Nile Basin Initiative
Transboundary Environmental Action Project

National Nile Basin Water Quality Monitoring Baseline Report

for

Sudan

March 2005

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Table of Contents

Table of Contents …… I

Acknowledgements ……. III

List of Tables …….. IV

List of Figures …….. V

Executive Summary ……. VI

Chapter One: Introduction

- General Introduction …….. 1
  - Water Resources of the Sudan …….. 1
  - The Nile System …… 3
  - The White Nile ……. 3
  - The Blue Nile ……. 3
  - The Nile Water Agreements …… 4
  - Wetlands in the Sudan …….. 4
  - Sudd Biodiversity ……. 5
  - The Water hyacinth …… 5

Chapter Two: Water Resources Management in the Sudan

Section (1)

Institutional Framework for Water Resources Management ……... 7

Legal Framework for Water Management in the Sudan…….. 7

Water Legislation Regulations and Acts ……. 8

Ongoing Projects …… 9

Section (2)

Institutions Involved in Water Quality Monitoring …… 9

1- The Ministry of Irrigation and Water Resources ……. 9

2- The Ministry of Higher Education …….. 10

3- The Ministry of Health …… 10

4- The Ministry of Science and Technology ……... 10

5- The Ministry of Energy and Mining …….. 11

6- State Institutions Involved in Water Quality Monitoring.. 11

Section (3)

Technical and Professional Capacities of Institution Involved in Water Quality Monitoring ……. 11

Chapter Three : Nile Water Quality Status 17

Section (1)

- Regular Monitoring Programmes Data …….. 17
- Water Quality Status Assessment …… 17
- Khartoum State Water Corporation (Water Quality Monitoring Results) …… 20
- Physical Parameters …… 21
- Chemical Parameters …… 21
- Microbiological Indicators …… 22
- Water Quality Research in the Sudan (Historical Perspective) 22
- Recent Studies …….. 23
- Pollution Assessment in the Nile System around Khartoum …. 25
- Heavy Metal Pollution around Khartoum …… 25
- Silt Sedimentation Research …….. 25
- Pollution Risks ……... 26
- Major Sources at Pollution to the Nile System ……. 26
  1- Agrochemicals Usage …… 26
  2- Urbanization ……. 27
  3- Industrial Pollution ……. 28

Chapter Four: International, Local Non-Governmental Organizations and Public Participation in Water Quality Issues) 29

a) International Organizations (UN agencies) Involved in Water Quality 29
- UNICEF …… 29
- WHO …… 29
- UNESCO …… 29

UNESCO National Commission ……. 29

b) International (foreign) Non-Governmental Organization Involved in Water Related Activities …….. 29

c) National Non-governmental Organization Involved in Water Related Activities …….. 29

d) Community awareness on Water Quality Issues …… 31

Chapter Five: Conclusions and Recommendations 32

a) Conclusions …….. 32

b) Recommendations …… 32
c) Proposed Stations for National Water Quality Monitoring Programme……. 33
References ……... 36
Annex (1): W.H.O. Drinking Water Guideline Values 1996 ……. 38
Annex (2): Some Sudanese Drinking Water Standards (2002) 39

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List of Tables

No.	Table	Page
1	Regular Water Quality Monitoring Sampling Points and their coordinates…..	9
2	Technical and Profession Capacity of GWWCL ……	12
3	Technical and Profession Capacity of IESAL ……..	13
4	Technical and Profession Capacity of The Sanitary Laboratory U. of K……..	13
5	Technical and Profession Capacity of the Hydrology Laboratory, Faculty of Science, Elneelain University ……	14
6	Technical and Profession Capacity of the National Chemical Laboratory …….	14
7	Technical and Profession Capacity of the Water and Food Microbiology Laboratory ……..	15
8	Technical and Profession Capacity of the National Water Corporation Laboratories …….	15
9	Technical and Profession Capacity of Construction and Environmental Laboratory ……...	16
10	Technical and Profession Capacity, Central Petroleum Laboratory ……..	16
11	Nile Water System Result of Physical and Chemical Analysis for three selected sites (2003-2004) Showing maximum and minimum concentrations (G.W.and W.D). ……	17
12	Malakal White Nile annual minimum and maximum values of water quality key parameters …….	18
13	Suba: Blue Nile: Annual minimum and maximum values of water quality key parameters ……..	18
14	Dongola : Main Nile: Annual minimum and maximum values of water quality key parameters ……	19
15	Average maximum and minimum concentration for the period (1997-2003)	20
16	Physico and Chemical analyses data for the whole Nile system in the Sudan (Combined from different sources) …….	24
17	Sediment concentration and Discharge to Gezira and Managil Schemes	26
18	Summary o basic information about local N.G.O.S. involved in water relatal activities …….	30
19	Sampling sites of the suggested water quality monitoring programme and their Geo-references ……	34

List of Figures

No.	Figure	Page
1	Map of the Nile system in Sudan …….	2
2	Overall maximum Chloride concentrations in the Nile system, for the years (2001-2004) ……	19
3	Overall maximum Nitrate concentration in the Nile system in the years (2001-2004) ……	19
4	Overall maximum Nitrite (NO2) concentrations in the Nile system in the years (2001-2004) …….	20
5	Overall maximum Ammonia (NH3) concentrations in the Nile system in the years (2001-2004) ……..	20
6	River Nile suspended solids and turbidity (wet season 2003 – 2004) ……	21
7	River Nile system Electrical conductivity ……..	21
8	Fluoride and Silica concentrations in the Nile system at Khartoum for the period (1997-2003) …….	21
9	Trace element max, min concentrations in the Nile system at Khartoum period (1997-2003) ……	22
10	Total cliform count /100ml , in the Nile system at Khartoum ……	22
11	Total count / 5ml …….	22
12	Average Iron concentrations in Nile Waters around Khartoum (year 2001)	25
13	Nile system in Sudan proposed (and existing) water quality sampling sites (map) ……..	35

Executive Summary

The Sudan water quality baseline report main objective was to make an inventory of the Nile system components in the country, focusing on the institutional and legal frameworks of its management, particularly water quality monitoring.

To achieve this, institutional technical and professional capacities and water quality status were assessed. International, local non-governmental organizations and public participation in water quality issues and the social level of awareness on them were also considered.

Methods include: personal communications, interviews, a questionnaire about technical and human capacities of institutions, summarization of existing monitoring programmes, and scientific research and surveys data. Departmental, annual reports technical reports and published literature were also used as sources of information.

It was concluded that, both the Nile water quality and the technical capacities of laboratories have deteriorated, however, the expertise level of the highly qualified leading staff is very high. A national plan for water quality monitoring is recommended, new stations must be erected, all the national capabilities-together with regional and international aids-must be integrated aiming for a better water quality monitoring.

The contents of the report fall in five chapters:

Chapter one is an introductory material consisting of a general introduction and an inventory of the Nile system components in the country.

Chapter two deals with the Nile water resources management, institutional and legal frameworks as well as water quality monitoring institutions and their technical and professional capacities.

Chapter three deals with the Nile water quality status, it is composed of three sections:

Section (1): deals with data of regular monitoring programmes, and section (2) deals with recent research studies and surveys data. Both were used as water quality indicators. The pollution risks threatening water quality were dealt with in section (3).

Chapter Four focuses on the International local non local governmental organizations and community participation in water quality issues.

Chapter (5) deals with conclusions and recommendations.

The status of water quality is. Although the Nile water may not be classified as polluted, a distinct build up of some chemical constituents was observed, e.g. chloride and nitrogen compounds.

The Blue Nile was higher in its chemical content while the White Nile around Khartoum was more bacteriologically polluted. The Nile system around Khartoum acquired levels of B. O. D, Oil and Grease and bacteriological counts that exceeded W. H. O. Guidelines.

Funds are lacked for research, laboratory equipments maintenance and repair.

A national plan for water quality of the Nile is recommended in which strong co-operation and co-ordinations between different institutions and specialized professionals are assured so as to serve one objective. The conservation of the Nile water, its quality and quantity.

Chapter One
Introduction

General Introduction:

Water is the backbone of life, on earth it regulates distribution of vegetation and animals, determines the type of climate and affects the human environments. This is the reason that many ancient civilizations developed in the basins of large rivers.

Rivers and streams are internationally the major features of most types of landscape. They play a very important role in socio-economic development. In Africa they can be regarded as the key for development.

Water in streams and rivers contains some constituents contributed by:-

- Precipitation, land erosion, during travel on or through the soil, or added by human activities which may originate in point, or non-point sources because of changes in land use patterns.

All these constituents alter some characteristics of water whether physical, chemical or biological. To assess the changes in water characteristics and test its suitability to various users such as the domestic uses, (including drinking), irrigation, industrial use, or and as a natural ecosystems habitat, is known as water quality monitoring and management.

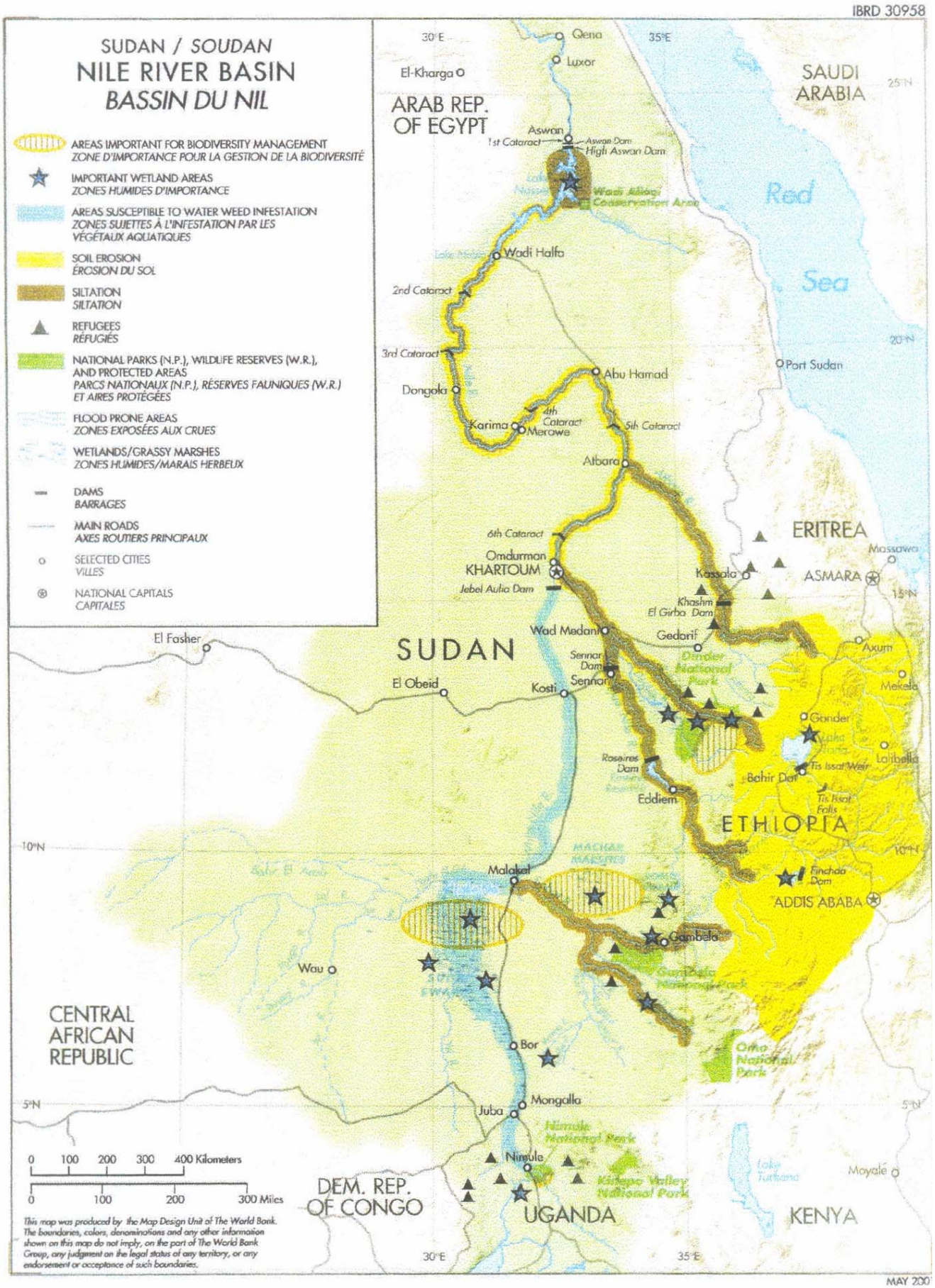
The Nile Basin Initiative (NBI) is a transitional mechanism that includes nine riparian countries as equal members in a regional partnership to promote economic development fight poverty throughout the Basin through equitable utilization of the common Nile Basin water resource.

The initiative shared Vision Program (SVP) includes eight projects. One of these projects is the Nile Transboundary Environmental Action Project (NTEAP). The main objective of the project is to support the development of a basin – wide framework for actions to address high priority transboundary environmental issues of which water quality threats constitute a very important component, Nile Team, (2003).

This is a baseline report for the Nile system water quality in Sudan. The institutional, technical and professional capacities of the country, as well as the current status of water quality was assessed

Water Resources of the Sudan:

Those include rain, ground-water and surface water resources. The latter includes: rain pools, khors, waddis, mountain streams, seasonal rivers, crater lakes, haffirs, swaps, lakes, and river systems of which the Nile and its tributaries – are no doubt – the most important. The river Nile system in Sudan is shown in Fig (1) "Map".


IBRD 30958
SUDAN / SOUDAN
NILE RIVER BASIN
BASSIN DU NIL
AREAS IMPORTANT FOR BIODIVERSITY MANAGEMENT
ZONE D'IMPORTANCE POUR LA GESTION DE LA BIODIVERSITÉ
IMPORTANT WETLAND AREAS
ZONES HUMIDES D'IMPORTANCE
AREAS SUSCEPTIBLE TO WATER WEED INFESTATION
ZONES SUJETTES À L'INFESTATION PAR LES VÉGÉTAUX AQUATIQUES
SOIL EROSION
ÉROSION DU SOL
SILTATION
SILTATION
REFUGEES
RÉFUGIÉS
NATIONAL PARKS (N.P.), WILDLIFE RESERVES (W.R.), AND PROTECTED AREAS
PARCS NATIONAUX (N.P.), RÉSERVES FAUNIQUES (W.R.) ET AIRES PROTÉGÉES
FLOOD PRONE AREAS
ZONES EXPOSÉES AUX CRUES
WETLANDS/GRASSY MARSHES
ZONES HUMIDES/MARAIS HERBEUX
DAMS
BARRAGES
MAIN ROADS
AXES ROUTIERS PRINCIPAUX
SELECTED CITIES
VILLES
NATIONAL CAPITALS
CAPITALES
30°E
35°E
Qena
Luxor
El-Kharga
ARAB REP. OF EGYPT
SAUDI ARABIA
25°N
Aswan
1st Cataract
Aswan Dam
High Aswan Dam
Wadi Allaqi Conservation Area
Red Sea
Wadi Halfa
2nd Cataract
3rd Cataract
Abu Hamad
Port Sudan
20°N
Dongola
Karima
Merowe
4th Cataract
5th Cataract
Atbara
6th Cataract
ERITREA
Massawa
Omdurman
KHARTOUM
Jebel Aulia Dam
Kassala
ASMARA
15°N
Khashm El Girba Dam
El Fasher
Wad Medani
Gedarif
SUDAN
Axum
Sennar Dam
Sennar
Dinder National Park
El Obeid
Kosti
Mekele
Gonder
Rosaires Dam
Lalibela
Bahir Dar
Tis Issat Weir
Eddiem
Tis Issat Falls
ETHIOPIA
10°N
Malakal
Finchaa Dam
ADDIS ABABA
Gambela
Wau
CENTRAL AFRICAN REPUBLIC
Bor
Omo National Park
5°N
Juba
Mongalla
Nimule National Park
Nimule
Kidepo Valley National Park
Lake Turkana
Moyalé
DEM. REP. OF CONGO
UGANDA
KENYA
0 100 200 300 400 Kilometers
0 100 200 300 Miles
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The Nile System:

The Nile which is the longest river in the world (6695 km) is the most dominant feature in north eastern Africa in which it is regarded as the key for socio-economic development. The Nile basin (2.9×10^6 km^2) extends from latitude 4°N to 31°N through the riparian countries. In the Sudan the Nile system extends between latitudes 4°N to 22°N i.e., from the tropical zone where the rainfall is more than 1200 mm to the desert area where is the rail fall decreases than 100 mml.

The Nile system in the Sudan is composed of the following subsystems:-

The White Nile:

This originates from the central equatorial lakes. "Victoria, Kioga, Edward, George and Albert. The Albert Nile leaves lake Albert and flows through the Nimuli gorges at the Sudanese – Ugandan border. In side the Sudanese land it has the name Bahr eljebel (mountain river), which further down stream enters the Sudd Swamps. Inside the Sudd region Bahr eljebel divided to form also Bahr elzaraf. Both are joined with Bahr alarab, B. elghazal and other smaller rivers such as Jur, Bosry, Yei, and Seewy. All these rivers form the White Nile after it receives the river Sobat just to the south of Malakal town.

The Sobat, Originates from the high lands of south west Ethiopia. It is formed of two rivers, Baro and Pibor.

The Sudd consists of 6,000 – 100,000 km^2 of swamps and shallow lakes such as lake Ambadi and Lake No.

The Blue Nile:-

The Blue Nile (Abay) with a catchment approximately 300,000km^2 drains the N – E Ethiopian Plateu. Its source Lake Tana a heart shaped body of water which contributes only about 7% of its annual discharge and most water is collected en route through the Ethiopian highlands from many tributaries the largest of which is the Diddesa Khor. The Sudan, Ethiopian border marks the end of the Ethiopian highlands and the beginning of the Sudan plains.

Inside the Sudan south of Sennar the Blue Nile is joined by two seasonal tributaries "the Dinder and the Rahad".

The Blue Nile flood season extends during the period June – October during which it contributes about 68% of the Nile water budget. Because of its rocky origin

and high speed the Blue Nile transports annually millions of tons of fertile soil, which causes high turbidity values in water and siltation of reservoirs.

The Blue Nile joins the White Nile at the confluence at Khartoum "locally known as Mogran", after which the river system is called the Main Nile, which joins the last tributary "the Atbara" which comes from the Ethiopian palateu at the town of Atbara after which it proceeds to discharge into the Mediterranean.

There are six cataracts along the Nile five of which are inside the Sudan (6^{th} - 2^{nd} and one in Egypt (the 1^{st}.).

The Nile Water Agreements:

After the construction of Sennar dam on the Blue Nile in 1925, the first agreement was signed in May 1929 between the governments of the Sudan and Egypt. Allocations were made on the basis of acquired rights. Egypt had an acquired right of $48\times10^9m^3$. The Sudan has no acquired rights although it needed $4.0 \times 10^9m^3$ for cotton growing.

In 1951 the agreement was amended to allow Sudan to use more water by heightening the Sennar Dam by one meter and the Jebel Aulia Dam by 10cm.

The second agreement was signed between Sudan and Egypt in 1959 to give the Sudan an acquired right of $4.0 \times 10^9m^3$ Sudan agreed to the building the High Dam and became free to build any storage facilities inside its borders. Sudan received an additional $14.5 \times 10^9m^3$ and Egypt an additional $7.5 \times 10^9m^3$. To assure continuous utilization of water in irrigation, Khashm elgirba Dam and the Roseires Dam were constructed on the Atbara and the Blue Nile respectively (completed in 1966). The High Dam was constructed at Aswan, Saghayroun, (1994).

The Sudan now has the right to use $20.5 \times 10^9m^3$ of the Nile water of which about 95% is used in irrigation.

Wetlands: in the Sudan

Wetlands are internationally among the most important ecosystems specially in biodiversity studies. About 3 percent of the Nile basin is covered by wetlands The most important in the Sudan are:

1. Sudd Swamps:

The Sudd is a wetland complex of vast swamps between lake No. and Mangalla. It's area is about 30,000 square kilometers, so it is considered as the largest wetland in

Africa. The lakes, swamps and marshes of the Sudd region buffer stream flows, so they help spread the flow of the Nile over the year.

The Sudd wetland is flat, with a slope of only 0.01 percent or less for 400 kilometers from south to north. The annual floods are a key feature gradually expanding and running over the banks of the main Bahr EL Jebel river then sweeping northwards, the flood water continues northward and reenter the main river channel supplemented by the Bahr EL Ghazal river.

The swamp vegetation is of three types: permanent semipermanant (seasonal) and the river flooded grass lands. Papyrus dominates in the permanent swamp while Typha dominates in the seasonal ones.

Sudd Biodiversity:

During the latest detailed investigation, Range and Swamp survey (1979-1983) 350 species of higher plants were identified, Sudan study on Biodiversity (2001).

- The area as relatively poor in its biodiversity compared to other African wetlands because of the harsh environments such as extremes of drought, floods and fire.
- Higher plants were of four types: climbers, macrophytes ferns and woody plants.

2- The Machar Marshswamps cover an area of about 6500 km^2. It receives the flood water of the Baro river as well as the local rainfall and water flow from Ethiopia, which move slowly through the marshes to the Nile system. It has a very important role in maintaing the river flow throughout the year.

Other important welands are located between the Rahad and Dinder rivers the main tributaries of the Blue Nile.

The Water hyacinth:

Eichhornia crassipes

-The white Nile system was invaded by the Water hyacinth since the fifties-last century.

-In 1958 during an expedition on the white Nile by the Hydrobiological Research Unit (HRU) Staff by the Research Vessel (Malakal)-still existing- *Eichhornia crassipes* invasion was discovered. Recently some of the equatorial lakes have been infested.

-It is as alien plant whose origin is thought to be the Amazon Basin in Brazil. In Sudan- all the area south of jebel-Aulia reservoir is infested. It has a considerable effect on water characteristics.

Much research has been done on its biology, ecology, control and utilization.

Alegislation was enforced since 1960 (Water hyacinth Act). Prohibiting moving it to non-infested areas.

Control methods include physical, mechanical, chemical and biological methods.

- The pesticide 2-4.D has been used in chemical control. It was efficient but ecological consequence were thought to be dangerous.
- Recently, Biological control methods using two *Neochetina* weevils "*Neochetina bruchi* and *N.eichhorniae* gave excellent results. About 350km of the infested area are permanently free of water hyacinth. Moths and Fungi were also used.
- Since early ninties the water hyacinth did not reach jebel-Aulia dam, that is why sharing the Sudanese experience in its biological control was considered a true co-operation between the Nile Basin countries. If implemented, Eltayeb, (2004).

Chapter Two
Water Resources Management in The Sudan

Section (1)

Institutional framework for Water resources management :

These include:

1- The Ministry of Irrigation and Water Resources.

This is responsible for:

1. Development, management, and monitoring of water resources
2. Polices and strategies formulation in water resources management.
3. Handling of shared water issues with neighbouring counties and also at the regional and international levels.

To achieve this, the Ministry has proposed the quarter of the century strategy for water resources (2002) aiming for the rational utilization of the water resource, so as to insure socio-economic development that depends on integrating, balanced and sustainable bases.

The following departments are enclosed within the Ministry:

a. The Natural water Directorate, formed of :-
   - Ground water and Wadis Directorate "chemical and Environmental Isotopes laboratories".
   - The Nile Water Directorate.
b. The Hydraulic Research Station for hydraulic, silt and sedimentation research. The collection and processing of hydrological data is a joint responsibility of the Ministry of Irrigation and Water Resources in Sudan and the Egyptian Irrigation Department (EID). A gauge system is established on the Nile System whose technical reliability is continuously tested.
c. The Permanent Joint Technical Commission for Nile Waters (PJTC) is responsible for the coordination between the Sudan and Egypt in Nile water management.
d. The National Water Corporation.

Historically there were two Corporations responsible for provision of drinking water those were: the National Corporation for Urban water Supply and the National corporation for Rural water supply.

In its meeting on 28.10.1992 the Federal Ministerial Council agreed to the formation of the National Water Corporation which replaced the two former corporations.

The new corporation is supervised by the Irrigation and Water Resources minister, for planning and investment in drinking water supply at the national level.

Production and supply of drinking water is the responsibility of the state governments (State Water Corporations).

They are managerially part of the Irrigation and Water Resources Ministry but technically part of the states ministries of Engineering Affairs.

2- The Ministry of Environment and Tourism:

- The Higher Council for Environment and Natural Resources:

This was established in 1992 as the national body responsible for environmental management. Its main function was to coordinate efforts and advocate the necessity of collaborative work towards conservation and sustainable use of natural resources.

In 1995 after the Ministry of Environment and Tourism was created, the council became its technical arm for resources conservation.

The Environmental protection Act – 2001 summerizes the councils main duties as follows:

- Formulation of environmental polices – in co-ordination with other institutions – for the assessment, development, sustainable use and deterioration prevention of natural resources.
- Formulation of along term federal policy for sustainable use of natural resources.
- Coordinate with the concerned institutions to make quality control measures that lead to environmental protection.
- Conservation of all sources of water and their protection from effects of pollution.

The council has proposed the Naitonal Biodiversity Strategy and Action Plan (NBSAP) and carried out the country study on Biodiversity, (2001), covering all the ecological zones of the country terrestrial or aquatic (fresh or marine) identifying domestic and wild resources of the fauna and natural and cultivated flora.

Legal framework for Water Management in the Sudan:
-Water legislations, Regulations and Acts:-

1- The constitution of the democratic republic of the Sudan (1998). This has called for the conservation, and efficient exploitation of the available water resources.
2- River control regulations.
3- Reservoirs compensation ordinances.
4- Irrigation regulations.
5- Nile pumps Control Board Ordinance, (issued 1939)
6- Taxation ordinances
7- The Fisheries Ordinance, issued in (1954). Regulates, fishing in fresh water and applies to all fresh waters applies to all fresh waters (rivers and lakes) in the Sudan. A similar Ordinance regulating marine fisheries is implemented
8- River Transport in the Nile and Inland Water Ordinance, (Enacted in 1907), (Amended 1990)
9- Sudanese River Transport Corporation Act - 1973.
10- Water Resource Act (1995)
11- Ground Water Act (1997)
12- The water Hyacinth Ordinance (1960)
13- The Environmental Health Act.
14- Wildlife Protection Forces Act. 1981.
Article (7): Forces responsibilities include:
(b) Management of Game Reserves, National parks and Bird Sanctuaries.
15- The Forestry and Renewable Resources Act-2002.
Chapter (3) – section (3). Declaration of a Forest Reserve:-
Article (34): When a Forest Reserve is announced by a regulation, that regulation must determine:
(b) Any water course or water resource open for public use in that area:
The definition of a water resources is:
A seasonal or a permanent river, a valley, an impoundment, a depression, a reservoir, a water pump or a well
16- The Environmental Protection Act (2000):-

Issued by the president of the Republic as a presidential decree with the objectives of environmental protection and sustainable use of resources. This act cancelled the Higher Council for Environment and Natural Resources Act (1991).

Summarized below are some articles of the Act of relation to water quality monitoring and pollution control: "Translated unofficially".

Chapter (3) - Article (18):

"The concerned authorities should observe and follow the following policies and directives for the protection and promotion of the environment:-

Article (18) (b): Conservation of the different sources of water and its protection from pollution.

Chapter (4):-

Article 20: Considered violating this law those who committed many adverse acts, one of which is water resources pollution, the resources include "rivers, seas, lakes, ponds, canals and natural or man made storage facilities.

Chapter (5):

Article (24): The Ministry of Environment and Tourism in coordination with the Higher Council for Environment and Natural Resources and other authorities concerned should issue standards and control remedies for pollution and advertise for them in mass media channels.

Ongoing Projects:

A dam under construction at Merwoe island (Northern Sudan) 30 km upstream from Karima town – A lake is expected to extend for about 180 km from Merowe island to Mograt Island.

A study on fish biodiversity by Abdel Halim et al (1997) revealed that there are twenty-five fish species beside other fourteen species mentioned by fishermen and inhabitants. Jonglei canal project was also proposed in the Sudd region. If implemented it is expected to reduce biodiversity and reduce the grass land area used by local inhabitants in livestock grazing.

Section (2): Institutions Involved in Water Quality Monitoring:-

These include:-

1- The Ministry of Irrigation and Water Resources

Ground Water and Wadis Directorate (GWWD):

Regular Water Quality Monitoring:

Although many institutions are involved in water quality programmes, Regular monitoring is done by the Ministry of Irrigation and water resources. Ground water and Wadis Directorate.

This programme started in 2001, so as to assess water quality status of the two main tributaries of the Nile (the White Nile and the Blue Nile) and also the Main Nile. The sampling is approximately monthly although this is not achieved always. Samples are collected by the Nile Water Directorate and chemical analyses is done at the Ground Water and Wadis Directorate (GWWD) Central Laboratories.

The following stations were chosen:

Table (1): Regular Water Quality Monitoring Sampling Points and their coordinates:

No.	Station	River	State	Coordinates (0)	
				Longitude	Latitude
1	Malakal	White Nile	Upper Nile	31.6 E	9.57 N
2	Soba	Blue Nile	Khartoum	32.46 E	15.44 N
3	Dongola	Main Nile	North	30.6 E	19.02 N

Detected variables include physical and chemical ones, pH, turbidity, electronic conductivity, total dissolved solids, hardness, alkalinity, major cations and anions and nitrogen inorganic compounds.

The laboratories are of two types:

1- Chemical Analysis Laboratories
2- Environmental Isotopes laboratories

2- The Ministry of Higher Education:

Water research is an important activity in most of the research programmes of the ministry departments and universities. The following are just examples:-

1- The university of Khartoum.
2- The Nilain University.
3- The university of Gezira (Wad-Medani)
4- The Sudan University of Science and Technology.
5- The University of Juba.
6- The Islamic University of Omdurman which hosts the UNESCO Chair for water.

In the university of Khartoum water quality research is tackled at many faculties including the Faculty of Medicine, Faculty of Engineering, Faculty of Science, Faculty of Agriculture, and Faculty of Public and Environment Health, and also at:-

- The Institute of Environmental Studies
- This was established in 1979. It offers the degrees of postgraduate diploma in Environmental Studies and Meteorological Studies, M.Sc. and Ph.D. in Environmental Studies.

Within all its research programmes there is a big concern of water but the programmes of Freshwater Ecosystem Management, Urban an Regional Management and Coastal zone management consider water research and monitoring as a priority. Although regular monitoring programmes do not exist but studying water characteristics, whether physical, chemical or biological is always an integral part of ecosystem management research.

3. The Ministry of Health :

Water Chemical and bacteriological analyses is done at the two following laboratires:

a. The National Chemical Laboratory:

Established in 1903 as "Welcome laboratories for Tropical Research for the chemical and bacteriological analysis for water, food, and other analysis of relation to public health.

b. Water and Food Microbiology Laboratory established 1965

4. The Ministry of Science and Technology:

1. The Animal Resources Research. Corporation
   a. The Fisheries Research Centre:

Conducts research on limnology, fisheries and Aquaculture of which studying water characteristics is an important part.

2. The National Centre for Research
   a. The Environmental Research Institute
   b. The Tropical Medicine Research Institute.
3- The Agricultural Research Corporation.
   a- Soil and water laboratory.
   b- Pesticide Chemical Analysis Laboratory.

5. The Ministry of Energy and Mining:

Sudan Petroleum Company, Petroleum Central Laboratories.

6- State Institutions Involved in water quality monitoring:

a. State Water Corporations: responsible for drinking water treatment and supply e.g.:

-Khartoum State Water Corporation.

- Gezira State Water Corporation at Wad Medani.
- River Nile State Water Corporation at Atbara, are examples.

These institutions are managerially part of the National Water Corporation, but technically they are the respensibility of State governments.

b. Khartoum State Ministry of Engineering:

Pollutants remove of the treated sewage effluents is tested at the constructional and Environmental laboratories.

Section (3): Technical and professional capacities of institutions involved in water quality monitoring:

The following laboratories of the previously mentioned institutions- undergo water quality analyses:

1- The ground water and Wadis Directorate Central laboratory (GWWCL).
2- The Institute of Environmental Studies Analytical laboratory "IESAL".
3- The Faculty of Engineering, Sanitary laboratory.
4- The Faculty of Science, Hydrogeology Laboratory. University of Elneelain.
5- The National Health laboratory – National Chemical Laboratory.
6- The National Health laboratory- water and food Microbiology laboratory.
7- The National water Corporation laboratories include:-
   a- Khartoum State water corporation laboratories.
   b- Gezira State water corporation laboratory, Wad Medani.
   c- Nahr Elneel state-water corporation laboratory, Atbara.
8- Khartoum State- Ministry of Engineering Constructional and Environmental. Laboratories.
9- The petroleum Company Central laboratories:

The type of water analyses, technical and professional capacities of different laboratories are summarized in the following tables (2-10).

- Beside these laboratories other specialized laboratories which tackle special tasks include:

1- The Hydraulic Research Station-Ministry of Irrigation and water Resources- (Wad Medani) for sedimentation research and silt monitoring mainly for the Blue Nile and its tributaries.

2- The Pesticides Chemical Analysis laboratory, Agricultural Research Corporation (Wad Medani). Which was established more than 25 years ago. Pesticide residues were tested for using gasliquid chromatography, "G.L.C" and thin layer chromatography "T.L.C" methods.

Most of the chromatographs are not in use now. The infrastructure of the laboratory has very much deteriorated and repair and rehabilitation financial needs exceed largely its available funds.

Ground Water and Wadis Directorate (GWWCL):

Central Laboratories: Established in (1989).

Table (2): Technical and Professional Capacity of GWWCL

Water Analyses	Equipment	Staff	Remarks
Physical chemical and bacteriological analyses.	Titration apparatus -Spectrophoto meter. -Detection probes for pH, conductivity and dissolved oxygen.	8 chemists. 3 Hydrogeologists 5 Technicians. 3 Assistant staff.	The following equipmented are not in use: 1- pH meter. 2- Oxygen meter. 3- Conductivity meter. 4- Flame Photo meter. 5- The liquid scintillation counter the main part Environmental isotopes laboratory.

This laboratory got the authority to issue certificates on the suitability of water to the intended use.

Periodical inter comparison by the International Agency for Atomic Energy (IAAE) conducted in 1997, for relevant laboratories in African countries assured the laboratory quality.

- If funds are allocated for equipment maintenance and training of staff, its efficiency will be highly raised.

Institute of Environmental Studies:

Analytical Laboratory: "IESAL"

- Established in 1953 as the Hydrobiological Research unit "HRU" as apart of the Faculty of Science, University of Khartoum.

- In 1992 it was officially considered as a part of the Institute of Environmental studies.

Table (3): Technical and professional capacity of (IESAL)

Water analyses	Equipments	Staff	Remarks
Physical and chemical analyses of water which include pH, D. O, B.O.D, C.O.D. conductivity -Nitrogen and phosphorous compounds. -Oil and grease. -Heavy metals. major cations and anions 2- Biological characteristics of water: - Phytoplaankton -Zooplankton, Benthos -and aquatic weeds.	1-pH meter, 2- conductivity meter (very old). in good condition: 3-HACH.DR 2000 spectrophotometer (A.A.S). -Those equipments are not is use "Faulty". 1- Oxygen meter. 2- An Ultraviolent/ Visible light (UV/VIS) spectrophotometer. * The research vessel (Malakal) which is a unique tool for long limnological research expeditions, by which long stretches of the Nile system can be studied.	1- Co-ordinator (Ph. D). 2- Two lab technicians. 3- Two lab assistants.	Chemicals for the HACH spectrophotometer and detection lambs for the A.A.S are not available -The building of IESAL is very old. No transportation facility (Vehicli" is available. Maintenance and daily needed funds for the equipments and R.V. Malakal are lacked.

Sanitary Laboratory of Civil Engineering Department
Faculty of Engineering
University of Khartoum
-Established at 1967 by W.H.O.

Table (4): Technical and Professional Capacity of the Sanitary Laboratory (Civil Engineering Department).

Analyses	Equipments	Staff
Physical, chemical and bacteriological tests for surface, ground, and waste water	-Turbidity meter -Dissolved oxygen meter -B.O.D apparatus -C.O.D apparatus -Incubators -Ovens -Microscopes -Others	-Two Ph. D holders in environmental engineering. -Two M.Sc. holders in sanitary engineering. -Two lab technicians.

Remarks:

- The staff of the sanitary engineering section is used to carry out training courses for water engineers in different organizations and institutions in the country. Three courses were conducted in 2004.
- The laboratory is in need for modern equipments with data loggers in order to raise its efficiency.
- The existing equipments need maintenance.

Six members of the Department staff are highly qualified in Hydrological and Water quality modeling.

Table (5): The technical and professional capacities of the Hydrogeology Laboratory Faculty of Science. Elneelain University

Analyses	Equipments	Staff
- Analyses of surface ground, and marine water - Physical, Chemical and bacteriological tests	pH meter - Calorimeter - Spectrophotometer - Flame photometer - Atomic Absorption Spectrophotometer - Filtration apparatus - B.O.D apparatus - C.O.D apparatus	Ph.D & M.Sc. holders - laboratory technians (B. Sc.)

The National Health Laboratory.

a- The National Chemical laboratory:

Established in 1903 as welcome Research Laboratories for the analyses of water, food and toxins for quality assurance.

It is composed of four divisions, food, water, toxins and the general division.

The water division tackles the following tasks:

1- Chemical analyses of drinking water to test its suitability for human consumption according to W.H.O guidelines and Sudanese standards.
2- Issuing quality assurance certificates for potable water, those certificates are accepted to health and legal authorities.
3- Chemical analysis for domestic and industrial sewage.
4- A regular monitoring programme for the Nile water around Khartoum was going on till 1994. It stopped due to technical and financial reasons.
5- Training of water analysis technical staff in other departments such as the National Water Corporation for Khartoum state water corporation and other states.

Table (6): Technical and Professional capacities of the National Chemical Laboratory.

Water Analyses	**Equipments**	**Staff**	**Remark**
Physical and chemical analyses of potable and waste water.	- pH meter - Conductivity meter. - Flame photometer - Calorimeter. - GLC (Gas liquid chromatograph) -HPLC (High performance liquid chromatograph). -Spectrophotometer. -Titration apparatus.	- Two scientific researchers. - Two scientific research assistants. - Three lab. technicians. -Two lab. attendants.	-The Atomic Absorption Spectrophotometer is not in use and needs fluoride electrode.

National Health Laboratory:

b- Water and food Microbiology Laboratory Established: 1965

Staff:

1- Senior Scientist (M. Sc. with long experience more than 15 years)
2- Scientists (M. Sc. experience not less than 4 years)
3- Assistant scientist (B.Sc. Hon.) lab. Tech. B. Sc. and lab. attendant:

Table (7): : Technical and Professional Capacities of the Water food Microbiology Laboratory

Analyses	Equipments	Remarks
Bacteriological tests, include: 1- presence- Absence coliform test 2- presence –Absence *Escherichia Coli* test. 3- Coliform test by: b- Membrane Filter Technique. c- Multiple- Tube Techniques. 4- Heterotrophic plate count "Standard plate count" by pour plate Method.	1- Autoclaves 2- Hot air oven 3- Refrigerators 4- Balance 5- Water bath incubator 6- Laminar flow Safety cabinets 7- Water purification system 8- Membrane filtration equipments 9- Colony counter 10- Digital thermometer	All the equipments one Media are provided by W.H.O and some are not always available. The water purification system is instable.

*** Activities of the laboratory:**

- Routine Analyses for water and food (on request).
- Training for health inspectors.
- Training for university students on routine analyses.

Funds for research are not available.

National water Corporation Laboratories:

Khartoum state water corporation laboratory:

Formerly: "Al mogran water works central Lab- established" at 1963.

Table (8): Technical and Profession Capacities of the National Water Khartoum State wall corporation laboratories:

Analyses	Equipments	Staff	Remarks
-Analyses for drinking water. -Microbiological tests.	-pH meter -spectrophotometer. - Conductivity meter. - Colorimeter. -Titration apparatus -Microbiological test equipments.	-Five lab technicians (B.Sc). -Two technicians with Diploma.	Expecting to have -Gas chromatograph. - Atomic Absorption Spectrophotometer.

b) Gezira State W.C. lab, Wad Medani

Since 1972.

Analyses	Equipments	Staff	Remarks
physical, chemical, and Microbiological tests for drinking water	-Spectrophotometer. -Dionic reading Turbidity meter T.D.S. meter. for bacteriological test oven, incubater Agar media.	1- Engineer director 2- Two lab technicians	The technicians need training

Khartoum State Ministry of Engineering Affairs

Table (9): Technical and Professional capacity of Construction and Environmental Laboratory

-Established (1993)

Analyses	Equipment	Staff	Remarks
-Physical and chemical analyses for a water domestic and industrial sewage. - Microbiological analyses: paur plate count Membrane filtration	pH meter colorimeter spectrophotometer conductivity meter B.O.D apparatus C.O.D apparatus.	-One scientist with M. Sc. - Five lab technicians (B. Sc). -One with Diploma.	C.O. D reactor faulty. Equipments repair personnel training are needed

Ministry of Energy and Mining (M.E.M)
Sudanese Petroleum Company (S.P.C)

Table (10) : Technical and Professional Capacity, Central Petroleum Laboratory

Analysis	Equipments	Staff	Remarks
- Physical and Chemical analysis for potable and waste water - Analysis for water used in petroleum extraction - Bacteriological tests for potable water	- pH meter - Conductivity meter - Colorimeter - Spectrophotometer - Atomic absorption Spectrophotometer - x-ray fluorescence (X.R.F) - Gas chromatography equipments. - Microbiological tests equipments (oven, microscope, autoclaves, incubators, bacterial cowter and laminer flow) - Titration apparatus.	- Three "B.Sc" lab technicians, trained locality. - Two assistants.	- Expecting to have - H.P.L.C. - B.O.D apparatus - Oil content test equipments - The laboratory is very modern. Analyses is done on request with High fees

CHAPTER THREE
Nile Water Quality Status

Section (1): Regular monitoring programmes data:

a. Ministry of Irrigation and Water Resources data Ground Water and Wadis laboratories.

The water quality results (physical and chemical analyses results) of the three regular sampling stations for the year (2003 – 2004) are ummarized in below:

Table (11) Nile Water System Results of Physical and chemical Analyses for three selected sites (2003-2004) show maximum and minimum concentrations, (G.W.&W Labs)

Location	NILE (Dongola)		BLUE NILE (Soba)		WHITE NILE (Malkal)	
	x	y	x	y	x	y
coordinate	30.6E	19.02N	32.61E	15.5N	31.6E	9.57N
Water level (m)	13.5	9.26	16.25	8	12.45	12.7
Discharge(m3/day)	680.64	49	552.6	8.3	97	12.08
PARAMETER	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.
Appearance	muddy	turbid	muddy	clear	muddy	turbid
TURBIDITY NTU	6575	5	7275	4	115	6
PH	8.4	7.3	8.4	7.5	7.6	7.3
CONDUCT. Us/cm	278	183	295	194	180	121
Hardness	116	50	132	80	86	26
Alkalinity	178	122	183	79.2	109	73
Calcium	40	14	37.6	24.8	5.6	
Magnesium	17	3	13.61	2.43	13	2.9
Chloride	34	7.1	22.72	4.6	9.9	5.7
Sulfate	39	1	42	8	5	1
Nitrate	12.3	0	3.96	0	5.7	0.3
Nitrite	0.99	0	0.52	0	0	0
TSS	8400	8	8875	3	126	84
TDS	194	126	189	125	18	2
Fluoride	0.85	0.2	0.7	0.2	0.9	0.6

Water Quality Status Assessment:

To assess the water quality situation. The results achieved for water analysis at GWWD was summarized. Five key parameters were chosen as indicators. Annual minima and maxima for these parameters were identified at the three monitoring stations (Malakal, Suba and Dongola:

The chosen five key parameters include: Electronic conductivity "E.C.), chloride concentration, and Nitrogen inorganic compounds concentrations "Nitrate, Nitrite and Ammonia" these are chosen as indicators of pollution, Elhassan and Abdelmajed (1986).

Table (11) Summerizes the water quality data key parameters at Malakal station on the White Nile:

This data can be considered as a record for the status of the White Nile after entering the Sudanese borders.

Table (12): Malakal White Nile annual minimum and maximum values of Water quality key parameters

Sampling Station Malakal: (White Nile) Coordinates : longitude 31.6 E Latitude 9.57 N

Year	Minimum and Maximum Values									
	E.C. µS/cm		Chloride mg/l		Nitrate (NO_3) mg/l		Nitrate (NO_2) mg/l		Ammonia (NH_3) mg/l	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
2001	121	158	5.7	9.9	0.31	5.72	0.0	0.02	0.02	0.02
2002	125	180	7.1	9.2	0.0	0.3	0.0	0.0	0.0	0.19
2003	176	236	3.5	7.1	2.2	8.8	0.003	0.09	0.11	0.30
W.H.O. Guidelines	-	-	250		50		3.0		1.5	

It can be observed that:

1- The maximum value of electronic conductivity increased through the years 2001 – 2003.
2- Maximum chloride concentrations are far below the W. H. O. standards. No chloride buildup is noticed.
3- The maximum nitrate and ammonia concentrations were recorded in 2003. The two are far below the guideline values of W. H. O.

Table (13): Suba Blue Nile: Annual Minimum and Maximum values of Water Quality key parameters

Station Suba Blue Nile Coordinates : longitude 32.46 E Latitude 15.4 N

Year	Minimum and Maximum Values									
	E.C. µS/cm		Chloride mg/l		Nitrite (NO_3) mg/l		Nitrite (NO_2) mg/l		Ammonia (NH_3) mg/l	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
2001	93.22	244	3.6	22.7	0.17	14.9	0.0	0.33	0.002	0.27
2002	183	644	4.9	28.6	0.0	10.56	0.0	0.1	0.0	0.45
2003	210	874	5.68	35.5	2.2	12.32	0.006	0.148	0.06	0.63
2004	241	258	0.0	16.2	0.0	3.96	0.01	0.36	0.04	1.29
W.H.O. Guidelines	-	-	250		50		3.0		1.5	

- Maximum (also minimum) values for electronic conductivity increased annually (2001-2003).
- Maximum (also minimum) concentrations for chloride increased annually through the period 2001 – 2003. values are very high compared to those of the White Nile at Malakal. A distinct chloride build up is going on in Blue Nile Water.
- Nitrate values are higher than those detected in the White Nile (at Malakal), Probably due to run off from irrigated schemes at the Blue Nile.
- Ammonia (NH3) values increased annually (2001-2004). They are very high compared to those of the White Nile. The last value approached the maximum W. H. O. guideline value.

Table (14): Dongola: Main Nile : Annual Minimum and Maximum Values of Water Quality key Parameters

Station Dongola Coordinates : longitude 30.6 E
Main Nile Latitude 19.02 N

Year	Minimum and Maximum Values									
	E.C. µS/cm		Chloride mg/l		Nitrate (NO_3) mg/l		Nitrite (NO_2 mg/l		Ammonia (NH_3) mg/l	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
2001	238	442.2	9.2	17	0.0	13.6	0.0	0.019	0.0	0.44
2002	184	318	7.1	12.8	0.0	13.2	0.0	0.102	0.0	0.38
2003	133	278	4.3	23.4	0.0	12.3	0.0	0.08	0.0	0.80
2004	183	309	7.8	34	0.0	9.24	0.003	0.99	0.0	0.98
W.H.O. Guidelines	-	-	250		50		3.0		1.5	

- The Maximum chloride concentrations increased through the years "2001 – 2003 – 2004"
- The Maximum Nitrate (NO3) concentration decreased and the maximum Ammonia concentration increased (2001-2003-2004) so, the water quality is shifting to the pollution direction (although not polluted).

The water of the three rivers is not chemically polluted but differences exist between the three stations data.

- The Blue Nile water recorded the highest values for chloride, nitrates and ammonia indicating the highest chloride buildup, maximum nutrient values (nitrates) and maximum ammonia (1.29mg/L) which is observed to be very close to the maximum W. H. O. guideline value (1.5 mg/L).
- The high discharge of the Main Nile and its self purification capacity make the water at Dongola of better water quality status.

The overall maximum concentrations of chloride, nitrate, nitrite and ammonia are shown in Figures 2-5.

Fig. 2-5: Overall maximum concentrations in the Nile system , for the years (2001 – 2004)

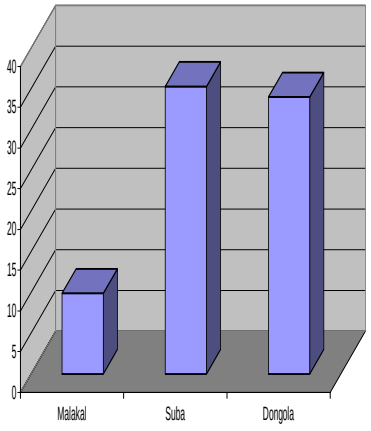


Fig: (2): Chloride

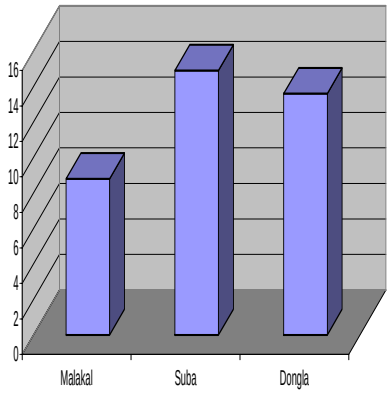
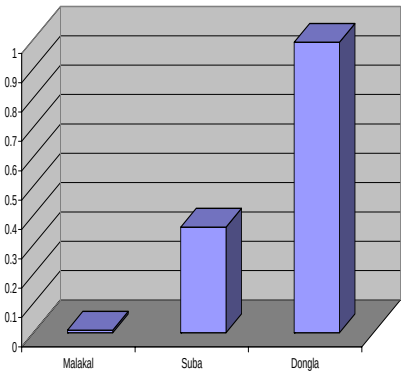


Fig: (3): Nitrate



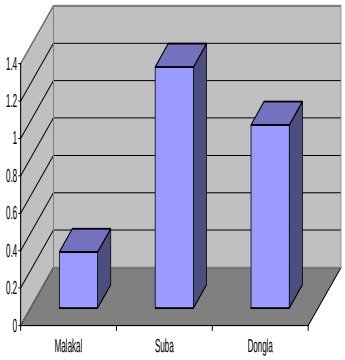


Fig: (4): Nitrite **Fig: (5): Ammonia**

Khartoum State Water Corporation Water Quality Monitoring Results:

Results of raw water analysis done at the three Khartoum State water corporation Laboratories so as to determine the required treatment for drinking water are summarized in below:

Table (15) Average max and min. concentrations for the Period (1997-2003)

Location	Main NILE		BLUE NILE		WHITE NILE	
	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.
PARAMETER						
Appearance	muddy	turbid	muddy	clear	muddy	turbid
Temp.°C	35	19	35	18	35	19
TURBIDITY NTU	21040	45	19575	2	22575	55
PH	8.7	7.9	8.9	7.8	8.9	7.8
CONDUCT. Us/cm	240	150	240	160	220	140
Hardness mg/L	70	50	75	50	60	50
Alkalinity "	120	70	120	70	120	70
Calcium "	30	18	28	18	30	20
Magnesium "	4.8	2.6	4.8	2.8	4.8	2.4
Chloride "	10	4	10	4	10	4
Sulfate "	16	6	16	8	16	7
Iron total "	0.1	0.03	0.1	0.02	0.1	0
Nitrate "	2.4	0	2	0	2.8	0
Nitrite "	0.001	0.0005	0.0003	0.001	0.0001	0.0007
Copper "	0	0	0	0	0	0
Manganese "	0.04	0	0.02	0	0.01	0
Silica "	4.2	2.8	4.8	1.8	4	1
TSS "	24600	40	22350	15	26950	70
TDS "	120	60	120	70	110	70
Fluoride	0.32	0.31	0.35	0.32	0.45	0.32
Total count /5ml	1700	170	1200	90	2100	200
Coli form /1oo	20	0	10	0	30	10

Due to the very strong current of the seasonal river Atbara during the flood period the total suspended solid of the Nile water increases and varies from 20000-50000 mg/l.

Most of the suspended solids consist of silt and sand. the other factor is colloids (about 15-25% of all the suspension.

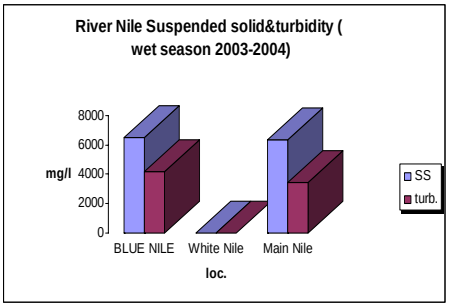
Source: Khartoum state water corporation, water quality control laboratory

Analyses and Interpretation of data:

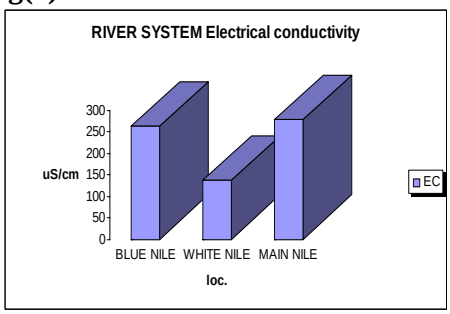
Physical Parameters:

Temperature, PH, Turbidity, Suspended solids, Appearance, Conductivity are the major Parameters measured in the laboratory. The result of SS and turbidity of the river system indicated that high values for SS, are registered from Blue Nile, and Main. Nile (>7000 mg/l), as well as turbidity and total dissolved solids, the reason is the high amount of silt which is carried by the riveres during flood Season.

Fig (6)



Fig(7)

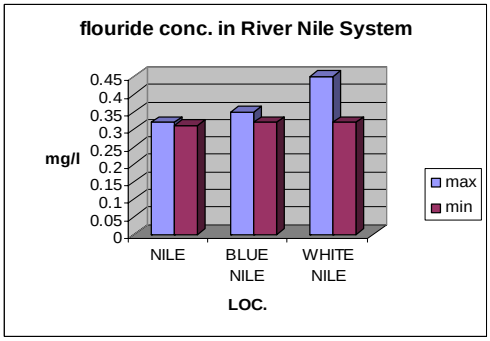


-Chemical parameters

Data collected from Khartoum water corporation for the period 1997 to 2003 show deficits in fluoride concentration in River Nile system, and the lowest value was measured in Blue Nile at Khartoum station (0.35), and (0.45) at white Nile, while 0.6 recorded at the Main Nile at Dongola station (see fig 8)

Generally these concentration are low compared with WHO permissible limit 0.5-1.05 mg/l

Fig (8) Fluoride, and Silica concentrations for the period (1997-2003)



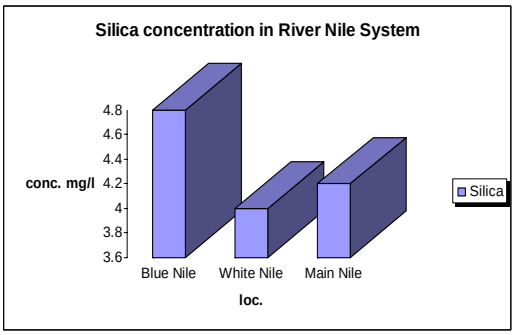
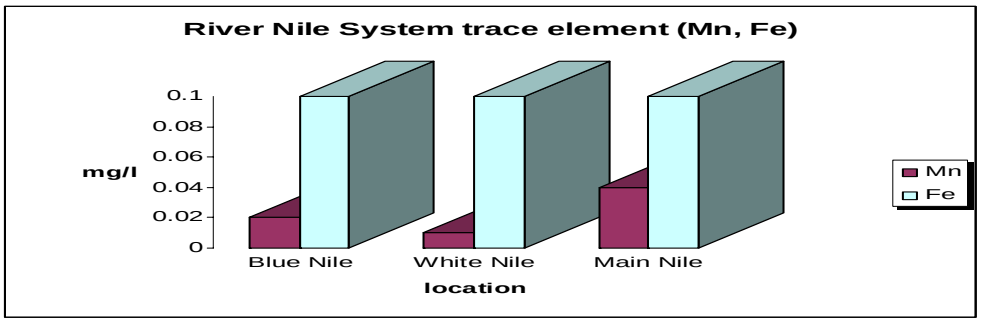


Fig (9) Trace element max, min, concentration period (1997-2003)



Results of analysis show that the trace element (Mn, Fe)
Are low compared with (WHO) Guidelines.

Microbiological Indicators:

Bacteriological tests showed that the highest contamination. (>30 colony/100 ml, was recorded in samples from White Nile water, and >20 colony/100ml total coli form in the main Nile, and lowest values at Blue Nile. The reasons behind that, the White Nile is very wide, its speed and discharge were low compared with the Blue Nile (self-purification), also the presence of weeds, organic and colloidal material, all these conditions help growth of bacteria. (Fig 10 & 11, table, 15).

Fig (10)

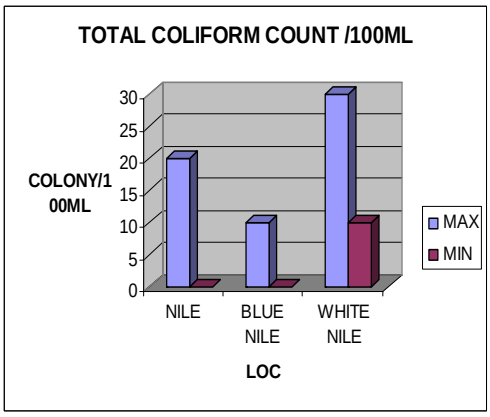
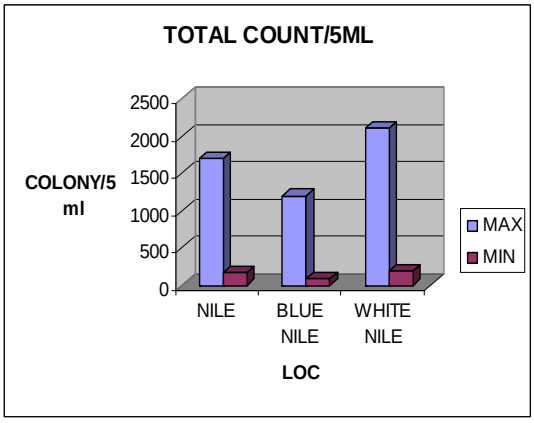


Fig (11)



Water Quality Research in the Sudan (Historical perspective):

These started by scattered observations on chemical composition of the Nile Water by Beam at 1906.

In 1953 the Hydrobiological Research Unit (H. R. U.) was created within the Zoology Department at the Faculty of Science with the goal of exploring the Nile system and adjacent waters within the Sudan. The venue and laboratory equipments of the Unit are now the analyses laboratories of the Institute of Environmental Studies (IESAL).

Water characteristics (physical and chemical) were studied in relation to ecological studies – mainly phytoplankton production.

- Maximum photosynthetic activity was found to be accompanied with a rise in pH and dissolved oxygen and depletion of plant nutrients mainly phosphates.

- Talling, (1957) studied the water physical and chemical characteristics of the White Nile between lake Victoria and Khartoum. He concluded that lake Albert had a very important role in addition of some dissolved salts "phosphates, sulphates and chloride'.
- Talling, (1963) analysed the Blue and White Nile waters : He found that the White Nile water contained lower sulphate and higher silicate values than the Blue Nile.
- Abu Gideiri, (1969) studied plankton development at the Mogran and at the northern part of the White Nile. Maximum planktonic growth was found to be accompanied with high pH and depletion of nitrates and phosphates.
- Sinada, (1972) studied phytoplankton production in the Nile at Khartoum. His study contained valuable data on water characterists.
- Mognraby, (1972) studied. Zooplankton of the Blue Nile and also wate characteistics were studied.
- The data contained in these studies is very useful to assess changes in water quality when compared to recent records, for example:-
- The average nitrate value recorded by Sinada, (1972) for the Blue Nile at Khartoum was 0.27 mg/l. If this value is compared with recent values found by the 'GWWD" laboratories (14 mg/L in 2001). The change that happened in the water nitrate content can be assessed.
- Biological studies have shown that the phytoplankton species diversity has changed. Some diatoms have disappeared and Blue – green algae and Macrophytes are increasing

Recent Studies

Recent studies and surveys by Ali (1994) on both Jebel-Aulia reservoir and Lake Nubia and Musso, (2000) at Jelhac on the White Nile showed that the chemical content of the Nile System is still within the W. H. O. Guideline values.

A very recent study on the Main Nile at Atbara, Hamed (2005) also showed that the water quality the Main Nile at Atbara falls within the W. H. O. Guideline values (Annex-1) and the Sudanese Drinking water standards (2002) - (Annex 2).

The above mentioned data together with that of the previously mentioned regular monitoring programmes of the "GWWDL" and "K.S.W.C." Laboratories and also limited data from "G.S.W.C" laboratories at Wad-Medani, were all combined in table (16) for the assessment of water quality of the whole Nile system in the Sudan.

The Nile System Water Quality Station in the Sudan:-

Table (16): Physico-Chemical analyses data for the whole Nile system in the Sudan (from different sources)

Location And Source, (Reference)	pH	D.O. mg/L	E.C. µs/cm	Cl mg/L	NO_3 Mg/L	NO_2 mg/L	NH_3 mg/L	Na Mg/L	Ca mg/L	Mg mg/L	K mg/L	SO_4 mg/L	PO_4 -P mg/L	SiO_2-Si mg/L
B.N. Wad Medani G.S.W.C. lab. (2005)	-	-	-	10	-	-	-	-	30	12	-	25	-	-
B. N. Soba G.W.W.C. lab. (2004)	8.4	-	295	22.7	3.96	0.36	1.29	-	37.6	13.6	-	42	-	-
B.N. Khartoum K.S.W.C. lab. (2004)	8.9	-	240	10	2.0	0.009	-	-	28	4.8	-	16	-	4.8
W. N. Malakal G.W.W.C. lab. (2004)	7.6	-	180	9.9	3.7	0.003	0.30	-	5.6	13	-	5	-	-
W. N. Jelhac. Musso, 2000	7.8	7.5	379.2	2.97	2.8	-	-	-	-	-	-	7.43	0.17	25.6
W. N. Jebel-Aulia. Ali, (1994)	7.45	7.8	270	-	0.77	-	-	-	21.8	6.1	-	-	0.033	34.5
W.N. Khatoum K.S.W.C. lab. (2004)	8.9	-	220	10	2.8	0.0001	-	-	30	4.8	-	16	-	4
Main Nile Khartoum K.S.W.C. lab. (2004)	8.7	-	240	10	2.4	0.001	-	-	30	4.8	-	16	-	4.2
Main Nile Atbara Hamed, 2005	7.02	-	1 87	12	1.76	0.03	-	20	21	11	4.11	4	-	-
M. N. Dongola G.W.W.C.Lab (2004)	8.4	-	278	34	12.3	0.99	0.98	19	40	17	-	16	-	-
M.N. Lake Nubia. Ali, (1994)	6.7	11.4	275.6	-	0.68	-	-	-	14.8	8.4	-	-	0.023	23
W.H.O. Drinking water Guidelines (1996)	-	-	-	250	50	3	1.5	200	-	-	-	250	-	-
Sudanese Standards For Drinking water mg/l (2002)	6.5-8.5	-	-	250	50	2	1.5	200	-	-	-	250	-	-

- Not Available

Pollution Assessment in the Nile System around Khartoum

Elhassan, (2002) conducted a valuable survey for the Nile System at Khartoum to identify sources of pollution. Nine sampling sites were chosen at the Blue, and the White and their confluence.

Two sites at the Blue Nile and the confluence area recorded a B. O. D. values higher than the maximum W.H.O. Guideline value. At all the sampling sites (except one) the Oil and Grease values exceeded the W.H.O. Guidelines value, the maximum values 231 and 237.2 were recorded at the power stations on the Blue Nile.

The high level of bacteriological pollution is shown from E.coli values at different sites. The higher value of colon bacteria at the Blue Nile (10,400/100ml) was recorded at the Freindship Hotel, and at the confluence area (17.00/100ml) while bacterial counts at the White Nile were uncountable, showing that it is more polluted. The Chromium (Cr^{+6}) level at the White Nile (0.42mg/l) was ten fold the W.H.O. guideline value (0.042mg/l).

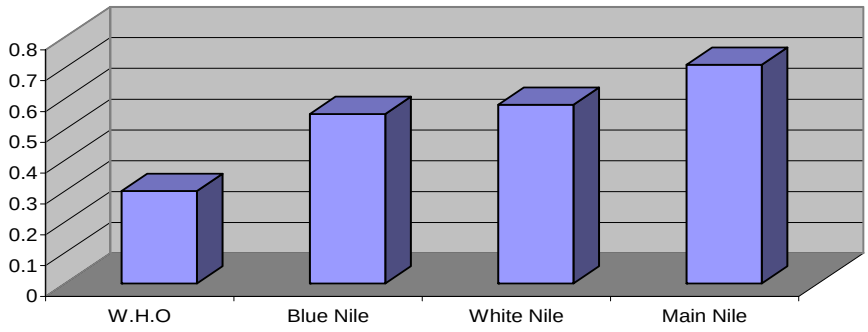
Saeed (2004) bacteriological survey on the Nile system at Khartoum also detected the colon bacteria (E.Coli) in all the White Nile samples, which was found to be more bacteriologically polluted than the Blue Nile.

Heavy Metal pollution around Khartoum:

As previously mentioned, Elhassan, (2002) detected chromisum at a very high level in the White Nile at Khartoum.

Saeed, (2004) detected iron concentrations in the Nile system around Khartoum, all the values were higher than the W.H.O. guideline values.

Figure 10: Average Iron concentrations in Nile Waters around Khartoum year (2001)



Silt Sedimentation Research:

The sediment monitoring programe was implemented by the Hydraulic Research station. (Ministry of Irrigation and Water Resources) since 1991.

In 1997 it was extended to cover the Rahad Scheme sedimentation at the Dinder river was also studied.

- The Blue Nile average annual contribution to the Main Nile was estimated as 69%, and its annual flood flow as 93 billion m^3.
- Its annually suspended load was estimated as 140 million tons. This load causes many problems such as Turbidity and deposition in reservoirs, and irrigation canals and blockage of turbines, Gism Alla, (2000).

- The sediment concentration was found to higher than 3000 ppm for the period July I – Sept. 1 at Roseires reservoir on the Blue Nile. At the Dinder River the maximum sediment concentration was 6738ppm.
- The quantities and input to Main Canals of irrigated schemes and the sediment concentrations of the Blue Nile at different locations are presented in table ( ).

Table 17: Sediment Concentration and Discharge to Gezira and Managil Schemes:

Quantities and % age of sediment input to the Main canals: 1995-1999

Year	Total Sediment (Million Tons)	To Gezira	To reanagil
1995	3.6	53%	47%
1996	8.0	56%	44%
1997	5.6	53%	47%
1998	6.5	55%	45%
1999	7.4	60%	40%

Source: Gismalla, (2000).

Pollution Risks:

The Nile systems in Sudan hosts many twons, many agricultural schemes and industrial projects (e.g. Sugar factories) are situated between or at its banks.This system therefore is vulnerable to pollution risks. Because it is sensitive to any change and even a mild degree of eutrophication could have a serious effect on it, due to its high temperature and radiation inputs, Hammerton, (1972).

Major sources of pollution to the Nile system:

1- Agrochemicals' usage:

Those include fertilizers, pesticides, hormones and other chemicals used in agricultural production.

- Fertilizers in runnoff rise the nutrients level in running water leading to algal blooms and multiplication of macrophytes and alter the phytoplankton species composition and hence all the ecosystem components.
- As Sudan's economy depends mainly on the production of cotton for which an irrigated area of about 500X103 feddans is allocated per season, and as cotton during its long growing season needs huge amounts of pesticides, the danger is very great.
- Sudan started pesticides application since mid thirties of the last century.
- D.D.T was started to be used in Gezira scheme in the mid-forties till 1982, after which it was replaced by Organophosphates and Carbamates. Lately neo-nicotinoids are being introduced, Elzurgani (2004).
- Cotton also demands considerable amounts of Herbicides and Fungicides (beside insecticides).
- With the elimination of natural enemies of pests and resistance development by pests, the required. Pesticides' quantities increased annually.
- The first law which organized pesticides usage was issued in 1974. (Pesticides Act-1974).
- Before this Act was issued, already more than 152 pesticides were used in the Sudan. Abdel Latif, (1993).
- Now more than 500 compounds are imported to be used as pesticides.

- The pesticides Act was apdated and the current law is the "Pesticides and Pest control Products Act, 1994" implemented by the National pesticides Council CNPC".
- 90% of the imported pesticides are used by large agricultural schemes which follow scientific methods in application while 10% is used by small farmers who mostly do not follow the rules of safe pesticides application.
- Irrigation canals in the Gezira irrigated scheme were considered as the major sites of freshwater pollution, George and ElMoghraby, (1978).
- Instensification of agricultural production in other parts of Sudan " in the west and the east", maximizes the hazard of run-off containing agricultural chemicals. Unknown amounts of these chemicals reach the Nile system either by drift through wind action during sparying or run-off through the fields or irrigation canals during the rainy season.
- Although concentrations of pesticide residues in the open water body are considerably lowered by dilution, adverse effects were recorded.
- Residues of organochlorine compounds have been recorded in Fish from lake Nubia more than 200km downstream. The Fish "kass". Hydrocyon Forkalii (CUV) fat tissue was found to have the highest residue levels ranging from 0.4 - 3.3 ppm, followed by muscles with concentrations 0.01-0.25 ppm, ElZorgani et al, (1998).
- Pesticide residues detection in blood and breast milk for inhabitants of Ghorashi area at Hasahesia twon (On the Blue Nile) where pesticides (DDT mainly) purchased by the Gezira Board were stored for more than three decades. showed that the range of D. D. E (D.D.T derivative) in blood samples was 8.41-50.84 p.p.m while in breast milk it was 2.58-15.95 p.p.m as reported by Elzorgani et al (1994).
- Cotton pesticides residues-which are very dangerous were detected on the surface and inside Tomato furits from Wad Medani vegetable market: Dursban concentration was 1.5ppm inside the Tomato fruits and b-Endousulfan 0.897pp, Osman et al, (1996).
- -Pesticide residues were also detected in blood samples for workers at the Agricultural Research corporaton Wad Medani. Samples were found to contanin D.D.E. and Heptachlor, as reported by Mohamed, (1998).

2-Urbanization:

Urbanization is taking place in many urban centres in the Sudan. The most important centres adjacent to the Nile system are Wad Medani on the Blue Nile and Khartoum at the Blue and White Nile confluence.

Khartoum is the capital and the largest urban centre in the Sudan. Its position at the confluence of the two main tributaries of the Nile (Mogran) adds very much to its beauity and uniqueness, but also qualifies it as the most attrackting living place in the country. It now hosts about one fifth of the Sudanese population “about 6 millions”. Urbanization in Khartoum is increasing, many industrial projects are continuously inplemented. Emigration of citizen to Khartoum is countinuously increasing. This will certainly impose more pressure on the Nile water around Khartoum. Remarkable effects on both its quality and quantity will be taking place. The former is affected by inputs from industrial, agricultural and domestic sewage sources, and the latter is affected by pumping more water to satisfy the needs of the growing population and various developmental needs.

Sources of pollution include:

a. Urban runoff, solutions of many solid water which may be of domestic or industrial origin and automobiles gaseoues exhausts are dissolved and carried to the Nile.
b. Some recently established buildings e.g student hostiles, Hotels are disposing their sewage effluents directly in the Nile system. Precise assessment of their danger is very necessary.
c. Recreational sites created at the banks of the Blue Nile, White Nile and the conference area are also threatening the quality of the Nile water. Very recent analyses have recorded high B.O.D values and bacteriological counts, Elhassan, (2002).
d. Power stations located near the Nile are using its water for cooling and disposing their exhaust oil in the Nile. Elhassan (2002) former survey recorded high values of oil and grease near Burri power station on the Blue Nile.
e. Domestic and industrial sewage.

In Khartoum the public sewage system covers only a small part of the city. Septic tanks are used as private systems in most of the twon. After treatment, the effluent goes to the groundwater, with an expected serious effect to its quality, (UNESCO, National comission). A part of the population still use traditional earth pits.

For the public sewage system, there are two plants for municipal waste water treatmen in Khartoum. Those plants belong to a public company called Khartoum Environmental and Sanitation Company. Those treatments plants are located at Suba (south of Khartoum) and Elhaj Yousif- (east of Khartoum North).

- Assessment showed that there was 71.30% B.O.D. removal, 60% C.O.D removal and 80% Total Suspended Solids removal, Constructional and Environmental Laboratory data, (2005).The sewage treatment plant at Suba uses biological control methods. (Stabilization Ponds).

The treated sewage effluent is used in irrigation of trees and other fodder cultivations. This is the situation as planned for but in certain situations like rainy seasons the sewage effluents may find an access to the river water. With the increasing population of Khartoum the Nile system may be decided on to receive treated sewage effluents in the future. If this happens very serious consequences must be considered.

The water human contact also may threaten the water quality, people are using the Nile system for swimming, bathing, car and clothes washing which may cause bacteriological pollution.

Industrial pollution:

Few industris are using water for industrial purposes either as an ingredient of products or in cooling systems. The most serious source of industrial pollution to the Nile in Sudan is the sugar factories. Which dispose highly enriched organic waste to both the Blue Nile and the White Nile .

The level of treatment achieved at those factories, the ecological consequences of waste disposal need a scientific assessment to assess the effects on the water oxygen content, light penetration and Biological Oxygen Demand (B.O.D) and their consequencies on primary productivity, and bottom flora and fauna.

Chapter Four
International, local Non-governmental Organizations, and Public Participation in Water quality issues

a) International Organizations (UN agencies) Involved in Water Quality:

UNICEF:

This has played a very important role in provision of drinking water as the major provider of hand pumps which proved to be a simple affordable and low cost technological alternative to boreholes and haffirs. UNICEF valuable information about children's mortality caused by different diseases- Some related to water is also very useful.

WHO:

- The role of WHO is establishing scientific laboratories especialized in water analyses, (the very most clear example is the National Health laboratory is very great.
- WHO guidelines for drinking water are followed in all analytical procedures and issuing certificates.
- WHO has assisted in many training programmes of relation to water, sanitation, and water borne diseases.

UNESCO:

- UNESCO contribution to water management programmes is internationally recognized in all parts of the world Sudan is not an exception in this respect.
- UNESCO chair for water is hosted by Umdurman Islamic University. Faculty of Engineering. Many research and training programmes in water related studies are tackled by it.

UNESCO National Commission orgnizes many activities such as:-

1- The annual celebration of the International Water Day (22-march). During this year celebration the education Minister announced the introduction of a water awareness component in the primary schools corricula. The National UNESCO commission also recommended a public awareness programme for the whole society which reflects the importance of water and its rational consumption as an implementation effort for the International Decade for water Development.

2- *UNESCO* national commission also conducted a study to assess the groundwater pollution in Khartoum State by analyses of wells water.

b. International (foreign) Non. Governmental organizations involved in water related activities:

Many foreign organizations are involved in water related activities:

Plan-Sudan, Care International, Oxfam, International Rescue Committee (I.R.C), Save The Children organizations, are just examples.

c. National Nongovernmental Organizations Involved in water related activities:

Table (18): Summary of Basic information about local N.G.Os. involved in water related activities:

Society	Main objectives and Activities	Activities related to water issues
1- Sudanese Environmental Conservation Society *SECS* -Registed in September 1975. - Has branches in most states of Sudan. - Members many thousands	The main objective is enhancing the conservation and sustainable use of natural resources through: 1- Scientific based analyses, and solving environmental problems. 2- Organizing seminars, workshops, training and environmental awareness programmes. 3- Cooperation and co-ordination with national, regional and international institutions in environmental conservation issues.	A seminar on the Environmental consequences of Merwe reservoir was organized in karima town 1992. Aprogramme was held in primary schools in Khartoum to improve the schools environment- One of its components was the provision of safe drinking water.
2-The Environmentalists Society (ES) **-Founded in 1986.** **-Braches exist in Khartoum, Eastern and Western states of Sudan.** - More than 400 I.E.S graduates and other volunteers. ES profile (2003).	1-The main objective was to involve the graduates of the institute of Environmental Studies in community work by organizing:- 2-Seminars, workshops and training programmes aiming for the implementation of environmentally sound developmental projects. 3-A monthly news letters is publicated and distributed free (Sudan Environment) in Arabic.	-1998. A project was implemented with local communities in Butana central Sudan, to introduce new improved approaches on water harvesting 1998. an Environmental impact Assessment (E.IA) was done for Sabaloka Abbateur and mitigation measures were recommended.
3- Water Technology Society (WTS) **- Founded in 2002**	1-Raising water awareness and wise water consumption. 2- Collect information on water resources, for both their quality and quantity. 3- Conduct research and studies on issues related to water, charceristics and reuse of waste water. 4- Capacity building and human resources development in water related fields.	Many activities related to capacity building and raising public awareness on water issues
4-Drinking water provision organization "Elsugya" -Founded in 2000	1-The strategic main objective is the provision of safe drinking water for humans and animals by coordination with individuals and institutions involved in water provision. Programmes by concentrating in rural areas. 2- Establishing amodern data base and training plan for water related information and modern techniques for drinking water provision.	1-Digging wells, and construction of water pumps and haffirs for provision of drinking water in rural areas.eg. North kordofan. -For 2005, 20% of the overall budget is planned to come from the public for the planned projects.

Community awareness on water quality issues:

-The general level of awareness on water quality issues its improved during recent years:

1- Hygeine practice of families specially among educated mothers is very high, the water storage utensils and practices are receiving considerable care, more filters are used in houses in urban centres.

2- More volunteers are contributing in non governmental organizations water related activities.

3- The public financial participation is non governmentals water programmes has increased, "Elsogya" charity organization has planned to gain 20% of its financial budget from the private sector.

4- More requests are received at laboratories from individuals and private sector companies for analyses of water intended to be used for various purposes.

5- More factories of bottled water are established. Since 2001 bottles of pure drinking water constitute an important commodity in supermarkets in urban centers specially Khartoum.

However, more attention should be paid and greater efforts are needed for planed awareness programmes among non-educated sectors of the population, so as to minimize mal practices that deteriorate water quality (e.g car wash, excreta deposition, disposal of oils and other materials aiming for better conservation of water resources).

Chapter Five
Conclusions and Recommendations

a) Conclusions

* The Nile system in Sudan although can not be classified as chemically polluted is subjected to various sources of pollution, the most important of which are the non-point sources particularly agricultural run-off from cultivated areas and urban run-off from large urban centres.
* Comparison of the chemical content of the two main tributaries show that the sulfate content of the White Nile is lower than that of the Blue Nile.
* A distinct build up of chloride and nitrogen inorganic is observed in the Nile system.
* Ammonia (NH_3) values are more higher at the Blue Nile at Khartoum indicating more deterioration in its water quality.
* Bachemiological counts and B.O.D. values at Khartoum exceeded the W.H.O. Guideline values. The highest values were recorded at the White Nile due to its low speed and more man-water contact.
* Values of oil and Grease at Khartoum exceeded the W.H.O. Guideline values. The greatest hazard was caused by power stations.
* The heavy metals hazard is not receiving the required attention. Iron concentrations exceeded the W. H. O. Guidelines value and chromium concentration was ten fold the permissible level.
* A high organic load is imposed on the water system mainly by sugar factories. This load needs quantitification and its characteristics need to be studied. The ecological consequences of its disposal in the Nile system need to be studied.
* Major gaps exist in the monitoring programme these include:-
  Measurements of B. O. D, C. O. D. And D. O. as oxygen balances are very important as river water quality determinants.
* The professional capacity of analytical laboratories is high, the senior staff is highly qualified. This technical infrastructure of laboratories has deteriorated. To commence a national water quality monitoring programme specific recommendations for each laboratory are specified in the recommendations.

b) Recommendations:

1- A national water quality monitoring programme with permenant monitoring stations must be established. The existing programme at the Ministry of Irrigation and Water Resources must be strengthened. The Laboratories at "G.W.W.D" should be rehabilitated. The Scientific equipments maintenance, and personnel training are very necessary. Provision of modern data storage facilities equipments repair and financial support for the two sections of the National Health Laboratory which has been functioning for more than a century-will enable it to resume its historical monitoring programme which was discontinued because of lack of funds.

2- The sugar factories effluents and other industrial effluents- should be studied. Their characteristics. B.O.D and C.O.D levels at their discharge sites must be tested. The sanitary laboratory of the Civil Engineering Department, Faculty of Engineering, University of Khartoum, if

provided with more modern equipments, with data loggers can do the required assessment.

3- Ecological consequences of high nutrient inputs from agricultural run-off, and high organic loads from industry their role in changing the species diversity and ecosystem stability must be studied. The Analytical Laboratories of the Institute of Environmental Studies (I.E.SAL) if provided with modern scientific equipments for Bioassay studies, digital mioroscopes, and repair services for its equipments is well qualified to do that.

4- the continuously increasing pesticides' application request environmental monitory. The role played by the Pesticide. Chemical Analysis laboratory is highly appreciated. Its toxicological analyses of pestcide residues in living tissues were the indicators for the magnitude of pesticides problem. The infrastructure restrengthening, rehabifftation of gas chromatographs and provision of chemicals supply and spare parts will enable it to play a leading role in this respect.

In the future modern techniques that enables for the scientific assessment of environmental hazards in the water bodies must be used, e.g. using indicator organizms for the direct assessment of environmental pollution.

The existing water Corporation Laborotaries located on the Main Nile and tributaries (in Kosti on the white Nile, Wad Medani on the Blue Nile and Atbara on the Main Nile, should be involved in the wide national water quality programme. The technical capacity of these laboratories must be incresed.

Proposed stations for National Water quality monitoring programme are shown in table (19).

Table 19 : Sampling sites of the suggested water quality monitoring programme and their Geo-reference

River and Site	Coordinates		Remarks
	Longitude	Longitude	
a. White Nile			
1. Nimuli	32.02E	3.52N	A transboundary station between Sudan and Uganda
2. Juba	31.74E	4.55N	Urban centre
3. Malakal	31.6E	9.57N	First gauging station existing monitoring station
4. Kosti	32.2E	12.93N	Urban centre
5. Jebel Aulia	32.30E	15.15N	Downstream (D/S) of Jebel Aulia Dam
6. Khartoum "shajara"	32.14	15.50N	Urban centre. A quaculture and Research centre
b. Blue Nile:			
7. Eldeim	34.94E	11.02N	At the Sudanese – Ethiopian border. Transboundary station
8. Eldamazein	34.06E	11.55N	Urban centre. Opposite to Roseires Dam
9. Sinnar	33.5E	13.97N	d/S Sinnar reservoir
10. Wad-Meddani	32.46E	14.15N	Urban centre point of water intake
11. Soba-Khartoum	32.35E	15.44N	Urban centre existing monitoring station
Main Nile			
12. Khartoum-Elgaili	32.35E	16.05N	Near Tammaniat gauging station. First station on Main Nile
13. Atbara	33.59E	17.5N	At the junction of Atbara River
14. Dongola	30.6E	19.02N	Existing montoring station
15. Wadi-Halfa	31.10	21.5N	A transboundary station between Sudan and Egypt

The sampling sites positions on different rivers of the Nile system are shown in Fig. (13) – Map.

These sampleing sites were chosen with the consideration of sampling sites measures mentioned by Adam and Hamad, (2002) and the existing monitoring programme stations.

* Finally, it can be stated that Sudan was histrically involved in water quality monitoring. Many persons can be considered as speciallized personnel in this field, but the highly qualified experts which were mostly trained abroad are ageing. Training programmes for young staff and modern analytical procedures know how together with modern laboratories are required, so as to be able to participate in the conservation of the Nile.

Fig.

Nile System in Sudan Proposed (and existing)

Water Quality Sampling Sites

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Annex (1)

WHO Guideline Values 1996

Inorganic constituents

parameter	Guideline value (mg/l)	Remarks
Fluoride	1.5	Climatic conditions, volume of water consumed, and intake from other sources should be considered when setting national standards
Nitrate (as nitrate)	50	The sum of the ratio of the concentration of each to its respective guideline value should not exceed 1
Nitrite (as nitrite)	3	The sum of the ratio of the concentration of each to its respective guideline value should not exceed 1

Substances and parameters in drinking water that may give rise to complaints from consumers:-

parameter	Levels likely to give rise to consumer complaints	Reasons for consumer complaints
Inorganic constitutes		
Chloride	250 mg/l	Taste, corrosion
Ammonia	1.5 mg/l	Odor and taste
Hardness	-	High hardness: scale deposition, scum formation. Low hardness: possible corrosion
Hydrogen sulfide	0.05	Odor and taste
Manganese	0.1	Staining of laundry and sanitary ware
Dissolved oxygen	-	Indirect effect
pH	-	Low pH: corrosion High pH: taste, soapy feel. Preferably < 8 for effective disinfect ion with chlorine
Sodium	200	Taste
Sulfate	250	Taste , corrosion
Total dissolved solids	1000	Taste
Physical parameters		
Color	15 TCU	Appearance
Taste and odor	-	Should be acceptable
Temperature	-	Should be acceptable
Turbidity	5 NTU	Appearance, for effective terminal disinfection median turbidity ≤ 1 NTU, Single sample ≤

Annex 2: Some Sudanese Drinking Water Standards (2002)

Parameter	Max. Permissible Limit in mg/l
Colour	15 TCU
Taste and Odour	Acceptable
Turbidity	5NTU
pH	6.5 – 8.5
Aluminium	0.2
Ammonia	1.5
Chloride	250
Iron (total)	0.3
Sodium	200
Sulfate	250
Total Dissolved Solids (TDS)	1000
Zinc	3
Cadmium	0.003
Chromium	0.04
Copper	1.5
Fluoride	1.5
Lead	0.007
Manganese	0.5
Mercury, Total	0.0007
Nickel	0.014
Nitrate as NO_3	50
Nitrite as NO_2	2
Selenium	0.007

All water intended for drinking or treated water entering the distribution system
A. E. Coli or thermotolerent coli form bacteria and
B. Pathogenic intestinal protozoa must not be detectable in any 100 – ml sample.