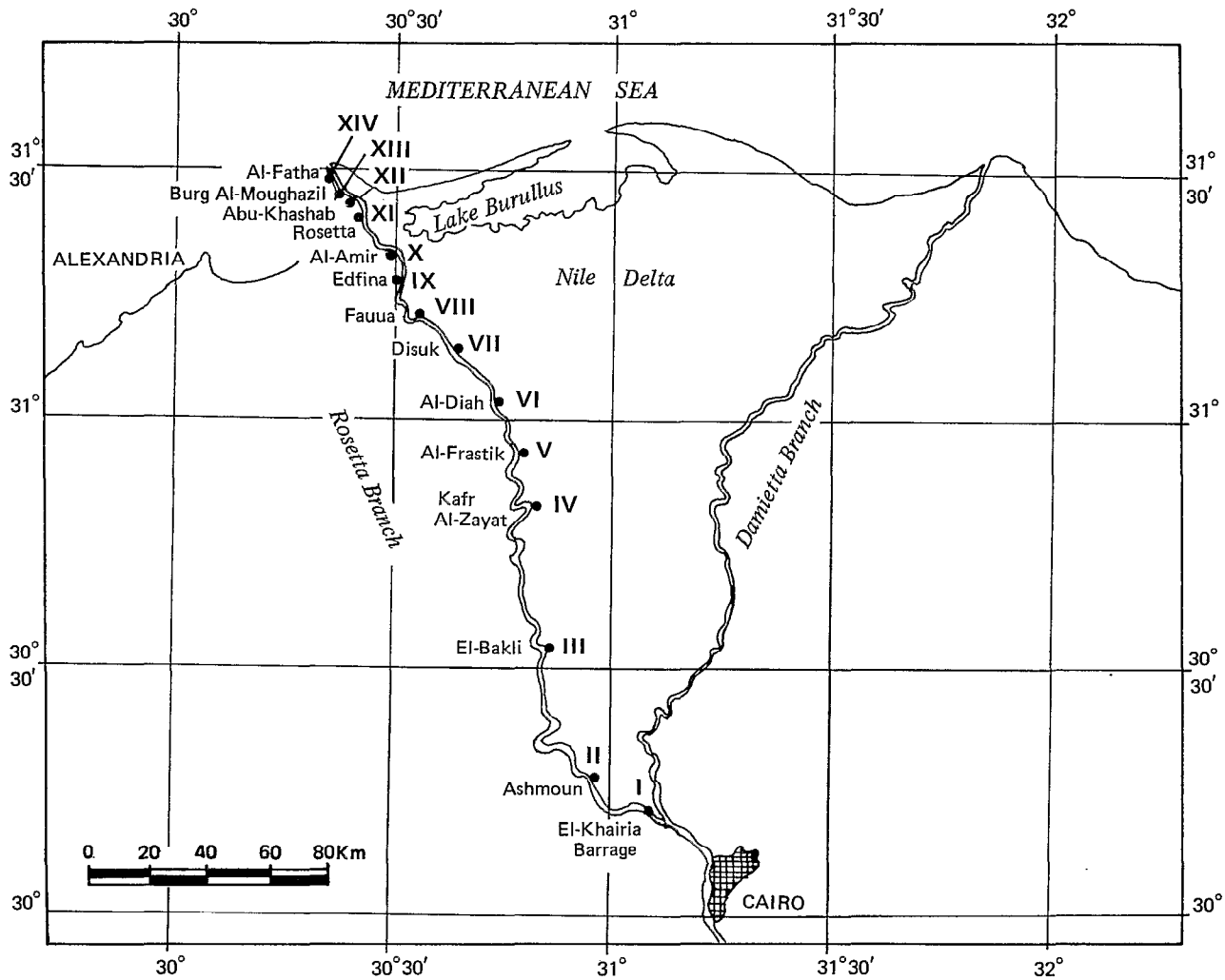

FIG. 1. — Map of the study area of Rosetta Branch, showing position of the stations
Carte de la branche de Rosette avec l'emplacement des stations

INTRODUCTION

The Nile is bifurcated at 23 km North to Cairo into two branches, Rosetta and Damietta. The Rosetta branch runs about 236 km northward along the west boundary of the Nile Delta and opens into the Mediterranean Sea (Fig. 1). The width of this branch differs from one location to another, with an average of about 500 m. Its depth shows, in general, noticeable local variations, with an average of 11.5 m.

In spite of the economical importance of fishing of the Nile in Egypt only limited limnological studies have been carried out. The present study, which is a part of a limnological program on Rosetta branch of the Nile, deals with the first information on the seasonal variations of transparency, suspended matter, total residue, fixed total residue and volatile matter along the whole length of this branch from its beginning near Cairo to its mouth in the Mediterranean Sea.

METHODS

Water samples were collected from the main channel of Rosetta branch at fourteen stations, selected along its whole length (Fig. 1). Samples were taken in April, July and October 1978 and January 1979 to represent spring, summer, autumn

TABLE I

Seasonal variations of the monthly discharge and the average water levels (m above sea level) at Al-Khairiia Barrage (A) and Edfina Barrage (B) during 1978-1979

Variations saisonnières du débit mensuel et des niveaux d'eau moyens (m au-dessus du niveau de la mer) au barrage Al-Khairiia (A) et au barrage Edfina (B) en 1978-1979

Months	Stations	Monthly discharge (million m^3)	Average water levels
April 1978	A	1395	16.63
	B	1193	1.50
May	A	1133	16.60
	B	933	1.57
June	A	411	16.62
	B	121	1.55
July	A	282-	16.69+
	B	16-	1.33
August	A	306	16.69+
	B	24	1.58
September	A	284	16.69+
	B	65	1.40
October	A	1007	16.53
	B	819	1.39
November	A	998	16.50
	B	846	1.39
December	A	1904	16.50
	B	1824	1.56
January 1979	A	2418+	16.54
	B	2217+	1.67+
February	A	1032	16.00-
	B	88	1.27-
March	A	667	16.60
	B	447	1.48
April	A	395	16.60
	B	225	1.41

The highest values are designated by (+) and the lowest by (—).

and winter, respectively, as well as in the spring of 1979 (April). Water samples were collected from three depths at each station to represent the surface, middle and bottom water layers. The surface samples were collected about 20 cm beneath the surface to avoid influence of floating matter. The bottom samples were taken 40 cm above the river bottom.

Transparency was measured, using a white enamelled Secchi disc (20 cm). The readings represent the averages of depth at which the disc disappeared and reappeared after lifting upward (WELCH, 1948). For the determination of suspended matter, 500 ml of each well shaked water sample were filtered, using a dry weighed filter paper of Whatman 41 (FRASCHINA, 1949). The residue retained on the filter paper, after removing the salts by several washings with distilled water, represents the suspended matter. Determination of total residue (TR), fixed total residue (FTR) and volatile matter (VM) was carried out according to American Public Health Association (1965). A known volume of well shaked unfiltered water sample was evaporated to dryness in a clean dry weighed porcelain dish on a water bath. The increase in weight over that of the empty dish represents the TR. The dish with the TR was ignited for one hour in a Muffle furnace at 550 °C. The increase in weight over that of the empty dish represents the FTR. The VM represents the loss in weight during ignition, i.e. difference between the weights of TR and FTR.

RESULTS

Data on the discharge and levels of Rosetta branch during 1978-1979 were obtained from Irrigation Department, which has two stations at Al-Khairiia Barrage and Edfina Barrage (Table I). The discharge recorded at Al-Khairiia Barrage in April 1978 was higher than that in October and April 1979. The lowest and highest discharge reached 282 and 2,418 million m^3 in July and January, respectively. The discharge at Edfina Barrage

decreased sharply from 1,193 million m³ in April 1978 to a minimum of 16 million m³ in July and then increased gradually to a maximum of 2,217 million m³ in January. The discharge was higher in April 1978 than in October and April 1979. The water levels at Al-Khairiia Barrage fluctuated between 16.00 m a.s.l. in February and 16.69 m a.s.l. in July, August and September. They ranged at Edfina Barrage from 1.27-1.67 m a.s.l. in February and January, respectively.

The current velocity was measured from 25.1.1979-6.2.1979 (winter closing of irrigation canals). The lowest and highest current velocities measured during that period were 0.350 and 0.597 m/sec., respectively. The average current velocity, calculated from measurements on four days, in January was 0.509 m/sec. and that in February 0.450 m/sec. (Table II).

TABLE II

Variations of the current velocity at Al-Khairiia Barrage during the period from 25.1.1979-6.2.1979 (winter closing of irrigation canals)

Variations de la vitesse de l'écoulement au barrage de Al-Khairiia du 25/1/1979 au 6/2/1979 (fermeture des canaux d'irrigation en hiver)

Date	Current velocity (m/sec.)	Date	Current velocity (m/sec.)
25.1.1979	0.597 +	1.2.1979	0.497
29.1.1979	0.479	3.2.1979	0.576
30.1.1979	0.499	5.2.1979	0.350 -
31.1.1979	0.461	6.2.1979	0.378
Average	0.509		0.450

The highest values are designated by (+) and the lowest by (—).

Transparency

The Secchi disc readings obtained along Rosetta branch of the Nile during the study period are shown in Fig. 2. In general, the transparency values varied obviously between the different stations in each season. The readings ranged from an absolute minimum of 33 cm at station II in January to an absolute maximum of 251 cm at station X in April 1979. At each station the transparency values varied remarkably in the different seasons. The lowest values were obtained in January at all stations except XII-XIV. The highest values were recorded in April 1978 at stations I-IV, XI and XIV and in April 1979 at station V-X. The readings were higher in October than in July at the majority of stations. The transparency values showed considerable wide range of fluctuations during the period of study.

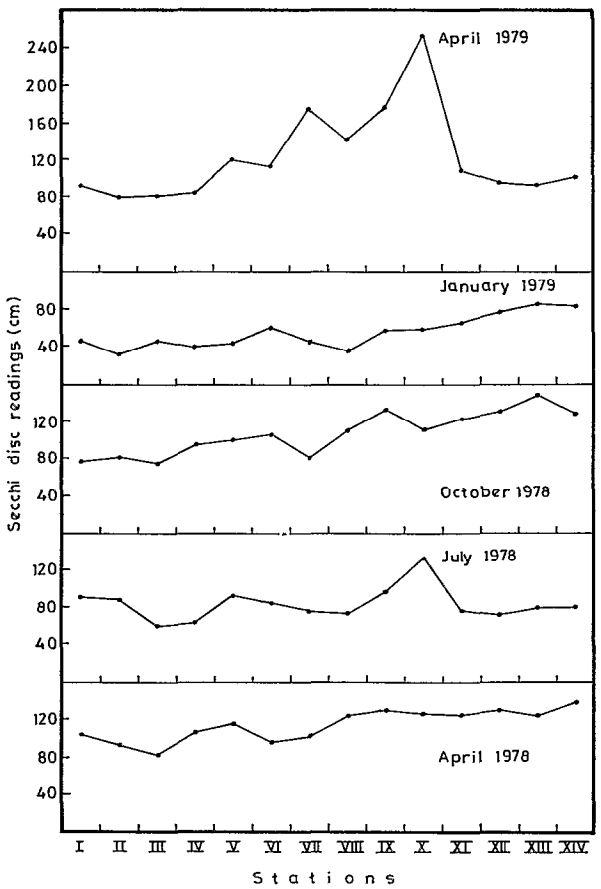

FIG. 2. — Seasonal variations of Secchi disc readings in Rosetta Branch during 1978-1979

Variations saisonnières des mesures effectuées par le disque de Secchi dans la branche de Rosette en 1978-1979

The regional average values of transparency (averages of all seasons at each station) varied from 69 cm at station III to 136 cm at station X (Table III). The seasonal average values (averages of all stations in each season) fluctuated between a minimum of 55 cm in January and a maximum of 122 cm in April 1979. The seasonal average was higher in April 1978 than in July and October (Table IV). The average value of transparency recorded along Rosetta branch during the study period amounted to 96 cm. This value is noticeably lower than the average found along Damietta branch of the Nile (117 cm) by ABDEL-MOATI (1981).

TABLE III

Regional average values of transparency (cm), suspended matter, total residue, fixed total residue and volatile matter (mg/l) in Rosetta Branch during 1978-1979

Valeurs moyennes régionales de la transparence (cm), de la matière en suspension, du résidu total, du résidu après ignition et de la matière volatile (mg/l) dans la branche de Rosette en 1978-1979

Stations	Average station depth (m)	Transparency	Suspended matter	Total residue	Fixed total residue	Volatile matter
I	6.4	83	93	311	254	57
II	4.1	75	90	410	340	70
III	3.2	69	101	371	308	63
IV	8.0	78	83	344	282	62
V	8.7	94	82	372	307	65
VI	6.8	92	64	367	305	62
VII	5.1	96	76	342	281	61
VIII	11.5	97	87	332	275	56
IX	9.8	118	60	372	308	64
X	7.6	136	64	3,508	2,917	591
XI	2.9	99	74	6,099	4,967	1,132
XII	6.1	100	59	13,322	11,106	2,216
XIII	8.8	106	65	15,411	12,593	2,818
XIV	7.0	106	52	20,081	16,402	3,679

TABLE IV

Seasonal average values of transparency (cm), suspended matter, total residue, fixed total residue and volatile matter (mg/l) in Rosetta Branch during 1978-1979

Valeurs moyennes saisonnières de la transparence (cm), de la matière en suspension, du résidu total, du résidu après ignition et de la matière volatile (mg/l) dans la branche de Rosette en 1978-1979

Months	Transparency	Suspended matter	Total residue	Fixed total residue	Volatile matter
April 1978	114	58	3,962	3,284	678
July	83	52	7,276	5,946	1,330
October	107	67	4,418	3,631	787
January 1979	55	130	420	348	72
April	122	69	5,940	4,879	1,060

Suspended matter (SM)

The average values of SM for all depths at each station are shown in Fig. 3. The values of SM increased with depth at majority of the stations in April 1978, 1979 and January. In July and October, the values showed irregular vertical variations and increased or decreased with depth. The increase with depth was pronounced at certain stations, where the differences between the surface and bottom values were considerable. Similarly, ABDEL-MOATI (1981) observed a general increase with depth in the values of SM in Damietta branch.

In general, the average values of SM varied obviously along Rosetta branch in each season, particularly in January. The averages ranged from 30 mg/l (absolute minimum) at station XII in April 1978 to 189 mg/l (absolute maximum) at station I in January. The average values of SM

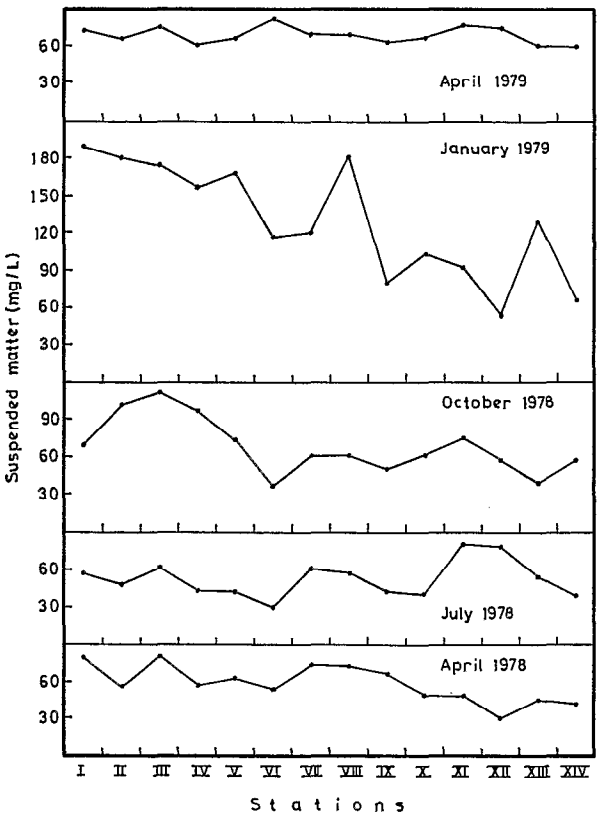

FIG. 3. — Seasonal variations of the average values of suspended matter in Rosetta Branch during 1978-1979

Variations saisonnières des valeurs moyennes de la matière en suspension dans la branche de Rosette en 1978-1979

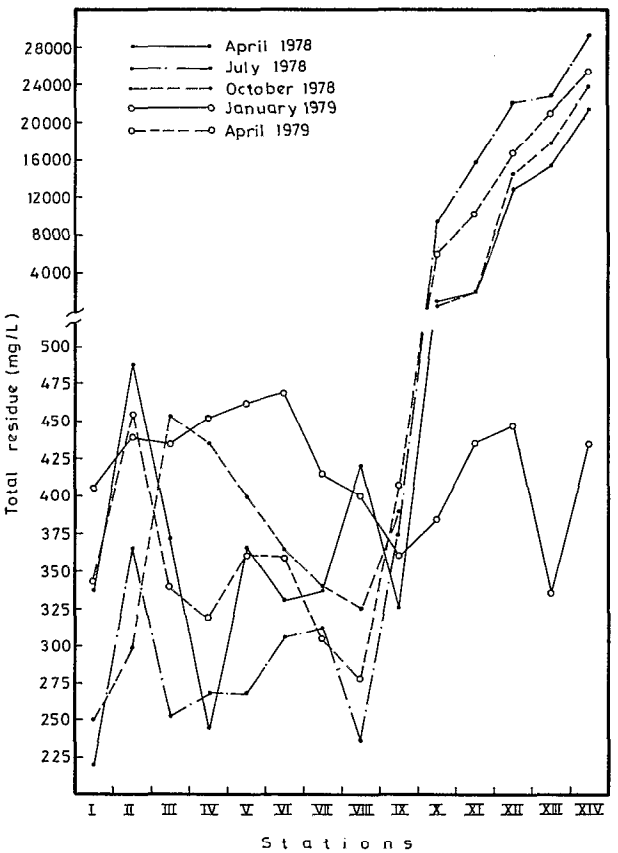

FIG. 4. — Seasonal variations of the average values of total residue in Rosetta Branch during 1978-1979

Variations saisonnières des valeurs moyennes du résidu total dans la branche de Rosette en 1978-1979

varied noticeably in the different seasons at each station. The lowest average values were obtained in July at most stations. The highest averages were recorded in January at all stations except XII. The average values found in April 1978 were lower than those in April 1979 at most stations. The average values of SM showed a wide range of variations during the study period.

The regional average values of SM fluctuated between 52 and 101 mg/l at stations XIV and III, respectively (Table III). The seasonal average values varied from 52 mg/l in July to 130 mg/l in January. The seasonal average obtained in April 1979 was higher than those in October and April 1978 (Table IV). The average value of SM attained along Rosetta branch during the period of investigation amounted to 75 mg/l. This value is much lower than the average obtained along Damietta branch of the Nile (297 mg/l) by ABDEL-MOATI (1981).

Total residue (TR)

The average values of TR for all depths at each station are shown in Fig. 4. In general, the values of TR at the different stations increased with depth in all months. Such increase was generally remarkable in the region from station X-XIV in all months, except in January. A constant concentration of 324 mg/l was found throughout the whole water column at station IX in April 1978.

The variations of the average values of TR between station I and IX were slight in each month. At station X-XIV, the average TR values increased sharply from station X towards the mouth (station XIV) in all months, except in January. The average values of TR varied from an overall minimum of 221 mg/l at station I to an overall maximum of 29,286 mg/l at station XIV in July. The variations of the average values of TR in the different seasons were slight at station I-IX and remarkable at

station X-XIV. The lowest and highest values at these latter stations were obtained in January and July, respectively. The average values were generally higher in April 1979 than in April 1978 and October and in October than in April 1978 at most stations. The average values showed a pronounced wide range of variation during the study period.

As shown in Table III, the minimum and maximum regional average values were 311 mg/l (station I) and 20,081 mg/l (station XIV), respectively. The seasonal averages fluctuated between 420 mg/l in January and 7,276 mg/l in July (Table IV). The average TR obtained along Rosetta branch during the period of investigation amounted to 4,403 mg/l. This value is much lower than the average value found by ABDEL-MOATI (1981) along Damietta branch of the Nile (21,004 mg/l).

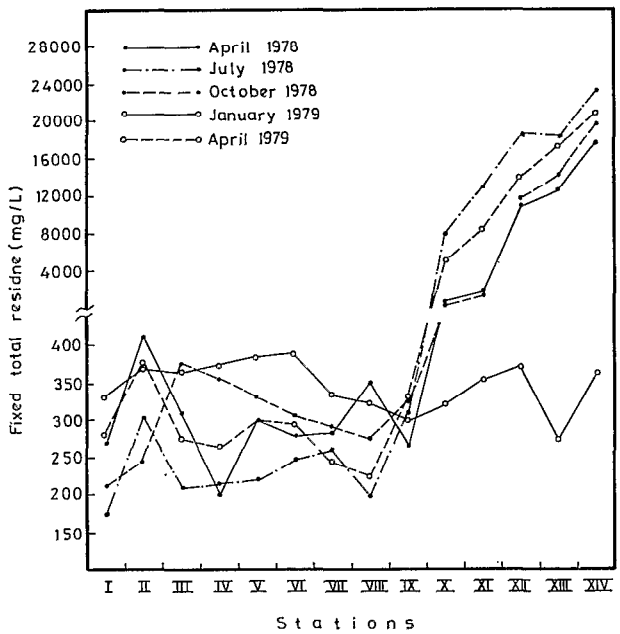

FIG. 5. — Seasonal variations of the average values of fixed total residue in Rosetta Branch during 1978-1979

Variations saisonnières des valeurs moyennes du résidu après ignition dans la branche de Rosette en 1978-1979

Fixed total residue (FTR)

The average values of FTR for all depths at each station are given in Fig. 5. The values increased with depth at the majority of stations. This increase was generally remarkable at station X-XIV in all months, except in January.

In general, the average values of FTR varied slightly from station I-IX in each season. From station X towards the mouth, the averages increased,

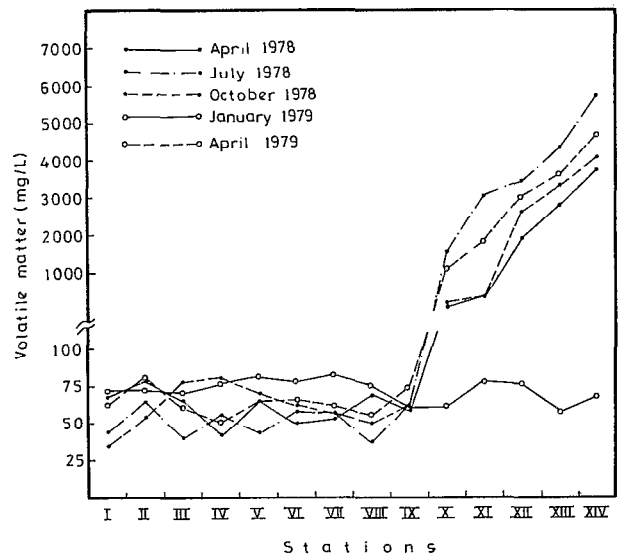

FIG. 6. — Seasonal variations of the average values of volatile matter in Rosetta Branch during 1978-1979

Variations saisonnières des valeurs moyennes de la matière volatile dans la branche de Rosette en 1978-1979

in general, enormously and reached maximum values at station XIV in all months, except in January. The average values varied from 176 mg/l (absolute minimum) at station I to 23,496 mg/l (absolute maximum) at station XIV in July. The variations of the average FTR values in the different seasons at station I-IX were slight, whereas those at station X-XIV were considerable. At these downstream stations, the lowest average values were recorded in January and the highest in July and the averages in April 1979 were higher than those in October. The average values obtained at station I-VIII were higher in January than in July. The average values of FTR showed a wide range of variation during the period of investigation.

The regional average values of FTR ranged from 254 mg/l at station I to 16,402 mg/l at station XIV (Table III). The seasonal averages fluctuated between a minimum of 348 mg/l in January and a maximum of 5,946 mg/l in July. The seasonal average of April 1979 was higher than those of April 1978 and October (Table IV). The average FTR obtained along Rosetta branch during the study period was 3,618 mg/l. This value is considerably lower than the average found along Damietta branch of the Nile (9,115 mg/l) by ABDEL-MOATI (1981).

Volatile matter (VM)

The average values of VM for all depths at each station are shown in Fig. 6. The values of VM

increased generally with depth at most stations. Such increase was pronounced at station XI-XIV in all months, except in January.

In each season, the average values of VM varied slightly from station I-IX and remarkably, except in January, between station X and XIV. The average values varied from 37 mg/l (overall minimum) at station VIII in July and I in October to 5,790 mg/l (overall maximum) at station XIV in July. The variations of the average values of VM in the different seasons were slight at station I-IX and generally considerable at X-XIV. At these latter stations, the lowest and highest averages were found in January and July, respectively. The average values in April 1979 were generally higher than those in April 1978, July and October at most stations. The average values showed a wide range of variation during the study period.

The regional average values of VM fluctuated between a minimum of 56 mg/l at station VIII and a maximum of 3,679 mg/l at station XIV (Table III). The minimum and maximum seasonal average values were 72 mg/l (January) and 1,330 mg/l (July), respectively (Table IV). The average VM found along Rosetta branch during the period of investigation amounted to 785 mg/l. This value is exceedingly lower than the average value given by ABDEL-MOATI (1981) for the whole Damietta branch of the Nile (11,901 mg/l).

DISCUSSION

Transparency

From Fig. 2, the variations of transparency along Rosetta branch in each season were pronounced, particularly in April 1979. A similar observation was also found by ABDEL-MOATI (1981) in Damietta branch of the Nile. The Secchi disc readings were minimum at station II in January and April 1979 and station III in April 1978, July and October. This is probably due to the shallowness of water and the sandy silty bottom at these two locations. The transparency values were generally higher in the estuarine region (station X-XIV) than in the rest of Rosetta branch. This is attributed mainly to the effect of the entering sea water, which acted as a barrier slowing down the movement of the river water and permitting the floating particles to settle.

As shown from Fig. 2, the Secchi readings showed at each station remarkable variations in the different seasons, particularly at station X where the values ranged from 58 cm in January to 251 cm in April 1979. The seasonal average Secchi disc values ranged from 55 cm in January to 122 cm in April 1979. The lowest transparency in January is due to the relatively high turbidity, resulted from the high discharge (Table 1) and the increase in the current velocity (Table II). EGBORGE (1972, 1974) found for River Oshun that during the rainy season the river water level, current velocity and discharge were high, whereas transparency was low.

VATOVA (1961) expressed the photosynthetic zone as a distance from surface down to a depth where the Secchi disc becomes invisible multiplied by a factor of 3.3. RUTTNER (1931), SREENIVASAN (1970) and SAAD & ANTOINE (1978) observed a direct relationship between phytoplankton production and transparency changes. The present Secchi disc data and those on phytoplankton did not show such direct correlation (SAAD & ABBAS, in press 2).

Suspended matter

The SM consists of mineral particles (clay, silt, sand..., etc.) and biogenic parts, including phytoplankton, zooplankton and detrites (ZEITSCHEL, 1970). In the Rosetta branch, the SM is due mainly to the mineral particles. The minimum seasonal average of SM (52 mg/l) obtained in July with the maximum density of phytoplankton and the maximum seasonal average of SM (130 mg/l) recorded in January with the relatively low phytoplankton density proved that phytoplankton plays a minor role for SM (SAAD & ABBAS, in press 2). WELCH (1952) stated that the silt, detrites and other nonliving materials constitute the major sources of turbidity in streams.

The variations of the average values of SM exhibited between different stations in each season were pronounced, particularly in January. These variations might be attributed to certain local conditions, such as the changes in current velocity and nature of the bottom sediments.

The variations of the average values of SM at each station in the different seasons were noticeable, particularly at station II where the averages ranged from 47 mg/l in July to 181 mg/l in January. According to PENNAK (1971), Rosetta branch, based on the seasonal average data, can be classified as slightly turbid-turbid. From Table I and Fig. 3, it is clear that SM is directly related to water discharge. The minimum seasonal average of SM was obtained in July during a period of low discharge and the maximum seasonal average was found in January during a period of high discharge. In addition, to the high discharge in January, rainfall might play a role in increasing the suspended load by increasing the land runoff (ABDEL-MOATI, 1981).

An inverse relationship was found, generally, between transparency and the surface values of SM. This inverse correlation was more pronounced in January, when the maximum seasonal average of

SM was accompanied by the minimum seasonal average of transparency. Such inverse correlation between these two variables was also noticed by ABDEL-MOATI (1981) in Damietta branch of the Nile.

Total residue, fixed total residue and volatile matter

TR and FTR represent mainly the total amounts of suspended matter and dissolved solids (SAAD, 1976). The values of TR and FTR increased, generally, with depth. This increase was considerable at station X-XIV in all months, except in January. At station I-IX, the increase of TR and FTR near the bottom is due principally to the increase in the amounts of suspended load stirred up from the bottom with water movements. ABDEL-MOATI (1981) gave a similar explanation for the increase in the values of TR and FTR near the bottom of Damietta branch. SAAD (1973) attributed the higher values of TR found at the bottom of the Nozha Hydrodrome to the stirring up of the bottom material by wind action. At station X-XIV, the entering sea water represents the major source of TR and FTR.

As shown in Fig. 4 and 5, the variations of the average values of TR and FTR in the different seasons between stations I and IX were slight, whereas from station X-XIV they were remarkable. At the estuarine stations, the TR and FTR increased gradually in accordance with the corresponding increase in the chloride content contributed by sea water (ABDEL-MOATI, 1981). This gradual increase of TR and FTR along the stretch of the river from station X-XIV was observed in all seasons, except in January.

The seasonal variations of TR and FTR at all stations seem to be produced mainly by changes in the amounts of total dissolved solids, since the quantities of suspended matter obtained in most seasons were more or less identical. The seasonal variations of TR and FTR at station X-XIV coincided with those of chlorosity (SAAD & ABBAS, in press 1).

The VM represents the organic matter and loss due to the partial decomposition of minerals (SAAD, 1976), water of hydration and probably burning of carbonaceous matter (CUSHING, 1964). It is clear from Fig. 6 that variations of the average values of VM along Rosetta branch in the different seasons were similar to those of TR and FTR, i.e. slight at station I-IX and considerable at station X-XIV. At the latter estuarine stations, the major bulk of VM found in all seasons, except in January, seems to be produced by partial decomposition of minerals.

Manuscrit reçu au Service des Éditions de l'O.R.S.T.O.M. le 16 mai 1984

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