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# ETMA PROGRAM / SUDAN

Environmental Monitoring
Baseline and trend analysis reports

(3)

## BLUE NILE RIVER
« From the Ethiopian Border to Khartoum »

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# BASE LINE DATA AND POTENTIAL; PHYSICAL; CHEMICAL AND BIOLOGICAL INDICATORS.

Study Area : BLUE NILE RIVER
KHARTOUM-SENNAR STRETCH.

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# I. INTRODUCTION

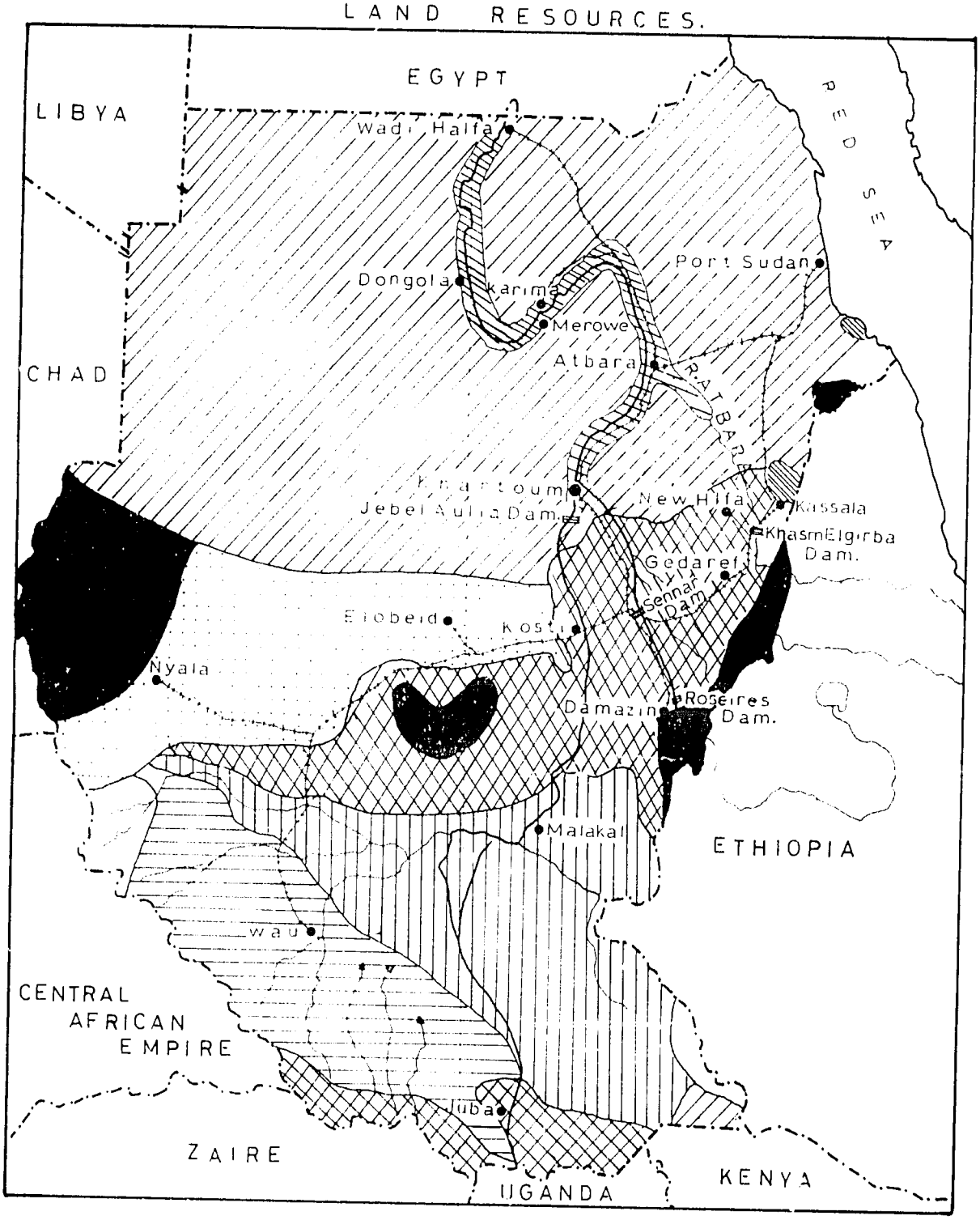
Although the River Nile is one of the largest in the world it is not the best known river. Not all parts of the Nile system within the Sudan have been studied equally well and most of the studies carried out are rather incomplete. Unfortunately no detailed programme of chemical and biological studies on Sudanese rivers had been carried out before in order to obtain sufficient knowledge of the ecology of our river which will help in pollution control. Determination of the biological effects and indicators of different types of pollution under Sudanese conditions are largely neglected.

During the past sixty years the Nile particularly the Blue Nile has undergone hydrological reconstruction changing its regime. Sennar Dam was constructed in 1925, and Roseires Dam was built in 1966 across the Blue Nile. Gebel Aulia Dam was completed in 1937 across the White Nile. These dams no doubt should have their influence upon the ecology and productivity of these rivers by creating reservoirs in which current velocity is much reduced and lake conditions are initiated. The Nile is used over a large part of its length by towns, industry or agriculture. It

seems beyond question that the best prospect of increasing the country's wealth lies in the further exploitation of the Nile waters. Map 1. Environmental scientists are increasingly alarmed by the fact that the Nile may suffer from contamination as a result of population and industry explosion. The present writers agree with Hammerton (1976) that even a mild degree of eutrophication from industrial and agricultural development could have a serious effect on the Nile because of the high temperature and high radiation inputs. It is thus obvious that the control of pollution has to be rigid and that a detailed programme to determine indicators of environmental changes in the Nile should be initiated.

The present report describes the scope, nature and results of research carried out on the Nile system within the Sudan since the turn of this century. Information reviewed in this report, includes previously unpublished data, material contained in accepted theses and data extracted from published papers. These materials will serve as the baseline upon which the impact of any future effect can be assessed and also will provide some information on

# LAND RESOURCES.




Arid & Semi arid Pediplain & Hill Soils.

Qoz Sands.

Gentral Clay Plain

Flood Plain Clays

Alluvia

Semi-Humid Residual Soils (Ironstoneregion)

Miscellaneous Hilly & Mountainous Regions.

0 100 200 300 Km.

effects of environmental changes which had occurred in recent times.

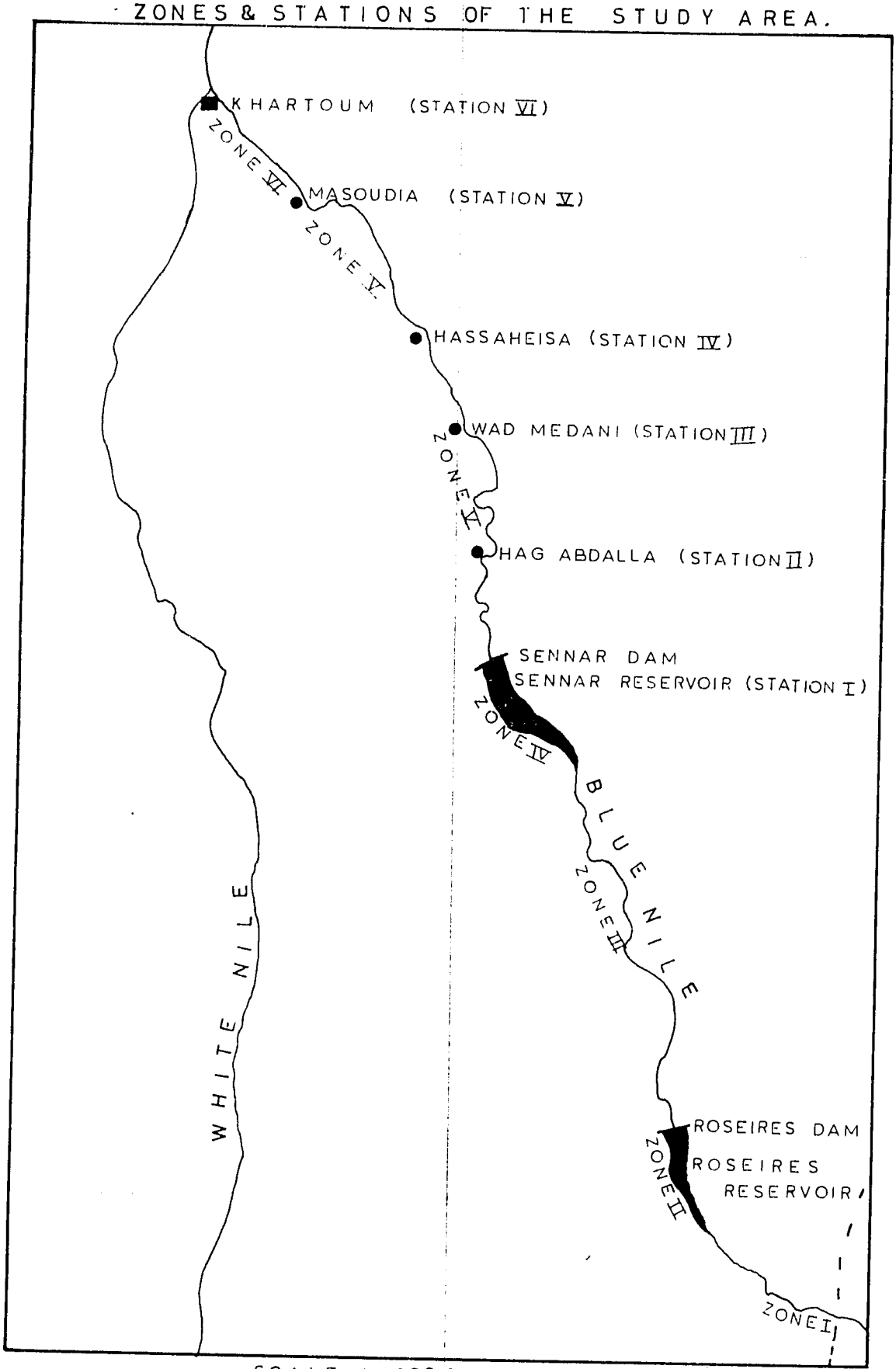
The Nile Study Group is one of seven groups monitoring indicators of environmental changes in the Sudan. This monitoring is part of ETMA Programme (Environmental Training and Management in Africa) which is a collaborative project that works with African institutions to support environmental training and resource management.

Since the River Nile System comprises very large distances, the Blue Nile River was chosen to carry the studies of indicators of environmental changes. Along the Blue Nile the area most subject to changes (Khartoum-Sennar) was selected as the study area. Increase in: population, impoundment of water dams, location of factories along the Blue Nile together form criteria for selecting the study area.

II. Spatial and temporal transects

For the purpose of the present evaluation the Blue Nile is divided into six zones (Map 2 ) along its length within the Sudanese border; thus:

ZONES & STATIONS OF THE STUDY AREA.




SCALE: 1:2,000,000

Zone I:

A zone of natural river flow not affected by the back water of Roseires dam. This zone extends from Sudanese border with Ethiopia to Roseires reservoir.

Zone II:

The Roseires Reservoir with a back water effect extending 100 km upstream.

Zone III:

A zone of free river flow not affected by the back water of Sennar dam. It extends from Roseires dam to Sennar reservoir.

Zone IV:

The Sennar Reservoir with a back water effect extending 140 km upstream.

Zone V:

A zone of free river flow extending from Sennar dam to a few km south of Khartoum.

Zone VI:

Khartoum area

Hydrobiological investigations of the Nile began with casual observations some 80 years ago. For the purpose of this report this period of time can be

divided into three "eras". Since dams have profound influence upon productivity and ecology of rivers the three eras were marked by the construction of dams across the Blue Nile. Thus:

First era:

The period ending in 1925 before the completion of Sennar dam.

Second era:

The period beginning with the formation of Sennar reservoir in 1925 and ending in 1966 before the completion of Roseires dam.

Third era:

The period beginning with the formation of Roseires reservoir in 1966 to present date.

III. The study area

Physical background of the Blue Nile System

The Nile is the second longest river in the world flowing from its distant source at lake Victoria (latitude 0° 30'N) on the Central African Lake Plateau for about 5695 km to its mouth at the Mediterranean Sea (latitude 31°N). The second source of the system is lake Tana on the Abyssinian Plateau and which lies 4600 km away from its mouth.

The Nile system consists of two main rivers: the White Nile which emerges from the former lake and the Blue Nile which comes out from the latter one. The two rivers meet at their confluence "Mogren" at Khartoum. From Khartoum the two Niles constitute jointly the Main Nile. The topography and hydrology of the Nile have been extensively studied by Hurst (1950,1952) Hurst & Phillips (1932-1945) and Hurst et.al. (1954). It is sufficient to recapitulate here.

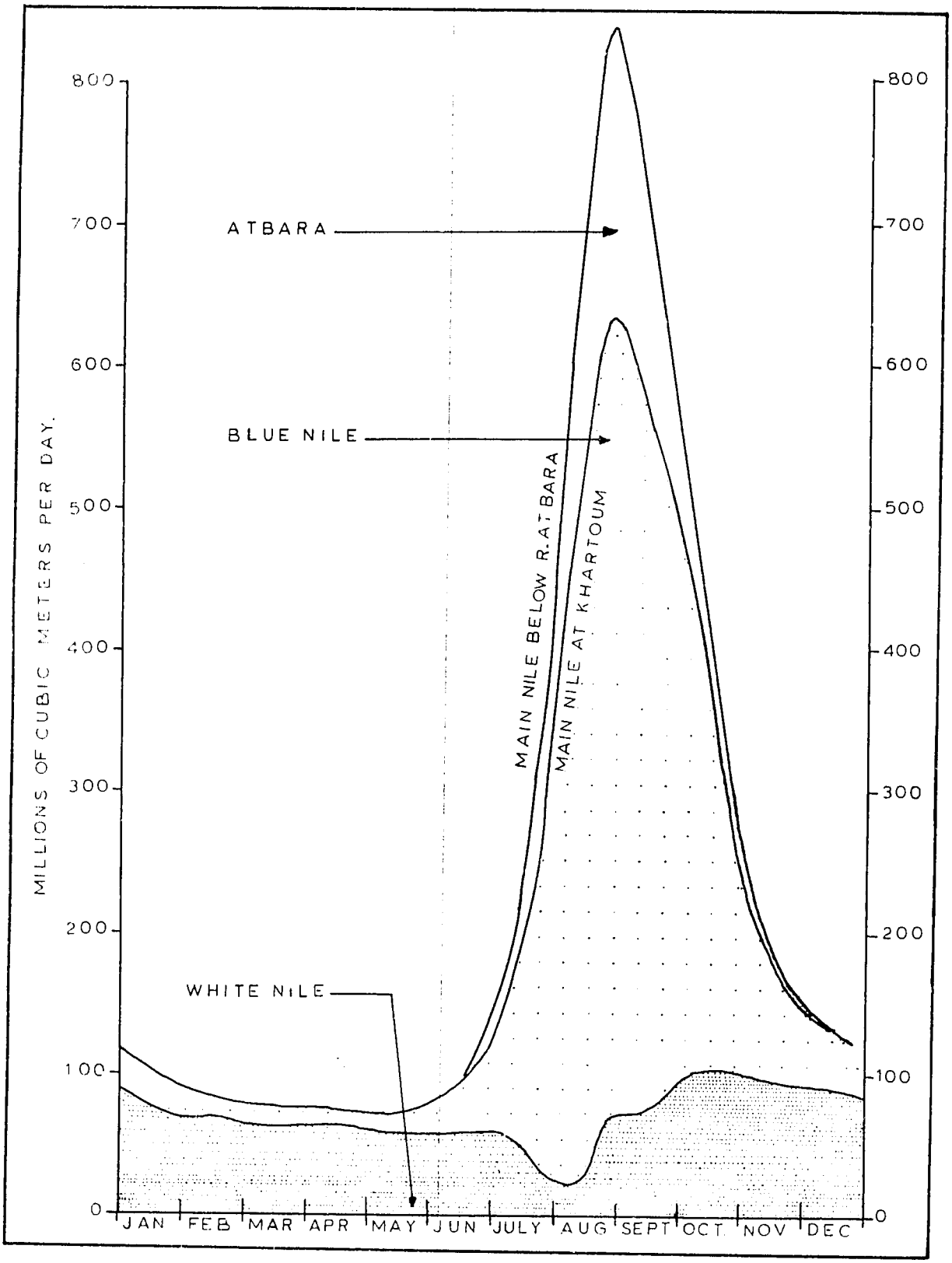
The Blue Nile

The Blue Nile flows out of lake Tana (altitude 1800 m; area 3100 sqm) at latitude 12° 30'N over a series of rapids and quickly descends into a deep gorge until it enters the Sudan plain south of Roseires at latitude 12°N. Between Lake Tana and the Sudan plain the Blue Nile receives many tributaries of torrential nature, which supply most of the river. The annual discharge from Lake Tana is only 7% of the corresponding water reaching Khartoum. The flood occurring annually at Khartoum (late June-October) is mainly due to the torrential rains on the Abyssinian Plateau which drain into the course of the

Blue Nile by these tributaries. The river is not navigable anywhere, except for short stretches, until well within the Sudanese boarder. In the lower part of its course in the Sudan, the Blue Nile receives two tributaries: the Dinder and the Rahad Rivers, both flowing down the Abyssinian Plateau. The contribution of these two tributaries is little, their combined annual discharge barely exceeding 8% of that of the main river. The contribution of these tributaries is only noticeable during the rainy season on the Abyssinian Plateau. No other tributary drains into the river until it joins the White Nile. (Map 3).

The Blue Nile has the characteristic of mountain streams. For instance its course is generally deeper and its banks are steeper than those of the White Nile. At the peak of its flood (August/ September) the Blue Nile at Khartoum may rise to more than 5m above its lowest level of May. Huge amounts of silt are carried annually by the Blue Nile, exclusively during the flood period (late June-October) transporting a total of 1[illegible]-1.50x10$^{6}$ tons of silt annually.

DISCHARGES OF THE NILE & ITS MAIN TRIBUTARIES.
AVERAGE 1912 – 1968.



The natural flow of the Blue Nile has been altered by artificial hydrological regimes within the Sudan. Two dams have been built across the Blue Nile: Sennar dam and Roseires dam.

Sennar dam

Sennar dam (360 km upstream Khartoum) was built in 1925. The dam holds $1x10^9 m^3$ of water producing a backwater effect for 140 km. The reservoir has an area of 160 $km^2$, maximum depth 17m and mean retention time of 32 days. Sennar dam was built to store water for irrigation from February to April.

Roseires dam

This dam (650 km upstream Khartoum) was completed in October 1966. The dam holds $3x10^9 m^3$ of water, producing a backwater effect for 100 km. The reservoir has an area of 290 $km^2$ and maximum depth of 45m.

Since the Blue Nile is abundantly rich in silt during the flood, a special system is used when its water is stored. The filling of the reservoirs behind the two dams is carried out in two stages in order to avoid adverse silt deposition. An initial

filling is carried out during the flood period (July-September) when most of the water passes through the dams. When the flood subsides the final filling of both reservoirs is completed. Usually by end of November the reservoirs reach their full capacities. The water in Sennar reservoir is gradually released for irrigation purposes until April-May when little re[illegible] and conditions of free river flow return. Roseires dam is utilized in regulating the level in Sennar reservoir.

Rainfall

On the Abyssinian Plateau the rain is heavy although it varies with latitude and altitude. In general the average annual rainfall over the plateau is 1200 mm. There is a well marked rainy season on the Abyssinian Plateau from June-September with the maximum rainfall occurring at about the end of July. On the other hand the amount of rainfall at Khartoum district is much smaller with an annual average of about 148 mm, most of the rain falling within the period July-September.

IV. Indicators of environmental change

Indicators of environmental change chosen in this work are grouped in 3 categories:-

A. Physical indicators

B. Chemical indicators

C. Biological indicators

A. Physical indicators:

1. Current velocity/Discharge
2. Temperature
3. Transparency/Turbidity
4. Suspended matter.

B. Chemical indicators:

5. Conductivity
6. PH
7. Disolved Oxygen
8. Biological oxygen demand B.O.D.
9. Chemical oxygen demand C.O.D.

Plant nutrients

10. Phosphate - Phosphorus
11. Nitrate - Nitrogen
12. Ammonia - Nitrogen

Heavy Metals

13. Copper
14. Zinc
15. Iron
16. Nickel
17. Lead.

Major ions

18. Calcium

19. Magnesium

20. Potassium.

21. Sodium

Organic pollutants

22. Herbicides

23. Fungicides

24. Insecticides.

C. Biological Indicators

25. Phytoplankton

26. Zooplankton

27. Bacteria

28. Macrophytes

A- Characteristics of Physical Indicators

1- Discharge/Current Velocity

$$D = V \times A$$

D = River discharge at a certain point

V = Current velocity

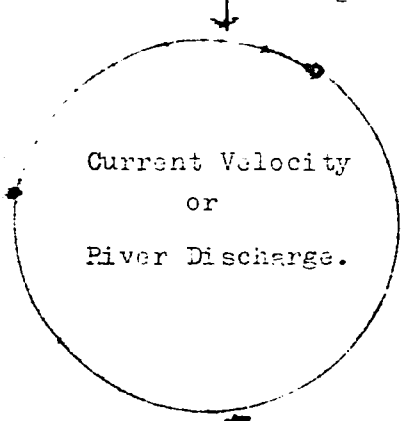
A = Cross sectional area of a certain point.

The current or dischage in any river system plays a major role in determining the aquatic river habitat, which in turn determines the type of biota which live on it (Fig.I).

**Fig. 1.** Current Velocity or River Discharge - Indicator of Environmental Change.

Factors Affecting Indicator → Indicator - 1 - of Environmental Change → Indicator's Effects Reflected on :

1. Nature of gradient.
2. Surface of the bed.
3. Wind (in very large slow-flowing rivers).
4. Distance from waterfall.
5. Morphology of the channel.
6. Seasonality of Rainfall.




1. Distribution of living biota.
2. Silt transport.
3. Temperature mixing.
4. Suspended matter

Impact of Man on Indicator

1. Impoundments.
2. Water withdrawal.
3. Return water uses.
4. Flood control.

2. Temperature

Temperatures of running waters are more variable than are those of standing bodies of water, but their absolute range is smaller. Seasonal variation as well as diurnal variations in temperatures of rivers and streams are two characteristics of all rivers. This variation is due to the many micro factors which operate to determine the value of temperature.

Direct and indirect activities of man interfere to change the temperatures of natural waters. Most obvious of these is thermal pollution, where water is used in cooling various industrial processes and operations in addition to being used for waste disposal. Fig. 2 summarizes the factors determining the temperatures of water bodies and the influence of temperature on other systems.

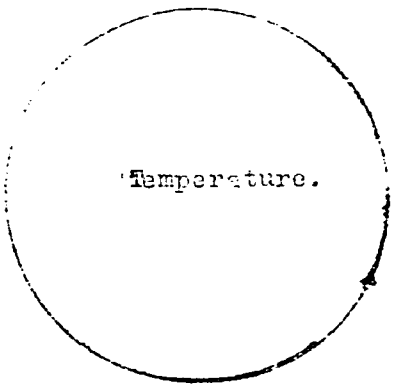
3. Transparency/Light penetration

The principal importance of light to aquatic ecosystems is that light serves as the energy source to support primary food production. Sunlight is rarely limiting to primary production in surface waters. Often less than 1% of sunlight is changed into photosynthetic products. (Fig.3).

Fig. 2. : Factors Affecting Water Temperature in Rivers.

Factors Affecting Indicator → Indicator of Environmental Change → Indicators Effects Reflected on :

1. Presence of Lakes.
2. Presence of Impoundments along the course of the river.
3. Nature of the source of the river.
4. Presence/Absence of shading vegetation.
5. Latitude/Attitude of the river.
6. Thermal Pollution.
7. Season/Climate.




1. Thermal Stratification.
2. Metabolic rates of aquatic life.
3. Acceleration of rates of synthesis and decomposition of organic matter.
4. Biotic and nutrient cycles.
5. Rate of growth, development and distribution of aquatic organisms.
6. Time and success of spawning.
7. Incidence of diseases.

Fig. 3. Transparency as Indicator of Environmental Change.

Factors Affecting Indicator → Indicator of Environmental Change → Indicator's Effects Reflected on :

1. Absorption by water.
2. Absorption by dissolved or suspended material
3. Scattering by particles.

Transparency
Light
Penetration.

1. Source of Energy.
2. Photoperiodic responses for :
   a) regulation of reproduction.
   b) migration patterns.

4. Suspended matter

Inorganic particulates are materials held in suspension because of water turbulence, or, rarely, unusual chemical conditions. Most important is the suspension of silt and clay. These are derived from transport into the ecosystem. (Fig.4).

B. Chemical Indicators :

5. Conductivity

The electrolytic conductivity of a solution of electrolytes refers to the ability of the solution to carry an electric current. Since electricity is carried in the solution by migration of ions, the conductivity under standard conditions may be expected to bear some relationship to the total ion concentration.

The changes in river water quality brought about by modern civilization can be assessed by the changes in the natural quality of water as measured in this particular case conductivity. e.g. changes in levels of ionic pollutants shall be reflected on changes in levels of total dissolved ionsor conductivity.

On the other hand, since changes in the river discharge(as a result of water impoundment caused by man)affects conductivity, conductivity can be used as an indicator of environmental changes in the river system. (Fig.5).

Fig. 4. Suspended Matter as an Indicator of Environmental Change.

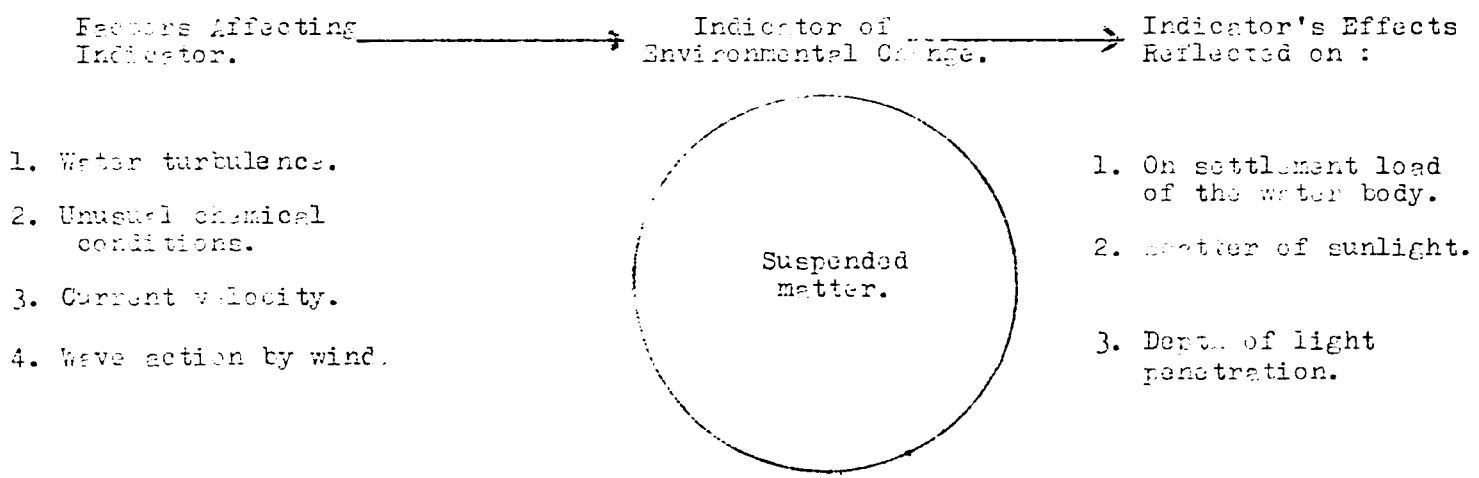
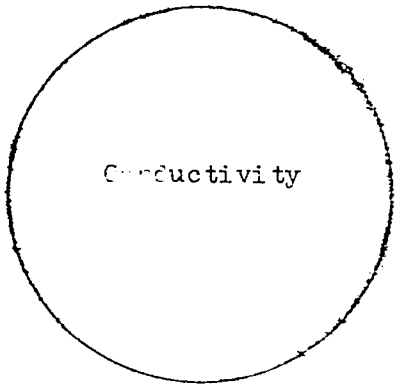


Fig. 5. Conductivity as an Indicator of Environmental Change.

Factors Affecting Indicator → Indicator of Environmental Change → Indicator's Effects Reflected on :

1. Geological Nature of rivers.
2. Rainfall.
3. Discharge.




1. Degree of water salinity.
2. Quality of drinking water.
3. Distribution of animal and plants.
4. Fertility of water.
5. Level of ionic pollutant increase in conductivity indicates increase of ions in the source or discharged in the river.

6. pH

pH is the logarithm of the reciprocal of the hydrogen ion concentration. It is used to express how acid or how alkaline the water is. Most important when considering this parameter are the factors which produce the hydrogen ion concentration rather than its absolute value. Pure water is weakly dissociated and neutral in reaction i.e. $H^+$ and $OH^-$ ions are present in equal proportions. If an acid, base or salt is added to this water, it dissociates and contributes $H^+$ or $OH^-$ ions, thus altering their concentrations in the solution. Fig. 6 lists the different variable factors which cause changes in pH value.

Dissolved Gases

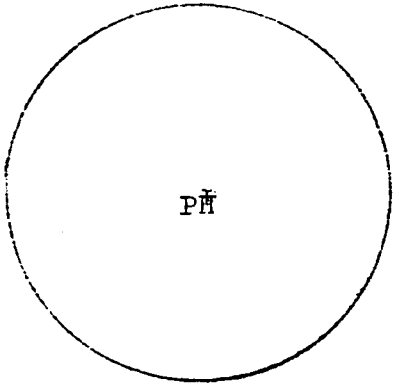
7. Dissolved oxygen

In aquatic environments oxygen is frequently a limiting factor of major importance. Dissolved oxygen enters and leaves fresh water through the photosynthetic or the respiratory activities (or both) of the biota. A litre of water in equilibrium with air at 20°C contains only 6.4 ml of oxygen. This initial scarcity of dissolved oxygen imposed by

**Fig. 6.** PH as an Indicator of Environmental Change.

Factors Affecting Indicator → Indicator of Environmental Change. → Indicator's Effects Reflected on :

1. Addition of acids, bases or salts.
2. Temperature.
3. Rainfall
4. Areas of limestone or other calcium-bearing rocks(bicarbonate amounts).
5. Free $Co_2$ in water.
6. Metabolic activity of the biota.




1. Extremes of PH effects osmotic system of living organisms.
2. Very low PH water often contains large amounts of dissolved organic matter and small amounts of calcium.
3. When the total alkalinity of a habitat is constant, PH change is proportional to $CO_2$ change and is therefore a useful measure of the latter.

physical processes is often intensified by subsequent chemical events. This is particularly true of waters containing large amounts of organic matter. (Bayly and Williams,1973).(Fig.7).

8. B. O. D. (Biological Oxygen Demand)

B. O. D. (mg/l ) is an arbitrary measure of the amount of oxygen taken up by a sample of water incubated at 20°C for a given period (5 days). The amount of oxygen absorbed is dependent mainly on the amount of organic material present(the greater the amount, the larger the demand)but it should be stressed that numerous other factors are of significance. The basic mechanism of the test is similar to that causing deoxygenation in streams polluted by organic wastes: bacteria break down the complex organic materials into simpler substances and in the process remove oxygen from the water. (Bayly and Williams 1973).

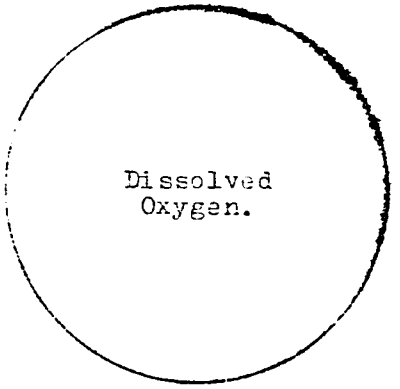
9. C. O. D. (Chemical Oxygen Demand)

Because the time required for completion of a B.O.D. analysis, which may be 5 days, is too great for the test to have application in many situations,

Fig. 7. Dissolved Oxygen as an Indicator of Environmental Change.

Factors Affecting Indicator. → Indicator of Environmental Change → Indicator's Effect Reflected on :

1. Current or Discharge.
2. Temperature.
3. Respiration of plants and animals.
4. Photosynthetic activity of plants.
5. Oxidation breakdown processes.
6. Atmospheric pressure/altitude.




1. Respiration
2. Photosynthesis.

the analysis of C.O,D, which requires 3 hr. or less, is often preferred. The C.O.D. procedure is based on the fact that most organic compounds can be oxidized to carbon dioxide and water by strong oxidants under acid conditions.

Most samples contain a high percentage of material which can be chemically, but not biochemically, oxidized, such samples will have C.O.D. values greater than their B.O.D. values. For example, textile paper, mill and other wastes containing high concentrations of cellulose have a high C.O.D., but a low B.O,D. On the other hand, distillery and refinery wastes have a high B.O.D. and low C.O.D. (CIA CCIO 1972).

Plant Nutrients

Nutrients discharged to a water course promote biological responses which may interfere with some desired uses of the water. Plankton blooms and excessive growths of attached algae such as Cladophora result from the over fertilization of lakes and rivers. The increase in the concentration of nutrients in a body of water is called eutrification and is one of the most important pollution problems (CIA CCIO 1972)

10. Phosphate Phosphorus

Phosphorus is an important constituent of living organisms and often present in them in significant amounts, the quantities of phosphorus occurring in most natural waters are very low. A large proportion of the phosphorus in surface waters originates from municipal waste effluents. A large proportion of this phosphorus comes from household detergents. Also runoff from manured land and urban runoff contribute a considerable amount of phosphorus to water bodies (Maitland,1978).

Nitrogenous Compounds

11. Nitrate-Nitrogen

12. Ammonium-Nitrogen

In addition to dissolved nitrogen molecules, ammonia, nitrate, nitrite and organic compounds are the most abundant forms of nitrogen in natural waters.

Nitrogen is an important component of the cells of living organisms, and the amounts available in a water body, though often small, are of major significance to the nature of the ecosystem. In the majority of natural aerobic waters, most nitrogen

occurs as nitrate. In eutrophic waters with large standing crops of algae or macrophytes, almost all the nitrate present may have been taken up and incorporated in the plant cells. In anaerobic situations, nitrates are often broken down through nitrite and nitrous oxide, occasionally as far as nitrogen itself. In addition, in the absence of dissolved oxygen free ammonia may occur as a result of protein breakdown. (Maitland,1978).

Nitrogen and phosphorus discharged to a watercourse promote biological responses which may interfere with some desired uses of the water. Plankton blooms and excessive growths of attached algae such as Cladophora result from the over fertilization of lakes and rivers. The unaesthetic appearance and odor of plankton growths make waters unfit for recreation and also for other purposes such as municipal and industrial water supply. The quantities of nitrogen and algae in water has been shown to limit algal populations. Both are common pollutants arising from municipal and industrial wastes and agricultural runoff.

Ammonia is favoured as the most reliable single parameter for measuring the quality of river water. Ammonia is present in sewage and some industrial wastes and the higher the degree of purification, the lower the ammonia concentration of the effluents, the ammonia being oxidized to nitrate.

Heavy Metals

Some heavy metals are among the most harmful of the elemental pollutants. These elements, which are in general the metals in the lower right hand corner of the periodic table, include essential elements like iron as well as toxic metals like lead, cadmium and mercury. Most of them have a tremendous affinity for sulfur and attack sulfur bonds in enzymes, thus immobilizing the enzyme. (Manhan 1979).

13. Copper

Copper is an essential trace element, not very toxic to animals, toxic to plants and algae at moderate levels. Its sources are: -

- metal plating
- industrial and domestic wastes,
- mining and mineral leaching.

14. Iron

Iron is an essential nutrient, a component of hemoglobin. It is not very toxic, however can damage materials such as bathroom fixtures and clothing. Its sources are corroded metal, industrial wastes and acid mine drainage.

15. Lead

Lead is a toxic substance. It can cause anemia, kidney disease, disorders of the nervous system and wildlife destruction. Its sources are industry, mining, plumbing coal and gasoline.

16. Zinc

Zinc is an essential element in many metalloenzymes and aids healing of wounds. However it can be toxic to plants at higher levels. Zinc can be a major component of sewage sludge limiting land disposal of sludge. Its sources are: industrial waste, metal plating and plumbing.

Major ions

(17. Calcium 18. Magnesium 19. Potassium and 20. Sodium)

Although major ions are generally not considered indicators of pollution or environmental change, they are parameters of the ambient quality of water and are therefore included in standard analysis procedures.

Calcium ion is a common constituent of natural waters, resulting from the dissolution of limestone, dolmite and gypsum. While not usually important from a physiological standpoint, calcium ion is unique in being desirable in moderate concentrations. Small concentrations are necessary to form a protective coating on the inside of steel pipes and biolers, but high concentrations result in harmful scale formation and waste of soap by precipitation of insoluble fatty acid salts. (Ciacco, 1972).

Unlike calcium, which is physiologically without effect in moderate concentrations, magnesium ion in concentrations above 125 ppm can produce cathartic and diuretic effects. Like calcium, it causes scale formation in pipes and biolers.

Potassium ranks seventh, immediately below and approximately equal to sodium in relative abundance in the lithosphere, but its concentrations in natural waters generally are much lower than sodium ion concentration.

Sodium ion is found in most natural waters and varies in concentrations from 1 ppm or less to several hundred parts per million in surface and ground waters.

22-24. Organic pallutants

Almost all natural waters contain measurable concentrations of organic matter. The organic materials arise through the natural processes of biological synthesis and degradation and through the various activities of man. Most important of these are pesticides, herbicides, insecticides and fungicides. Large quantities of these compounds enter water either directly, in applications such as mosquito control, or indirectly, from the drainage of agricultural lands. Most of the water-pollutant pesticides belong to the major groups of chlorinated hydrocarbons and organic phosphate, of which the latter group is generally more biodegradable.

An example of harmful effects of pesticides upon human being are indicated as the action of DDT. Like many insecticides, DDT acts upon the central nervous system, where it interferes with the transmission of nerve impulses;this might result in severe cases in killing of the target organism. (Manham 1979)

It can be summarized here that pesticides may be corcinopenic or toxic to human beings.

C. Biological Indicators

25. Aquatic Macrophytes

Macrophytes consist principally of the aquatic flowering plants, but also include the aquatic mosses, liverworts and ferns. Three types of macrophytes can be identified:floating, submersed and emersed.

Macrophytes are distributed in various water bodies depending on the physical and chemical characteristics of the ecosystem. Current plays the most important role in distributing plants and it is a determining factor in plant establishment process. The current affects the amount of water supply, the quantity and quality of light, reduces the daily variation between oxygen and carbon dioxide and minimizes temperature fluctuations. Most important of all, however, its effect on the river bed, which is both the source of mineral nutrientand rooting substratum.

In recent years aquatic macrophytes have been used as indicators of pollution. Some macrophytes grow only in clean water; others only in polluted water and yet a third group is indifferent to the pollution (Desougi,1980).

26. Bacteria

Bacteria are very small mostly unicellular organisms. Bacteria species are found in all parts of the world in marine, freshwater and terrestrial environments, as free-living forms, and inside the bodies of many plants and animals. Bacteria are responsible for a large number of plant and animal diseases, including many fatal to man. As such their presence in water can be used as indicator of water quality e.g. suitability for drinking or swimming etc.

Methods to identify and quantify bacteria are many, but the most common test is the Standard Plate Count for the indirect measurement of viable number of bacteria in a water environment. Total Coliform Group Density Test, which indicates the degree of fecal pollution is a standard test of the sanitary quality of water.

27. The Phytoplankton and Macrophytes

Phytoplankton may be regarded as one of the best biological indicators of environmental changes which may occur in bodies of water.

The chemical features of any body of water, as well as its optical properties, influence the biomass diversity, species composition and rates of production of the phytoplankton,(Fig.3).

In terms of biomass, bodies of water with high nutrient levels and high transparency, support dense algal growth. Biomass is obviously the best index of eutrophication and hence of environmental change, since one of the prominent phenomena associated with eutrophication is excessive growth of algae. Algal biomass can be expressed as cell volume or cell carbon by conversion from cell numbers. Chlorophyll a of waters has been demonstrated to correlate well with algal biomass expressed as total volume. Estimation of chlorophyll a is the simplest, most rapid and most widely used method in determining total algal biomass. In the Blue Nile Rzoska, Brook & Prowse (1955), Talling & Rzoska (1967) and Sinada (1972) have made some algal counts in the Blue Nile which can be converted to biomass. Unfortunately no records of chlorophyll a have been made.

The effect of increased nutrient input into a body of water is also reflected on the species diversity of plankton. Here by diversity is meant a

measure of the number of species. A high diversity means that many kinds of algae are present. In low diversity there is a monotony of a few species. A highly eutrophic body of water has a small number of genera and abundant populations whereas a less eutrophic one has a population which consists of a wide range of genera and a small number of each genus. Brook (1954) and later Sinada (1972)presented comprehensive systematic accounts of the phytoplankton. Comparing their accounts to future similar accounts may throw light on changes in diversity.

In terms of species composition, increase in nutrient supply, change in optical properties of the water or the changing the regime of the river is usually accompanied by the appearance of new species which favour the new conditions, and the disappearance of existing species which do not favour the new conditions. Different species of algae undoubtedly have different environmental requirements and it could be that a particular species dominates in a particular body of water because the prevailing conditions favour it. Therefore the appearance of new species of organisms and the disappearance of

existing ones could perhaps be useful indices of environmental changes. species list made by Sinada (1972) during 1966-1970, compared to that made by Brook (1954) during 1951-1953, shows that many species appeared and a few disappeared from the Blue Nile. Such a change in the algal flora of the Blue Nile within the short period of time of about 15 years implies changes in the environment. Similar species list made in the future will help to detect changes in the environment of phytoplankton.

## V. Trend Analysis and Base Line Data :

### 1. Discharge :

The First era (1912-1926)

Discharge data collected from the Ministry of Irrigation and Hydroelectric Power is given in Table 1. The fluctuation in annual discharge ranged between 139 and 157 $mm^3$. Lowest mean value recorded (9.6 $mm^3$) was in April during the period 1917-1921.

Second Era

This period followed building Sennar dam. Fluctuations on annual discharge passing Khartoum lies between 132-156. Lowest monthly mean (10.[illegible]) recorded was again in April during two periods 1927-1931 and 1937-1941.

Third Era

This era followed the building of Rosieres dam. The maximum discharge of water recorded passing Khartoum is 139 $mm^3$. This approximately equals the lowest values recorded for the above mentioned two eras. Lowest annual record is 104 $mm^3$ for the period 1971-1976.

Most significant is the very low discha[illegible] value during 1982 which reached only 71 $mm^3$. On analysing the monthly discharge at Khartoum during the last 3 years (1980-1981 and 1982) one notices that the lowest discharge values in the history of the Blue Nile River are recorded e.g. [illegible] in February 1980,

Table 1.

5 Years Average Monthly Mean Blue Nile Water Discharge in $mm^3$ at Khartoum (Roba Station).

| | | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| First Era. | 1912-16 | 40.6 | 19.0 | 15.3 | 14.2 | 16.8 | [illegible] | 147 | 515 | 471 | 296 | 131 | 77.7 | 149 |
| | 1917-21 | 37.5 | 25.6 | 16.5 | 9.6 | 13.1 | [illegible] | 146 | 485 | 478 | 261 | 119 | 55.7 | 139 |
| | 1922-26 | 38.3 | 24.5 | 16.9 | 10.8 | 13.7 | 30.2 | 187 | 487 | 562 | 326 | 124 | 62.5 | 157 |
| Second Era | 1927-31 | 25.1 | 16.0 | 11.6 | 10.4 | 11.7 | 42.1 | 167 | 477 | 477 | 256 | 98.1 | 51.1 | 137 |
| | 1932-36 | 24.4 | 15.6 | 14.6 | 13.0 | 17.3 | 42.9 | 215 | 558 | 532 | 253 | 83.2 | 42.7 | 151 |
| | 1937-41 | 18.1 | 13.3 | 13.9 | 10.4 | 13.8 | 39.7 | 170 | 493 | 452 | 247 | 80.3 | 35.1 | 132 |
| | 1942-46 | [illegible] | 13.4 | 11.2 | 11.9 | 14.9 | 27.4 | 156 | 532 | [illegible] | 236 | 59.2 | 37.2 | 132 |
| | 1947-51 | [illegible] | 15.4 | 15.3 | 12.4 | 13.4 | 43.2 | 176 | 496 | [illegible] | 252 | 85.6 | 39.2 | 139 |
| | 1952-56 | 27.5 | 17.4 | 15.2 | 16.7 | 17.3 | 40.6 | 199 | 565 | 470 | 291 | 78.2 | 40.4 | 150 |
| | 1957-61 | 23.4 | 15.8 | 12.2 | 12.0 | 14.7 | 33.8 | 174 | 535 | 529 | 287 | 67.0 | 45.7 | 146 |
| | 1962-66 | 19.9 | 14.8 | 11.0 | 13.7 | 18.0 | 27.5 | 136 | 624 | 605 | 349 | 56.2 | 33.8 | 156 |
| Third Era | 1967-71 | 19.6 | 16.3 | 12.8 | 16.6 | 12.0 | 16.8 | 165 | 634 | 498 | 241 | 40.3 | 22.6 | 139 |
| | 1972-76 | 14.2 | 9.3 | 7.7 | 12.2 | 15.6 | 14.3 | 40.2 | 515 | 372 | 203 | 36.2 | 11.5 | 104 |
| | 1980 | 6.00 | 4.0 | 5.0 | 6.5 | 14.5 | 10.5 | 112 | 637 | 394 | 670 | 21.0 | 9.0 | 107 |
| | 1981 | 6.00 | 4.5 | 5.0 | 6.0 | 10.0 | 10.5 | 51.5 | 545 | 521 | 103 | 21.0 | 6.0 | 106 |
| | 1982 | 9.00 | 6.0 | 4.5 | 13.5 | 6.0 | 9.0 | 44.0 | 392 | 205 | 138 | 17.5 | 8.0 | 71 |

Source : Ministry of Irrigation and Hydro-Electric Power.

4.5 $mm^3$ in February 1981 and 4.5 $mm^3$ during March 1983.

The consequences of this lower discharge values are reflected in the appearance of aquatic weeds along the Blue Nile at Khartoum (refer to section on Macrophytes for more details). Also appearance of new islands on the course of the river is another indicator of environmental change caused by the human interference with the natural regime of the river.

2. Temperature

First, Second and third eras

Water temperature in the Blue Nile was found always to be below the air temperature. The value reached depends upon the season of the year and on the time of the day e.g. Dessuqi (1980) recorded a 10° difference between air (30°C) and water (20°C) temperature at (4.40 pm) in January 1979 at Sennar reservoir.

Meghraby (1972) recorded temperature ranges along the Blue Nile from Khartoum to the Ethiopian border to be between 17°C and 30°C during the period 1965-1970.

Thermal stratification is absent over most of the Nile. However, stratification is recorded in dam reservoirs e.g. Roseires reservoir (Hammerton 1972 b and 1972 c). Clear variations along the Blue Nile in temperature are noticed only between the Sudanese plains and Lake Tana in the Ethiopian Plateau.

Diurnal changes in temperature were recorded by Ali (1982) at Khartoum ranging between 23-28°C, with the highest value at 4 pm and the lowest at 6 am (29 April 1982).

Thermal pollution is possible in the Blue Nile, because the Gunied Sugar Factory use Blue Nile water in its cooling process.

3. Transparency/light penetration

First era:

No transparency data on the Blue Nile is available in this period.

Second era:

During this period transparency measurement of 11 meters was recorded at Lake Tana on 12 March 1964. (Talling and Rzoska 1967). Gradual change from flood to low water conditions caused the depth of transparency to increase from 0 to 0.5 m and more (Hammerton, 1976). This observation on seasonal changes in transparency was also recorded at Khartoum by Talling and Rzoska (1967), where transparency during flood season (July, August, September) was nil but gradually started to increase as the flood past.

3rd era:

Hammerton (1972) noted that transparency (Secchi disc) increased from 0.5 to 2.8 in the reservoir of the new Roseries dam with values of 1.8 m at Sennar and 0.6 m at Khartoum. After the dam started functioning, silt began to settle down above the dam; this increased depth of the euphotic zone 670 km downstream to Khartoum.

4. Suspended matter

First era:

Beam (1906) recorded suspended matter in the Blue Nile water at Khartoum to be in the range of 4.1 ppm (in February 1905) and 993.5 ppm (in August 1905). It should be stressed here that information concerning the sediment load of the Nile is limited compared to the wealth of available river discharge data.

Second era:

Measurements were taken on the Blue Nile (1954 and 1955) as part of the studies for Roseires dam by the Ministry of Irrigation. The average annual suspended sediment (million tons) was found to be 134; composed of 62 million tons of Sand and 72 Silt and Clay. Maximum sediment concentration, in mg/l, measured was 10,540 and the minimum was 170.00.

3rd era:

Studies on transport of sediment in the Blue Nile River were carried by El Bedri (1969/1970) during his Ph.D. work. El Bedri calculated that in the 1969 flood period, 69 millions of sediment were transported past Khartoum, of which 40 million tons were sand-silt and the remainder was fine clay particles.

These figures compare with a total of 36 million tons in 1968, composed of 22 million tons of sand and silt and 14 million tons of clay.

The above values are much lower than those obtained in the 1959-60-61 seasons by the hydrologists of the Ministry of Irrigation and H.E.P. It is thought that deposition of silt in the new Roseires reservoir is largely responsible for the lower quantity now past Khartoum.

5. Conductivity

1st era:

Salinity measured as solids in solution in ppm was found higher during the low water flow than high flow (Beam 1906).

2nd era:

Seasonal changes in conductivity at Khartoum were investigated by Talling and Rzoska (1967) during 1954-1956 and were found to be less than two hundred with a few high values (conductivity 200 umho/cm). In September, March and April samples from 1956, 1963 and 1964., the values recorded were respectively; 145, 228 and 238.

Pammerton (1972 a) gave a range of 140-390 umho/cm for values recorded at Khartoum in the period 1965-67.

Maghraby (1972) during 1965-1970 showed the conductivity of the Blue Nile to be in the range of 120-350 umho/cm. This indicates a moderate amount of solutes in solution. The minimum values of conductivity were found during the flood and in October and November. These were followed by an increase towards January and values shot up to a maximum during April-June. Maghraby worked on eleven stations along the Blue Nile. It should be noted here that (1) data between the same month from year to year varied greatly e.g. during January 1969 conductivity was 240 umho/cm and in January 1970 it was 160 umho/cm and (2) No measurements have been made during flood periods, except at Khartoum station.

Dessouki (1980) measured the conductivity at Sennar reservoir in November 1978, he found it to be 145 umho/cm. Ali (1982) gave the value of 235 umho/cm at Khartoum during April.

6. pH

First era:

No data from this period are available.

Second era:

According to Talling and Rzoska (1967), the values of alkalinity indicate that at equilibrium with atmospheric carbon dioxide, pH values of 8.1-8.3 would be expected. (e.g. Talling and Talling 1965). Appreciably lower values, below 8.0 were found only in silt-laden water, and probably correspond to increased concentrations of carbon dioxide resulting from organic decomposition. Much higher pH values, around 9.0, were reached from the photosynthetic consumption of carbon dioxide during the two seasonal maxima of phytoplankton (January-March and May-June). The highest pH value recorded in the Blue Nile, 9.2, was found in January (16.1. 1954, 31.1. 1955) during the first Anabaena maxima.

Third era:

Several researchers have measured the pH value in the Blue Nile water during this period. Their results were as follows:

Hammanton (1976), 7.9-9.1 pH during 1965-67 at Khartoum.

Sinada (1972) 7.5-9.3 pH during 1968-70 at Khartoum.

Meghraby (1972) 7.4-9.4 pH during 1966-70 " "

at eleven stations from Khartoum to the Ethiopian border.

Dessugi (1980)- 8.8 November 1978 Sennar reservoir.

Ali (1982)- 7.9-8.7 diurnal variation during April/82 at Khartoum, maximum at 7.00 and 8.00 am and lowest at 12 midnight till 2.00 am.

7. Dissolved Oxygen

First era:

No data are recorded for this period.

Second era:

Talling and Rzoska (1967) showed that during 1953-55 in the Blue Nile at Khartoum the seasonal trend for surface water indicates a moderate degree of sub-saturation during the phase of flood water, and a slight super-saturation during the two maxima of phytoplankton. A pronounced oxygen deficiency e.g. below 50% of saturation, was never found. This oxygen seasonality is accompanied with seasonal variation in temperature, of the surface water.

Hammerton (1976) while studying the limnology of the Blue Nile, before building Roseires dam, recorded that the percentage saturation of oxygen in surface water varied, with occasional super-saturation in January-February (Cyanophyceae bloom); absolute concentrations were lower during the flood period.

Third era:

Meghraby during his Ph.D. studies (1966-1970) stated that in the Blue Nile the surface waters are usually in a state of slight supersaturation (6.0 mg/Litre = 75.5 saturation). During the flood however moderate degree of sub-saturation is sometimes found. One incidence of oxygen deficiency below 50% saturation, was recorded at Khartoum during the flood of 1968.

Hammerton (1972 a,b and 1976) reported that periods of variable deoxygenation have occurred in the Roseires reservoir, including an episode of complete deoxygenation soon after its first filling.

Diurnal variations in dissolved oxygen in the Roseires reservoir were studied by Meghraby (1965-70). He found a maximum value of 10.4 mg/L $O_2$ during the period of high photosynthetic activity at 12.00 noon and lowest value of 6.5 mg/L $O_2$ at 18.00 hours.

Ali (1982) found diurnal variations between 7.8 mg/L and 8.2 mg/L during April 1982. The lowest concentration was recorded at 3.00 am and the highest one at 3.00 pm afternoon. From the above data clear day and night variations in dissolved oxygen

values can be seen. Oxygen surface-supersaturation was recorded by Talling and Rzóska (1967) during the period of annual phytoplankton maximum.

8. B. O. D./9. C. O. D.

To date no studies, for the B. O. D. and C. O. D. parameters, have been made.

10. Phosphate-Phosphorus

First era:

No data are available for this period.

Second era:

According to Talling (1976) concentrations of soluble Orthophosphate were about 100 ug $PO_4$-P/L in the Blue Nile before the main period of phytoplankton development (Prowse and Talling 1958; Talling and Rzóska 1967, Hammerton 1972 a), but declined thereafter to 10 ug $PO_4$-P/L. The first part of the decline may be influenced by hydrological changes upstream, such as the continued [illegible] of flood-water in the Blue Nile. This phase included the initial growth of the major diatom Melosira granulata in the Blue Nile river, which occurred in a relatively phosphate rich medium.

Hammerton (1972 b) measured a decline in phosphate and nitrate in the Roseires reservoir for the 1967-68 inter flood season, these nutrients also decreased along a longitudinal section towards the dam.

The later part of the phosphate decline observed by Talling at Khartoum was due to uptake associated with dense phytoplankton which included abundant blue-green algae-especially Anabaena flos-aquae f. spiroides

Dessougi (1980) measured values between 64 and 70 ug/L $PO_4$-P in eleven of the Gezira irrigation canals between Medani and Khartoum in January 1979. The canals receive their water from Sennar reservoir.

Ali (1982) detected diurnal phosphate concentrations at the Blue Nile at Khartoum in April 1982 to be in the range of 6-18 ug/L with no obvious changes recorded between day and night.

Sinada (1972) reported a range of phosphate concentration at Khartoum to be between 14.0 ug/L and 300 ug/L during 1968-1970.

11. Nitrate-Nitrogen

First era:

Beam (1906) measured the nitrate-nitrogen for

one year between November 1904 and October 1905. Maximum values of 0.054 ppm were recorded in June while the minimum value of 0.015 ppm in January. There is no data available for the annual flood period (July, August, September).

Second Period

Talling and Rzóska (1967) showed that large seasonal changes in nitrate nitrogen take place. During 1954-1956 period the flood water contained large amounts of nitrate-nitrogen occasionally exceeding 500 ug/L. A decline to levels below 20 ug/L occurred in November/December during the first maximum bloom of the diatom, *Melosira granulata* and low concentrations were maintained throughout the following maximum bloom of *Anabaena flos-aquae* f. *spiroides*. However in absence of adequate analysis of upstream water, it is not possible to separate the consequences of subsiding flood water and uptake by phytoplankton.

Third era:

Moghraby (1972) stated that during the flood the nitrate-nitrogen had a concentration of 0.08-0.1 mg/L. This rapidly decreased to 0.002 mg/L or less at the end of December-January.

Sinada (1972) showed that the range of nitrate concentrations at Khartoum to be between 80 ug/L and 200 ug/L.

Hammerton (1972) indicated that the nitrate-nitrogen levels at Khartoum ranged between 1 and 100 ug/L. At Roseires reservoir he recorded the following concentrations 55 ug/L in November 1967 and 2 ug/L $NO_3$-N in May 1968 (1972 b).

Dosouqi measured $NO_3$-N in the Gezira irrigation canals to be in the range of 0.52-and 1.00 mg/L during January 1979.

Ali (1982) stated that at Khartoum, the Blue Nile water performs diurnal changes in nitrate-nitrogen content between 0 and 25 ug/L.

12. Ammonium-Nitrogen

First era:

Beam (1906) measured ammonium-nitrogen to be in the range of trace (in December 1904) to 0.032 ppm (in June 1905); No data are recorded for the annual flood period (July, August, September) at Khartoum.

Second & 3rd era:

The range of values recorded was always below 0.50 ug/L N (Talling & Rzoska 1967).

To date there have been no studies done on ammonium nitrogen.

Heavy Metals (13.Cu, 14.Fe, 15.Pb, 16.Zn).

No studies have been conducted to study the heavy metals on the Blue Nile River.

18-21. Major ions (Ca , Mg , K , Na)

First era:

Beam (1906) recorded maximum values for the major ions in June 1905 and lower values in December 1904 as follows: Calcium 25.53 and 18.4, Magnesium 5.89 and 4.34; Potassium 1.90 and 1.4 and Sodium 7.81 and 5.57 ppm.

Second era:

Green and Snow (1939) measured the major ions in the Blue Nile (at Kelani 1936-37) to be in the following: Calcium 20.5-23.4 mg/L; Magnesium 4.8-5.3 mg/L and Potassium 8.4-8.9 mg/L.

Talling and Rzóska (1967) stated that the major ions measured from Khartoum to Singa (Blue Nile) in December 1955 were as follows: Calcium 1.5; Magnesium 0.72; Potassium 0.06; and Sodium .47 meq/L.

Hammerton (1961/1963) found the major ions at Khartoum to be calcium 29.2, Magnesium 4.9, Potassium 3.7 and Sodium 3.7 mg/L.

Sinada (1972 ) gave a range of values for the season 1968-1970 as follows: Calcium 18-34.7 mg/L; Magnesium 3.5-9.0 mg/L; Potassium 1.3-5.3, and Sodium 5.0-15.0 mg/L.

Moghraby (1972) summarized his work along the Blue Nile during the period 1966-1970 in this way "The major ions were always found in fairly high concentrations (Calcium 12.8-28 mg/L; Magnesium 3.6-7.8, Potassium 1.2-2.8 mg/L and Sodium 4.1-9.5 mg/L."

Dessougi (1980) gave the following values for Sennar reservoir during November 1978: Calcium 18.44; Magnessium 5.10; Potassium 0.94 mg/L; and Sodium 6.90 mg/L.

Ali (1982) showed that there are no diurnal changes in the values of the major ions at Khartoum during April where he recorded the following Calcium 20.0-23.0 mg/L; magnesium 9.6-11.6 mg/L Potassium 1.8-2.1 mg/L and Sodium 8.7-11.2 mg/L.

22-24. Organic pollutants

To date there have been no studies done on organic pollutants in the Blue Nile.

C. Biological Indicators

25. Macrophytes

Macrophytes were not abundant in the Blue Nile, they were assumed to be less important primary producers than phytoplankton. According to Desougi

(1980) the following species were recorded in the lake as well as in the Sudanese plains:-

- Ceratophyllum demersum
- Echinochloa stagnina
- Nymphaea caerula
- Nymphaea lotus
- Pistia stratiotes
- Typha domigensis.

Desougi also noted the absence of the Potamogeton species (P. crispus, P. nodosus, P. pectinatus and P. perfoliatus) which are very common in the Gezira irrigation canals. Potamogeton species are also absent from the water pools "mayas" of the Dinder National Park and Sennar reservoir.

Andrews (1945) and Desougi (1980) recorded the prevalent plant species in the Sennar reservoir. (See Table 2). Notice absence of Potamogeton species in both records. However the later author recorded the presence of Potamogeton crispus in April (1981) in the Blue Nile at Khartoum and along the Main Nile up to the surveyed 20 km. The appearance of Potamogeton is attributed to the reduced current velocity. The plant is also recorded 80 km south of Khartoum at El Massodia.

Table 2
Plant species recorded by Andrews (1945) and Dessougi (1980) in Sennar reservoir

| | Andrews 1945 | Dessougi 1978 |
|---|---|---|
| Ceratophyllum demersum | + | + |
| " submersum | - | + |
| Chara globularis | + | + |
| Cynodon dactylon | - | + |
| Cyperus alopecuroides | + | + |
| " rotundus | + | + |
| Echinochloa stagnina | + | + |
| Ipomea reptans | + | + |
| Najas marina | - | + |
| Najas pectinata | + | + |
| Najas schweinfurthii | - | + |
| Nitella batrachosperma | + | + |
| Nymphaea caerulea | + | + |
| " Lotus | - | + |
| Ottelia alismoides | + | - |
| " ulvifolia | + | - |
| Panicum maderanium | + | + |
| " repens | - | + |
| Pistia stratiotes | + | + |
| Polygonum glabrum | + | + |
| " lanigerum | + | - |
| Spirogyra Sp. | - | + |
| Utricularia inflexa | + | + |
| " stellaris | + | + |
| " thonningii | + | - |
| Vossia cuspidata | + | + |

+ present - not present

26. Periphyton, benthos and bacteria

Although the scientific and economic importance of the Nile have long been recognized, many aspects of its biology have been largely neglected and some biocenoses especially benthos and periphyton have not been examined.

Surprisingly bacteria have not been studied at all. Most of the biological studies have concentrated on the phytoplankton and zooplanbaton.

27. The Phytoplankton

First era (1831-1925)

Hydrobiological studies were not carried out, on the Blue Nile, before the construction of Sennar dam in 1925. Indeed most of the work which has contributed greatly to our knowledge of the ecology of the Nile within Sudan has been carried out long afterwards by members of and collaborators with the Hydrobiological Research Unit which was established in the University of Khartoum in 1953. Prior to the formation of the Sennar reservoir, ecological research was largely neglected in the Sudan. The only material pertaining to the Nile consisted of some occasional notes by passing biologists. These include notes on algae

and freshwater fauna by Ehrenburg & Hemprich (1831), Schweinfurth (1862), Grunow (1870), Ekman (1903), Daday (1910), Garney (1911) and Chappium (1922). Beam (1906) indicated that the plankton was scanty and mixed with detritus and adventitious forms, a finding which is in conformity with our present speculations.

Second era (1925-1966)

All of the work which has contributed significantly to our knowledge of the biology of the Nile began in the early 1950s long after the construction of Sennar dam. Most of this work however, was carried out within the vicinity of Khartoum.

Ethiopian headwaters

Due to the topography and the nature of the river on the Abyssinian Plateau, it is expected that the Ethiopian headwater do not contribute significantly to the plankton of The Nile. Talling & Rzoska (1967) sampling the Ethiopian headwaters during March 1964 found only a sparse and rudimentary plankton population.

Zone I - Zone II and Zone III

Hammerton (1970 a,b, 1971 a) in three different surveys carried during February 1964, February 1965

and February 1966 found an extremely sparse plankton population in 400 km section of the river upstream of Sennar dam. The diatom Melosira granulata and the blue-green alga Anabaena flos-aquae - two principal components of the Blue Nile north of the Sennar reservoir- were present in very small numbers around 20 cells $ml^{-1}$ within this stretch of the Nile. All the samples collected during 1964-1966 contained visible quantities of silt and fine sand and some organic detritus with a Secchi disc visibility less than 50 cm. Therefore poor light penetration, coupled with relatively high current velocity seems to be the sole factor checking the development of phytoplankton within this stretch of the Blue Nile, before the construction of Roseires dam.

Zone IV (Sennar reservoir)

As mentioned before no hydrobiological studies were carried out within this zone prior to the construction of Sennar dam.

Hammerton (1970 a,b; 1971 a) confirming the findings of Talling & Rzoska (1967) found that as the water entered the dam basin most of the silt settled out. The Seccki disc visibility increased considerably

resulting in a dense phytoplankton development within the reservoir. Melosira granulata increased from around 20 cells $ml^{-1}$ in zones I-III to 2140 cells $ml^{-1}$ in the reservoir. There was a similar increase in the numbers of Anabaena flos-aquae. Unfortunately no work was carried out after 1970.

Zone V

Talling & Rzoska (1967) made the first longitudinal survey of its kind along the Blue Nile during December 1955. They observed that densities of Melosira increased appreciably in the first 150 km stretch below the dam but not further downstream. Increase in Anabaena population was much more pronounced in the lower river stretch below the dam. Talling&Rzoska (1967) concluded that most of the phytoplankton biomass reaching Khartoum is produced in true river conditions below Sennar reservoir.

Hammerton (1970 a,b; 1971 a) in his three different longitudinal surveys confirmed the views of Talling and Rzoska (1967) that the plankton population which was brought to full development in Sennar dam basin persisted as a true river plankton throughout zone V over 350 km downstream with little loss in numbers.

Zone VI (Khartoum)

This zone has been thoroughly and better studied than other stretches of the Nile.

Brook (1954) presented systematic account of the phytoplankton of the Blue Nile from samples collected at Khartoum between 1949-1952. Over 90 algal taxa were identified. This detailed study was not repeated until after the completion of Roseires dam when Simola (1972: unpublished) presented a similar systematic account (see below).

Of the 90 taxa reported by Brook (1954) only few contributed significantly to the total phytoplankton biomass. Rzóska, Brook & Prowse (1955) and Talling & Rzóska (1967), from records made during 1951-1953 and 1954-1956 respectively, have shown that the dominant species in the Blue Nile were Melosira granulata and its variety angustissima, Anabaena flos-aquae f. spiroides and Lyngbya limnetica. These findings are summarised below:-

The concentration of plankton was very low during flood period of July-October when adverse conditions of rapid flow and high turbidity existed. As the current subsided in November diatoms were the first

group to appear in numbers particularly Melosira granulata which was favoured by the post-flood relatively high concentrations of nitrate-nitrogen and phosphate-phosphorus. The former nutrient reduced to 10-20 $\mu g l^{-1}$ was responsible for the primary check to the increase of Melosira which was surpassed by Anabaena flos-aquae. The latter alga produced higher population densities in January-February and probably responsible for the depletion of phosphorus. A declined of phytoplankton occurred between March-April after which a second maximum developed during May/early June before the entire plankton was washed out by late June. The components of the second maximum were Melosira granulata, Anabaenopsis cunningtonii, A. tanganyikae, Anabaena scheremetievi Raphidiopsis curvata and Synedra acus. Lyngbya limnetica was a minor component of the maximum of May-June 1956 (Talling&Rzoska 1967) although a major one in 1953 (Rzoska et al, 1955).

No further seasonal studies on the phytoplankton of the Blue Nile were carried between 1956 and 1962. However the Hydrobiological Research Unit launched a long-term study in 1963 to determine the impact of

the Roseires dam on the biological conditions of the Blue Nile. Hammerton (1970 a,b, 1971 a) sampling the Blue Nile at Khartoum during 1963-1966 observed seasonal cycles and succession of phytoplankton which were remarkably predictable and similar to those recorded by previous workers without changes in the species composition of the plankton.

Third era (1966-1983)

Man-made lakes have profound influencies on the biological productivity and ecology of rivers. With this in mind the Hydrobiological Research Unit (University of Khartoum) made plans in 1963, three years before the completion of Roseires dam, to carry a long-term study of the whole 740 km length of the Blue Nile to determine the impact of Roseires dam on the biological conditions of the river. A survey of conditions before and after the dam was put into use, was carried out. The valuable studies carried out by Brook (1954), Rzoska et al (1955), Talling & Rzoska (1967) and Hammerton (1970 a,b, 1971 a) have provided much of the baseline data for comparison with conditions in the newly formed reservoir and in the river after the filling of the reservoir.

Zone I

This zone is not affected by the formation of Roseires reservoir. Within this zone normal river conditions existed with large detritus suspension and few adventitious organisms (Moghraby,1972).

Zone II (The Roseires Reservoir)

The reservoir of the Roseires dam was first filled in October 1966. Shortly after that, Hammerton (1971 b) observed a moderately rich plankton in the reservoir, with Microcystis flos-aquae and Phormidium mucicola as important components. Microcystis became rapidly dominant and in December 1966 the surface of the lake was bright green. It was interesting to note that Microcystis had never previously been a major component of the Blue Nile (Brook, 1954). Melosira granulata, always an important component of the Blue Nile plankton was present throughout the sampling season with peak growths in November 1966, March and May 1967. The other important component of the Blue Nile Anabaena flos-aquae did not appear until January 1967 and reached a peak growth in February 1967.

The following season - November 1967-May 1968- the phytoplankton of Roseires reservoir showed considerably heavier growth than during 1966-1967 with the dominant algae being the same, namely Melosira granulata, Microcystis flos-aquae and Anabaena flos-aquae (Hammerton, 1971 c). Many other algae were present including Pediastrum spp. which were particularly prominent. Melosira granulata was already abundant in November 1967 and increased through December to a peak of 4150 cells $ml^{-1}$ in January 1968. During February 1968 there was a sharp decrease, recording only 44 cells $ml^{-1}$ in March but increased again to 5220 cells $ml^{-1}$ in May 1968. Microcystis flos-aquae and Anabaena flos-aquae were present in November 1967 but formed dense surface blooms during December-February 1968. In March 1968 Pediastrum spp became dominant while Microcystis reappeared in enormous numbers in May 1968.

During 1969-1970 season the Roseires reservoir showed further differences from the "usual" seasonal cycle though Melosira granulata produced a heavy growth in November (Hammerton 1972 c). Unexpectedly

Volvox aureus dominated the phytoplankton in December 1969 but this disappeared in January 1970 to be replaced by a large growth of Pediastrum simplex var. duodenarium which continued throughout February 1970. It was surprising that only trace amounts of Anabaena and Microcystis were found during that season-the first time that blue-green algae failed to be a major component of the phytoplankton of the Blue Nile.

It is apparent that the reservoir during the first three years of its filling (1966-1970) had not stabilized biologically. The seasonal cycles and succession of phytoplankton as described above differed from year to year. Unfortunately, as far as we are aware, no further studies were undertaken after 1970 and is not possible to point out if and when the biological regime of the reservoir had thoroughly stabilized. However it can be safely stated that the formation of the Roseires reservoir had brought about changes in the species composition and seasonal cycles of the plankton in the Blue Nile.

Zone III

The phytoplankton within this stretch has not been studied. However Hammerton (1971 c) reported that phytoplankton densities were reduced to 40% of that of Roseires reservoir.

Zone IV (The Sennar Reservoir)

The phytoplankton in Sennar reservoir has not been studied on a seasonal basis before the construction of Roseires dam in 1966. However Hammerton (1971 c,d, 1972 b) followed the seasonal cycles of the phytoplankton in the Sennar reservoir for three consecutive seasons, thus: November 1967-May 1968, November 1968-May 1969 and November 1969-May 1970. His findings are summarised below:-

Melosira granulata was dominant in the reservoir during the whole season of 1967-1968 increasing from 3145 cells $ml^{-1}$ in November 1967 to a large peak of 11770 cells $ml^{-1}$ in January 1968, then decreasing to 1530 cells $ml^{-1}$ in March before rising to a second smaller peak of 5000 cells $ml^{-1}$ in May 1968. Anabaena flos-aquae , co-dominant throughout much of the season, also showed peak growths in January and May 1968 of 4900 and 3610 coil-turns $ml^{-1}$ respectively. It is interesting that total population densities in Sennar reservoir were higher than those in Roseires and still higher than any previous records in the Blue Nile. It is striking that Hammerton (1971 c)

did not mention Microcystis flos-aquae in Sennar reservoir although it was a co-dominant member of the phytoplankton of Roseires reservoir.

During 1968-1969 two periods of phytoplankton growth were noted in Sennar reservoir. The first period started from October 1968 to February 1969 with Melosira granulata being dominant; the second period extended from April-June 1969 with Microcystis being the dominant alga and Melosira was co-dominant. However, similar to conditions in Roseires reservoir, Anabaena flos-aquae was not reported to constitute any phase in the plankton of Sennar reservoir during that season.

Similarly during 1969-1970 season, two periods of maximum algal growth were observed: a shorter period during October-December 1969 with a dense growth of Melosira in November, and a second period from March to June 1970. During the latter period Melosira peaked in April, to be followed by Microcystis which dominated the plankton in May 1970.

It is interesting to note that Anabaena flos-aquae, an alga prominent for so many years in the Blue Nile, became less important during November 1968-May 1970.

Further studies were not carried out after 1970 to ascertain the role played by Anabaena flos-aquae in Sennar reservoir after the construction of Roseires dam. The fluctuations in the densities of Melosira, Microcystis and Anabaena within the Sennar reservoir during 1968-1970 closely reflected the seasonal changes of the numbers of these algae in Roseires reservoir. This indicates that the formation of the Roseires reservoir greatly influenced the phytoplankton composition and density within the Sennar reservoir.

Zone V

The only available longitudinal survey carried out along this stretch of the Blue Nile during the third "era" indicated that the seasonal variations in species composition and densities of the phytoplankton closely reflected the changes in Sennar reservoir. However there was a decrease in the densities of the major components of the phytoplankton downstream of the Sennar dam, with a slight increase near Khartoum (Hammerton, 1971 d). The populations near Khartoum were less healthy than at Sennar.

Zone VI (Khartoum)

Sinada (1972) studied the phytoplankton of

the Blue Nile during the period August 1968-December 1970. The principal components of the phytoplankton during this period were Melosira granulata, M. distans, Synedra acus, Lier cystis flos-aquae. Anabaena flos-aquae was prominent only during January-February 1969 (800-2800 cell-turns $ml^{-1}$). It was surprising that this blue-green alga remained in very low numbers during the rest of the period of the above-mentioned study as found in Roseires reservoir by Hammerton (1971 c,d, 1972 b). Melosira granulata in this zone showed a definite and regular seasonal cycle. It appears in September/October and quickly establishes a peak in November/December after which it decreases sharply to lower numbers which are maintained until May. In late May/early June a sudden summer peak occurs before being washed out in late June (Sinada 1972). This seasonal cycle of Melosira reported during 1968-1970 is reminiscent of that reported by Rzoska et al (1955) and Talling & Rzoska (1967) fourteen years earlier.

The maximum development of Melosira distans in the Blue Nile at Khartoum during 1968-1970 always occurred in November-December although it was likely

that this period might extend until February (Sinada 1972). It is interesting to note that this diatom was not reported in the Blue Nile before 1968.

Microcystis flos-aquae attains its maximum development during February-May although the magnitude may vary considerably from year to year. The period July-October is obviously unfavorable for the growth of all algae. Significant increase in numbers of Microcystis occurs in November-December(Sinada 1972).

Synedra acus showed definite and recurrent peaks during November-December and May-early June.

Sinada (1972) showed that the annual flood of the Blue Nile is the most important factor limiting numbers of phytoplankton. The scarcity of planktonic algae during the flood, despite of high nutrient concentrations is attributable to the high silt content ($> 4$ $gl^{-1}$ suspended matter). The Secchi disc visibility during the flood season is in the very low range of 0-5 cm. In addition the current velocity may be as high as 1.8 m $sec^{-1}$ compared to $\leq 0.09$ m $sec^{-1}$ during May/early June when the second maximum of algal growth occurs. The increase in algal densities begins in late October/early November when the current

subsides (velocity $< 0.35$ m $sec^{-1}$) and most of the silt settled out (secchi disc visibility $>20$ cm). Therefore poor light penetration coupled with high current velocity is the sole factor checking the development of phytoplankton in the Blue Nile during the flood season (Sinada 1972). These conditions reported in the Blue Nile during the annual phase of the flood during 1968-1970 were no different from these reported before the construction of Roseires dam by earlier workers.

Sinada (1972) listed over 150 algal species belonging to 74 genera of the various algal classes. Comparing his list with that of Brook (1954) made over forteen years earlier it is obvious that there was an increase in diversity of species. Many algae appeared though in very small numbers in the Blue Nile at Khartoum during 1968-1970 and a few others disappeared (See Tables). Of the important species which appeared during 1968-1970 were Melosira distans and Attheya zachariasi which contributed significantly to the total algal biomass of the Blue Nile at one time or another. Likewise, one species namely Microcystis flos-aquae which had

reported by Brook (1954) in 1951-1953 as being an unimportant component of the phytoplankton of the Blue Nile, preponderated shortly after the construction of the Roseires dam and continued to constitute an important phase in the phytoplankton of the Blue Nile throughout 1968-1970. Occasional samples taken from the Blue Nile at Khartoum during 1977-1983 have shown that Microcystis as well as Melosira distans, have established themselves (Sinada, unpublished). On the other hand certain blue-green algae like Anabaenopsis spp which were recorded by Rzoska et al. (1955) and Talling & Rzoska (1967) as important members of the plankton of the Blue Nile during 1951-1956 were rarely observed during 1968-1970 by Sinada. Similarly Lyngbya limnetica which constitued an important component of the Blue Nile in the early 1950s (Rzoska et al., 1955) disappeared from the Blue Nile during 1968-1970 (Sinada, 1972).

It is obvious that the algal flora of the Blue Nile has undergone a considerable change within a short period of time between 1956 and 1968. This change in the algal flora of the Blue Nile may be attributed to the construction of the Roseires dam across the Blue Nile in 1966.

28. The Zooplankton

Little work has been carried out on zooplankton and no study worth mentioning was undertaken during the first era.

Second era (1925-1966)

As far as we are aware the only studies carried out were those of Rzóska et al.(1955) and Talling & Rzóska (1967) and few casual observations made by Hammerton (1970 a,b).

Zones I, II and III

The only available data were the outcome of a preliminary survey carried out during December 1955 by Talling & Rzóska (1967) and during February 1964 and February 1965 by Hammerton (1970 a,b). They showed that the zooplankton was very scanty within this stretch of the Blue Nile before the construction of Roseires dam. The quantities of the zooplankton were not assessable, with few Naina lubia and Thermocyclops species. However adventitious forms were numerous in the detritus- rich waters. This finding is not surprising considering the topography of the area within this stretch of the Nile.

Zone IV (Sennar reservoir)

As the water approached the Sennar reservoir, the zooplankton built up, chiefly within the last 100 km above the dam (Talling & Rzoska 1967). Near the dam a moderately rich and varied zooplankton was present in the middle of the reservoir. The principal components were Cyclochaetia cornuta, C. dubia and Moina dubia.

Zone V

No record of the zooplankton within this stretch of Nile was available before 1966.

Zone VI (Khartoum)

The only available records were those of Rzoska et al (1955) and Talling & Rzoska (1967) who were engaged in studying the Nile at Khartoum during 1951-1955. The zooplankton during that period followed the same pattern as the phytoplankton with two peaks. There was no plankton discernible in the silt-laden waters of July-October except for few Moina dubia and adventitious forms. Plankton began to appear in November rising sharply in numbers to peak in February before a drop in March or April. A second rise followed in May-early June before the plankton is

washed out in late June. During the first period of maximum growth two species of Ceriodaphnia were most numerous with C. dubia following C. cornuta. The second maximum of May/June appeared to be more variable in composition with Diaphanosoma excisum and C. cornuta being dominant in 1952 and Cyclopoids in 1953.

Third era (1966-1983)

Machrady (1972) started a four-year extensive investigation of the zooplankton of the Blue Nile just after the first filling of Roseires reservoir in November 1966. His valuable study remains to be the only available record of the zooplankton of the Blue Nile after the completion of Roseires dam.

Zone I

Machrady (1972) noted that within this zone normal river conditions existed, with large amounts of detritus suspension and few organisms most of which are adventitious forms. This finding was in conformity with previous findings obtained during 1955 by Talling & Rzóska (1967) indicating that this zone is not affected by the formation of Roseires reservoir. No further records were available after 1970.

Zone II (Roseires reservoir)

Meghraby (1972) pointed out that the formation of the Roseires reservoir resulted in a dense community of zooplankton with an increase up to 316 times more than in the river upstream the reservoir within zone I. Rotifers which were particularly absent within zone I were fairly represented in the reservoir. The zooplankton in Roseires reservoir, typical of that of a tropical reservoir, was characterised by larger numbers of Crustacea than Rotifers; Cladocera were more numerous than Copepoda. The plankton community within the reservoir showed a maximum in November and another during February-April.

No further records were made after 1970 to follow up the impact of Roseires dam on the zooplankton community.

Zone III

Meghraby (1972) observed that the zooplankton downstream the dam exhibited a seasonal cycle similar to that in Roseires reservoir although the densities decreased in conditions of free river flow below the dam. No further studies were undertaken after 1970 within this stretch of the Blue Nile.

Zone IV (Sennar reservoir)

Mashraby (1972) noted that the densities of the zooplankton in Sennar reservoir were greater than in the river above and even greater than in the Roseires reservoir. The greater concentrations at Sennar were attributable to the greater inoculum flowing into the Sennar basin from Roseires reservoir. Comparing the results obtained by Mashraby (1972) with those of Talling & Rzoska (1967) obtained over a decade previously, it is interesting to note that the presumably biologically-stable Sennar reservoir showed higher densities of zooplankton during 1966-1970 than during the period preceding the construction of Roseires dam.

The seasonal cycle of zooplankton at Sennar reservoir was similar to that at Roseires, with a maximum in November, a pulse in January or February and a peak during March-April (Mashraby, 1972).

Zone V

Mashraby (1972) recorded a decrease in zooplankton densities at Wad Medani and Hassaheisa (See Map 1). However, the densities of the zooplankton within this stretch were generally

higher than those recorded during 1951-1953 by Talling & Rzoska(1967). The seasonal cycles of zooplankton at Wad Medani and Hassaheisa were similar to those at Sennar although the succession and dominance of species differed especially among Crustacea (Moghraby, 1972). Unfortunately no further studies were undertaken after 1970.

Zone VI (Khartoum)

Moghraby(1972) observed that in late October the density and number of species of zooplankton increase abruptly at Khartoum with a peak in February followed by a second peak in May-early June before being washed out in late June. Only Cyclopoids and Moina dubia remain in the silt-laden waters of July-October with few adventitious forms. This indicates that the annual cycles of zooplankton at Khartoum during the period 1966-1970 remained remarkably similar to those reported by Talling & Rzoska(1967) some fourteen years previously. However, Moghraby(1972) noted that Cladocera were more numerous than Copepoda and Diaptomidae were fewer than Cyclopida, thus following the upstream trend.

Ceriodaphnia dubia, C. cornuta and Diaphanosoma excisum became less dominant than during 1951-1953. Thermodiaptomus galebi became a prominent member of the zooplankton replacing Thermocyclops neglectus (Mashreki, 1972). Similarly Keratella tropica, K. cochlearis and Filinia longiseta became less numerous in the Blue Nile while Daphnia lumholtzi and D. barbata became more prominent than previously recorded. These changes in the densities of the plankton may be attributed to the influence of the Roseires reservoir.

Table 3.

Algae of Blue Nile Water at Khartoum collected during 1951-1953 by Brook (1954) but did not appear during 1968-1970.

Gonium pectorale

Volvox globator

Pediastrum boryanum var. granulatum.

P. boryanum var. longicorne.

Sorastrum americanum

Micratinium radiatum

Tetraedron enorme

T. limneticum

T. bifurcatum

Polyedriopsis quadrispina

Westella botryoides

Dimorphococcus lunatus

Crucigenia quadrata

Scenedesmus bijugatus

S. opoliensis

Coelastrum microsporum

C. proboscideum

Ophiocytium capitatum

Euglena granulata

Lyngbya limnetica

Table 4.

Algae of Blue Nile water at Khartoum collected during 1968-1970 by Sinada (1972) but were not present during 1951-1953.

| | |
|---|---|
| Phacotus lenticularis | T. lacustris |
| Phacotus sp. | T. dybowski |
| Pteromonas aculeata | T. pulchella |
| Golenkinia paucispina | Trachelomonas spp. |
| Errerella bronkhorstiensis | Glenodinium sp. |
| Pediastrum obtusum | G. quadridens |
| Echinosphaerella limnetica | Stiritococcus sp. |
| Treubaria triappendiculata | Mallomonas sp. |
| Lagerheimia spp. | Melosira distans |
| Selenastrum westii | M. argus |
| Tetraedron spp. | Atthey zachariesi |
| Ankyodriopsis spinulosa | Synedra capitata |
| Scenedesmus bijuga | Pinnularia gibba |
| Scenedesmus incrassatulus var monomas | Epithemia turgida |
| Staurastrum spp. | Rhopalodia gibba |
| Penium margaritaceum | Cymatopleura solea |
| Closterium aciculare | Surirella capronii |
| C. parvulum | S. robusta var splendida |
| Euglena acus | S. linearis var. constricta |
| E. proxima | S. tenera |
| Trachelomonas superba | Oscillatoria limnetica |
| T. volvocina | Oscillatoria spp. |

Conclusion:

The ecology of the Blue Nile River is controlled by the natural regime of rainfall of the watershed area of the river in the Ethiopian plateau. This phenomenonis the major factor causing seasonal variations in current velocity, water discharge, amount of silt delivered downstream of the river and degree of turbidity or suspended matter or transparency. These physical factors by their turn generate changes in the chemical and biological constituents of the Blue Nile river ecosystem. The broad outline of the changes either in time (since 1900) or in region ( from the Sudanese border to Khartoum) are pointed below.

Construction of 2 dams (Sennar 1925 and Roseires 1966) across the Blue Nile river channel brought with it changes in the discharged water passing Khartoum especially during the low flow season. In the last 3 years (1980-1983) reduction of more than 60 to 70 % in the discharge was recorded in comparison of the mean values before the construction of Roseires dam. These new conditions made the river habitat appropriate - during the low flood season - for the appearance and growth of aquatic weeds on the Blue Nile.

Changes in water temperature due to the construction of the dams were recorded, specifically in the reservoires zone. Thermal stratification during sometimes of the year was observed. This took place because of the creation of large huge masses of water bodies.

Industrial cooling processes are potential sources of thermal water pollution along the Blue Nile. Incidents were recorded where the river water is under use for that purpose.

Changes in transparency and suspended matter in the Blue Nile water were also directly correlated with the Sennar and Roseires dams. Where transparency and silt precipitation in the dams reservoirs increased and less values were recorded at Khartoum.

The chemical characteristics of the Blue Nile are unfortunately not fully studied. Basic information on the following is lacking: Biological Oxygen Demand (B.O.D.), chemical Oxygen Demand (C.O.D.); the heavy metals, copper, zinc, iron, nickel, lead; herbicides, fungicides and insecticides. The scarce available data on the rest chosen chemical indicators

are summarized in the following:-

The conductivity of the Blue Nile water varies with season and from year to year. The range recorded was found between 120-350 umho/cm.

The pH values recorded showed the same trend of variation between seasons. But the pH values fluctuated around 8 with lower values reaching 7.4 and higher values up to 9.4.

The surface water of the Blue Nile is in a state of slight oxygen super-saturation (6.0 mg/l). However, incidences of oxygen deficiency below 50 were recorded. In the Roseires reservoir oxygen concentration was found to be a function of depth where with increase of depth decrease of oxygen concentration was recorded. It is to be noted here that temperature governs the solubility of oxygen gas in water. Diurnal variations in oxygen concentration was stated by many workers.

Phosphate-phosphorus was found to be up to 100 ug/l, but declines with the development of phytoplankton to reach values of 6 ug/l.

High nitrate-nitrogen values recorded reached up to 1000 ug $NO_3$-N/L during the flood water of the Blue Nile at Khartoum. These values, however, varies with the season and depends upon the development of phytoplankton.

Ammonium-nitrogen was always found to be below 0.50 ug/l.

The major ions were found ranging between 18-34.7 mg/l calcium, 5.5-9.0 mg/l magnesuim, 1.3-3.3 mg/l pottassuim and 5-15.0 mg/l sodium. There again varies with variations in season.

It is to be concluded here that the literature revi. and trend analysis showed beyond doubt that the data available in the physical and chemical indicators are scarce, scattered in a large period of time and unified methods for analysis were used. As well, the studies were not carried on some specific locations/station to ensure systematic procedure. For some indicators complete ignorance has been reported. It is therefore highly recommended that continious monitioring of the Nile system should be carried out. This can only be done by creating an

environmental agency for protection of the environment. The limited resources of the University of Khartoum allows up and then studies on detection of the changes which are taking place in the environment.

Phytoplankton productivity is a function of nutrients and light. Light does limit the aquatic production in waters which have large amounts of suspended solids that increase turbidity. The Blue Nile in its upper reaches has always had waters with large quantities of silt and detritus. Such conditions affect the plankton growth adversely and the concentrations of phytoplankton and zooplankton in the upper stretches of the Blue Nile are always very low.

In rivers water storage and low current flow favour the increase in number of plankton. Therefore the construction of dams like Sennar dam and Roseires dam initiate lake-like conditions in which the silt settles out, resulting in clearer waters which favour the growth of the phytoplankton and zooplankton.

It has been demonstrated by Hammerton (1972 a) Moghraby (1972) and Sinada (1972) that the construction

of Roseires dam in 1966 has exerted profound influence on the biological conditions of the Blue Nile at Roseires as well as downstream the river at Khartoum. Unfortunately no hydrobiological studies were carried out on the Blue Nile before the construction of Sennar dam in 1925. The effect of the formation of Sennar reservoir on the ecology of the Blue Nile remains largely speculative.

The formation of Roseires reservoir in 1966 has brought noticable changes in the species composition and densities of the phytoplankton and zooplankton (Hammerton, 1972 a; Moghraby, 1972; Sinada,1972). Presumably, the Roseires reservoir has become biologically stable by now. Any future changes in algal flora or zooplankton may result from changes in the chemical and physical features of the Nile. The chemical features of any body of water influence the biomass, diversity and species composition.

Therefore it is recommended to monitor:-

(i) total algal biomass by chlorophyll a.

(ii) densities of major components of the zooplankton and phytoplankton communities.

(iii) diversity and species composition of the plankton by making exhaustive species lists of zooplankton and phytoplankton of the Blue Nile.

Previous workers have shown that the concentrations of plankton were very low in the Blue Nile during the annual phase of high flood water between late June-October inclusive. There is no reason to assume whatsoever that those flood conditions will change in the future. Therefore it is not worth the effort to sample the Blue Nile during this period.

Different workers have established that recurrent growth peaks of plankton along the Blue Nile occur during November-December, January-March and in May-early June.

Therefore it is recommended to sample the Blue Nile regularly thrice a year during December, February and early June. For this purpose six stations are carefully selected along the Blue Nile within the constraint of time and facilities (see p. 4).

## BIBLIOGRAPHY.

Ali, H.G., (1982),
Diurnal Changes of the Physical and Chemical Water Characteristics of the Blue Nile River at Khartoum. B.Sc. Honours Thesis, CNRES, University of Juba.

Bayly, I.A.E., and Williams, W.D., (1973),
Inland Water and their Ecology, Longman, Australia.

Beam, W., (1906),
Report of the Chemical Section, in Second Report, Welcome Research Laboratories, Khartoum, Rep. Wellcome Trop. Res. Labs. 2 : 206-214.

Brook, A.J., (1954),
A Systematic account of the Phytoplankton of the Blue and White Nile. Ann. Mag. Nat. Hist.,Ser., 12,7 : 648-65[illegible]

Chappuis, P.A., (1922),
Rev. Suisse Zool. 29, No.5.

Ciaccio, L.L., (1972),
Water and Water Pollution Handbook, Vol.III, Dekker Publication.

Daday, [illegible].V., (1910),
Beitrage zur Kenntnis der Mikrofauna des Nils. S.B. Akad. Wiss. Wien, 119: 537-589.

Dessougi, L.A., (1980),
Untersuchung zur Gewasser vegetation der oberen Donau, des Blauen und des Weissen Nil-Systems.

Ehrenburg, G. and Hemprich, C.G., (1831),
Symolae Physicae seu Icones et descriptiones animalium evertebratorum sepostis insectis quae ex itienere per Africam Borealem et Asiam occidentalen. I, Phytozoa : 1-2[illegible] Zool.II (Berlonini).

Ekman, Sv., (1903),
Res. Swed. Zool. Exped. Egypt, 26, 18pp.

Grunow, A., (1870),
Algae in "Reise der Osterreichischen Fregatte 'Novara' um die erde in den Jahren 1857, 1858, 1859", Botanische Th[illegible] 1:1-104 (Wien).

Gurney, R., (1911),
Ann. Mag. Nat. Hist. Ser 8,7 : 25-33.

Hammerton, D., (1970a),
Water Characteristics and Phytoplankton Production.
11th. Annual Report, Hydrobiol.Res.Unit,University of Khartoum.

Hammerton, D.,(1970b),
Longitudinal survey of the Blue Nile. 12th.Annual Report, Hydrobiol.Res. Unit, University of Khartoum.

Hammerton, D., (1971a),
Blue Nile Survey,13th. Annual Report, Hydrobiol.Res. Unit, University of Khartoum.

Hammerton, D., (1971b),
Blue Nile survey. 14th. Annual Report, Hydrobiol.Res. Unit, University of Khartoum.

Hammerton, D., (1971c),
Blue Nile survey. 15th. Annual Report, Hydrobiol. Res. Unit, University of Khartoum.

Hammerton, D., (1971d),
Blue Nile survey. 16th. Annual Report, Hydrobiol. Res. Unit, University of Khartoum.

Hammerton, D., (1972a),
The Nile River - A Case History. In: River Ecology and Man: 171-207 Acad. Press, New York and London.

Hammerton, D., (1972b),
Blue Nile survey, 17th. Annual Report, Hydrobiol. Res. Unit, University of Khartoum.

Hammerton, D., (1976),
The Blue Nile in the Plains. In: Rzoska, J. (ed.), The Nile, Biology of an Ancient River, Junk Publishers, The Hague.

Maitland, P.S., (1978),
Biology of Freshwaters. Blackie, Glasgow and London.

Manahan, S.E., (1979),
Environmental Chemistry. Willard Grant Press, Boston, Massachusetts.

Moghraby, A., (1972),
The Zooplankton of the Blue Nile. Ph.D. Thesis, Fac. Science, University of Khartoum (Unpublished).

Rzoska, J., Brook, A.J., and Prowse, G.A., (1955),
Seasonal development in the White Nile and Blue Nile near Khartoum. Verh. int. Ver. Limnol., 12 : 327-334.

Schweinfurth, G., (1868),
Plantae quaedum Nilotices. Chera. 48(Berlin).

Sinada, F.A., (1972),
Bilogical and Productivity Studies on the Phytoplankton of the Blue and White Nile near Khartoum. M.Sc. Thesis, Fac. Science, University of Khartoum(Unpublished).

Talling, J.F., (1961),
Analyses of the Blue and White Nile Water. 9th. Annual Report, Hydrobiol. Res. Unit, University of Khartoum.

Talling, J.F., (1963),
Analyses of the Blue Nil and White Nile Water. 10th. Annual Report, Hydrobiol. Res. Unit, University of Khartoum.

Talling, J.F., and Rzoska, J., (1967),
The development of plankton in relation to hydrological regimes in the Blue Nile, J.Ecol. 55 : 637-662.